1987

Lost U.S. aluminum competitiveness 1978-1986: an import demand study

Jim Corr

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LOST U.S. ALUMINUM COMPETITIVENESS 1978-1986:
An Import Demand Study

By
Jim Corr
B.S., Lewis and Clark College, 1984

Presented in partial fulfillment of the requirements for the degree
of
Master of Arts

UNIVERSITY OF MONTANA
1987

Approved by:

Chairman, Board of Examiners

Dean, Graduate School

Date July 13, 1987
Since 1978, the competitive position of U.S. primary aluminum producers has been rapidly deteriorating. As a result, U.S. imports of aluminum have nearly doubled. Prior to this study, lost U.S. aluminum competitiveness has been primarily attributed to the fact that electricity prices paid by domestic smelters have risen in some cases over 900 percent since 1978. One important factor missing from these earlier studies is that they typically ignore the adverse impact on U.S. aluminum competitiveness resulting from a strong U.S. dollar. The major purpose of this study is to estimate a U.S. import demand function for aluminum in order to determine how important exchange rates have been relative to U.S. electricity prices in explaining rising import demand.

Employing monthly data from January of 1978 to March of 1986, U.S. import demand was estimated using both the technique of ordinary least squares (OLS) and the technique of principal components. Both techniques produced an over all R-square of approximately 0.90. The standardized OLS electricity coefficient was .52 while the standardized OLS exchange rate coefficient was .65. The principal components' results were very similar. The derived exchange rate coefficient was .83 while that on the derived U.S. electricity rate was .61. These statistical results indicate that exchange rates have been at least as important in explaining U.S. import demand as have been U.S. electricity prices.

Because previous research has typically excluded exchange rates, it has probably been subject to substantial specification bias. As a result, the role of electricity prices in causing U.S. primary aluminum smelting competitiveness to decline has most likely been overstated in past studies.
ACKNOWLEDGEMENTS

Special recognition is due to those individuals whose moral and technical support made the completion of this thesis possible. First, I would like to thank my thesis committee members (Tom Power, Dick Barrett, and Arnold Silverman) for their criticism, comments and moral support. Moreover, I would like to additionally thank my committee chairman Tom Power for both his patience and fairness that he exhibited while working with me.

Barbara Coles from Battelle Laboratories and Paul Spies from Bonneville Power Administration also deserve special thanks for the advice that they shared, the data sources they provided, and their general encouragement. Without the technical information given by Paul and Barbara, it is doubtful that this thesis could have been completed in the necessary time period.

More than any other person, I want to thank my wife Karen for being such an understanding friend during all the trials, traumas, and frustrations that accompanied this thesis. As a token sign of appreciation for being such a rare friend, I dedicate this thesis to Karen Corr.
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CHAPTER ONE
STATEMENT OF THE PROBLEM

I. INTRODUCTION

Prior to the late 1970's, the United States dominated the world aluminum market, controlling over 40 percent of western world capacity. During the last decade, the U.S. competitive position has eroded. One indication of lost competitiveness is that aluminum exports to the U.S. from Canada have doubled during the last eight years. While the demand for Canadian aluminum has been increasing, U.S. demand for aluminum in general has not kept pace. Thus, imports of Canadian aluminum have tended to displace domestic production. Nearly 20 percent of U.S. aluminum capacity has been permanently closed since 1978.

The standard explanation for this lost competitiveness is that U.S. aluminum production costs have increased relative to those of Canadian producers, more specifically that the electricity cost component has increased. Between 1979 and 1984, electric rates paid by U.S. aluminum companies increased on average by 75 percent while rates faced by Canadian firms remained constant (see figure 1). The relative increase in U.S. power rates pushed U.S. production costs up by nine cents per pound. Today, electricity costs account for 29 percent of U.S. variable production costs. In comparison,
### TABLE 1

**ELECTRICITY RATES FOR NORTH AMERICA 1979 vs. 1984**

*(IN U.S. DOLLARS)*

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>YEAR</th>
<th>MILLS/KWH</th>
<th>CENTS/LB.</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>1979</td>
<td>13.2</td>
<td>11</td>
</tr>
<tr>
<td>CANADA</td>
<td>1979</td>
<td>4.0</td>
<td>3</td>
</tr>
<tr>
<td>U.S.</td>
<td>1984</td>
<td>24.0</td>
<td>20</td>
</tr>
<tr>
<td>CANADA</td>
<td>1984</td>
<td>4.0</td>
<td>3</td>
</tr>
</tbody>
</table>

### FIGURE 1

**U.S. - CANADIAN ELECTRICITY COSTS**

![Graph showing electricity costs](image)

SOURCE\(^1\): Merner Research *Projected 1983 Power Costs for Aluminum in North America with Comparisons to 1979* Sept. 3, 1982


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production costs. Given the importance of electricity as a variable input, it is reasonable that a substantial portion of the decline in U.S. competitiveness be attributed to differential power costs.

Unfortunately, the emphasis on electricity prices has diverted attention from a potentially more important factor, that of a strong U.S. dollar. In January of 1978, one U.S. dollar was worth 1.1 Canadian dollars. By March of 1986, one U.S. dollar could be traded for 1.406 Canadian dollars (see figure 2). To date, no attempt has been made to assess the impact on U.S. imports of Canadian aluminum of this 27 percent increase in the rate of exchange. The purpose of this thesis is to determine whether differential electricity prices or the rate of exchange has been the more important factor explaining U.S. imports of Canadian aluminum.

II. PROPOSED RESEARCH

This thesis will apply regression analysis to time series data in order to examine the relative importance of exchange rates and differential energy costs in explaining U.S. import demand for Canadian aluminum. To make this comparison, a U.S. import demand function for aluminum will be estimated. The hypothesis to be tested is that exchange rates explain more of the increase in U.S. aluminum imports from Canada than do differential electricity prices. Econometrically, this means that for a given confidence interval (95%), the coefficient attached to the standardized exchange rate variable is expected to be larger than the coefficient associated with the standardized U.S. electricity price variable.
TABLE 2

U.S. - CANADIAN EXCHANGE RATE
(IN CANADIAN DOLLARS)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>EXCHANGE RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>1.1400</td>
</tr>
<tr>
<td>1979</td>
<td>1.1713</td>
</tr>
<tr>
<td>1980</td>
<td>1.1692</td>
</tr>
<tr>
<td>1981</td>
<td>1.1989</td>
</tr>
<tr>
<td>1982</td>
<td>1.2259</td>
</tr>
<tr>
<td>1983</td>
<td>1.2324</td>
</tr>
<tr>
<td>1984</td>
<td>1.2950</td>
</tr>
<tr>
<td>1985</td>
<td>1.3654</td>
</tr>
<tr>
<td>1986*</td>
<td>1.4066</td>
</tr>
</tbody>
</table>

* March of 1986 is the last month represented

FIGURE 2
RATIO OF CANADIAN DOLLAR TO U.S. DOLLAR

III. EXPECTED FINDINGS

Even without resorting to regression analysis, intuition tells us that both the U.S. - Canadian exchange rate and rising U.S. electricity prices have been important factors explaining U.S. import demand for aluminum. For example, we know that the relative rise in U.S. power rates has resulted in a nine cent per pound production cost advantage for Canadian producers. Since this nine cent per pound advantage has evolved during the same time period that U.S. imports of Canadian aluminum have doubled, there is little doubt that a strong causal link exists between rising U.S. electricity prices and U.S. aluminum imports.

Likewise, the 27 percent increase in the value of the U.S. dollar relative to the Canadian dollar also suggests that Canadian producers have been gaining a production cost advantage due to favorable exchange rates. This is especially true since only 23 percent of the increase in the U.S. dollar's strength can be attributed to higher Canadian inflation. The net result is that exchange rates have been responsible for as much as a 20 percent relative production cost gain for Canadian producers. On a cost per pound basis, this could translate into a five to ten cent per pound advantage. Again, there is little doubt that a causal link exists between a strong U.S. dollar and the quantity of U.S. aluminum imports from Canada.

On a priori grounds, it is difficult to conclude that one factor has been significantly more important than the other in explaining U.S. aluminum import demand. At first glance, one might be tempted to conclude that the relative increase in U.S. electricity costs is the
more important factor. However, a portion of the nine cent per pound Canadian electricity cost advantage is a result of exchange rates (approximately two cents/lb.). Because a significant portion of differential electricity prices is due to the rising value of the U.S. dollar, it is quite possible that exchange rates have explained more of U.S. aluminum imports since 1978 than have differential electricity prices.

IV. THESIS OUTLINE

The following is a brief summary of the content discussed within each subsequent chapter:

Chapter Two; An Overview of the North American Aluminum Market

This chapter defines the North American aluminum market and describes its evolution. Special attention is devoted to the decline in U.S. aluminum competitiveness that occurred after 1978. A detailed description is presented explaining how rising U.S. electricity costs have affected competitiveness in each of the six North American aluminum regions. The chapter concludes by examining how the rising value of the U.S. dollar could have impacted domestic aluminum competitiveness.

Chapter Three; Literature Review

Literature reviewed in this chapter is divided topically into two sections. Initially, studies are examined which either descriptively or analytically document the recent decline in U.S. aluminum competitiveness. Then, a brief theoretical model for estimating a reduced form import demand is presented.
Chapter Four; Modeling U.S. demand for Canadian Aluminum

Chapter Four begins by presenting the major assumptions that are made in this thesis to facilitate the modeling process. This is followed by the mathematical derivation of the reduced form import demand function that will be employed in testing the thesis hypothesis. Chapter Four concludes by discussing the signs that are likely to be attached to the estimated variable coefficients.

Chapter Five; Estimating U.S. import Demand for Aluminum

This chapter uses the model developed in Chapter Four to estimate U.S. import demand for Canadian aluminum. In addition, this chapter discusses and applies corrective measures to problems contained in the data set. Chapter Five concludes by discussing the estimation results and by suggesting additional research.
CHAPTER TWO
OVERVIEW OF NORTH AMERICAN ALUMINUM MARKET

I. INTRODUCTION: DEFINITION OF THE MARKET

The aluminum market relevant to this study encompasses the North American countries of Canada and the United States. Each country is unique in what it contributes to the market. Canada's role is largely that of a supplier of unwrought aluminum. Although Canada is the world's second largest primary aluminum producer, it exports over two-thirds of its production. Over 60 percent of these exports are destined for the United States. Canada's role as an aluminum consumer is relatively insignificant when compared to the U.S. This can be attributed to at least two factors. First, Canada's population is one sixth that of the U.S. population. Thus, there are fewer potential aluminum consumers in Canada. Second, per capita aluminum consumption in Canada has been approximately 40 percent lower over the last ten years than U.S. per capita aluminum consumption.

The United States is significant in the North American aluminum market both as a producer and a consumer. Historically, as much as 50 percent of the world's aluminum capacity was located in the U.S. Although this share has dropped during recent decades, the U.S. still controlled over 25 percent of western world capacity in 1986. The U.S. consumes approximately 30 percent of the
western world total. Consumption that is not satisfied by domestic primary production is satisfied by domestic secondary production (recycling) and by imports. 60 to 90 percent of the U.S.'s unwrought unalloyed aluminum imports come from Canada.

The Alcoa Monopoly

Between 1893 and 1940, Alcoa virtually controlled 100 percent of all North American capacity. Initially this monopoly was a result of the fact that the first commercially viable process for producing aluminum was developed and patented by the Pittsburgh Reduction Company which was later renamed the Aluminum Company of America (Alcoa). Because other companies could not infringe on Alcoa's patent rights, the monopoly was legally sanctioned until the patent rights expired. Between 1909 and 1940, Alcoa's monopoly was maintained by various legal and illegal actions. These included the following tactics: the purchase of over 90 percent of all known U.S. bauxite holdings; manipulation of the financial markets by the Mellon family (Alcoa's primary stock holder) to exclude financial backing for potential entrants; the outright purchase of companies that were interested in expanding into aluminum production; and at times, predatory pricing.

In the early 1940's, the U.S. government sued Alcoa for monopolizing the domestic primary aluminum market. In 1945,
Alcoa was found guilty of anti-trust violations. The most important consequence of this case occurred in 1951 when the government ruled that major Alcoa stock holders could not own stock in both Alcoa and Alcan (Alcoa’s Canadian subsidiary). Nine Alcoa stock holders were given until October, 1955 to divest their holdings in at least one company.

Ironically, the increase in aluminum demand resulting from World War II was also a factor in Alcoa’s downfall. During the war, the U.S. government paid Alcoa to construct several new aluminum smelters. Alcoa assumed that it would have the right to purchase these facilities once the war ended. However, the government chose to sell the capacity to two new producers Kaiser and Reynolds. This was part of the government’s overall plan to decrease Alcoa’s share of domestic capacity. By 1956, Alcoa’s share of North American capacity had dropped to 33 percent. Alcan controlled 27 percent of the market and the other 40 percent was split between Kaiser and Reynolds.14

As Alcoa’s monopoly eroded, several new firms entered the North American market. Today, there are 32 aluminum plants in the United States and 7 in Canada. These 39 plants are operated by 14 different companies and are located in the following six North American geographic regions: the Pacific Northwest (PNW), the Southeast (S.E.), the Northeast (N.E.), the Ohio Valley (O.V.), the Gulf Coast (G.C.), and Canada (Quebec).15 The common denominator
possessed by each region is that it has historically been the site of relatively cheap electricity. Figure 3 illustrates both the location of the six North American aluminum regions and the plants within those regions.

Aluminum Demand 1893-1977

Demand for aluminum, like any product, is largely a function of income, price, price of substitutes, tastes, and market size. During the fledgling years of aluminum production, the most important factor was price. Between 1852 and 1893, the price of aluminum fell from 750 dollars per pound to 50 cents per pound.\(^6\) This dramatic drop in price can be attributed to two factors. First, it was discovered that an electrical current could be used both to bring a solution of aluminum dioxide (alumina) to a molten state and to separate the aluminum from the oxygen by the process of electrolysis.\(^1^7\) By its nature, aluminum production is highly electricity intensive (see figure 3A). The second factor responsible for the dramatic fall in the price of aluminum was the development of relatively low cost electricity which made the electrolysis process economically feasible.\(^1^8\)

As the price of electricity decreased, the price of aluminum also decreased. This continued until after World War II when the price of aluminum reached a low of 15 cents per pound. Of all U.S. basic industrial sectors, the post World War II aluminum industry was one of the most dynamic. Because aluminum is light-weight, corrosion resistant, highly electrically and thermally conductive,
### TABLE 3
NORTH AMERICAN ALUMINUM REGIONS AND CAPACITY

<table>
<thead>
<tr>
<th>REGION</th>
<th>CAPACITY (tons/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Northwest (PNW)</td>
<td>1,822,000</td>
</tr>
<tr>
<td>Ohio Valley (O.V.)</td>
<td>1,497,000</td>
</tr>
<tr>
<td>South East (S.E.)</td>
<td>1,009,000</td>
</tr>
<tr>
<td>Northeast (N.E.)</td>
<td>352,000</td>
</tr>
<tr>
<td>Gulf Coast (G.C.)</td>
<td>945,000</td>
</tr>
<tr>
<td>U.S. Total</td>
<td>5,625,000</td>
</tr>
<tr>
<td>Canada</td>
<td>1,360,000</td>
</tr>
<tr>
<td>North American Total</td>
<td>6,985,000</td>
</tr>
</tbody>
</table>

### FIGURE 3
LOCATION OF NORTH AMERICAN ALUMINUM REGIONS

SOURCE: Battelle The Direct Service Industries: Their Contribution to the Northwest Power System and Economy April 1983
FIGURE 3A
ELECTRICITY CONSUMPTION IN ALUMINUM PRODUCTION

100% IMPORTED

45% IMPORTED

20%-30% IMPORTED

BAUXITE
4.6 mt

58 \times 10^6 \text{ BTU}

ALUMINA
1.95 mt

95 \times 10^6 \text{ BTU}

ALUMINUM
1 mt

ELECTRICITY
4.57 \text{ KWH} + 7.5 \text{ KWH} = 12.07 \text{ KWH}

SOURCE: Minerals and Materials A Bimonthly Survey June/July 1986


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and relatively inexpensive, it was increasingly used to replace other materials such as wood, copper, iron etc..

Demand for aluminum is typically calculated in terms of apparent consumption which can be defined as domestic production corrected for inventory change plus net imports. During the 1950's and 1960's, annual increases in U.S. apparent consumption averaged between eight and ten percent (see figure 4). During the 1970's, this average annual rate had fallen to less than four percent because various end-use markets had become saturated. As the product life cycle of aluminum entered its stage of maturity, growth in demand for aluminum moved closer to the growth rate of GNP.

II. LOST U.S. COMPETITIVENESS (1978 - 1986)

As the decade of the 1970's passed, trouble struck the U.S. aluminum industry on two fronts. First, the world demand for aluminum declined by 12 percent between 1980 and 1983. Figure 5 illustrates the decline in U.S. demand that occurred during that time period. Several forces contributed to this decline including the recession that accompanied the early 1980's, market saturation in significant previous high growth end-use areas such as beverage containers, and increased competition from substitutes such as vinyl siding. Although demand for aluminum declined, non-U.S. capacity continued to expand (including Canadian capacity). This kept the price of aluminum depressed. Thus, only the most cost efficient smelters continued to make money.
### TABLE 4
U.S. APPARENT CONSUMPTION (1950-1985)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>CONSUMPTION</th>
<th>YEAR</th>
<th>CONSUMPTION</th>
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<th>CONSUMPTION</th>
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<tbody>
<tr>
<td>1950</td>
<td>896</td>
<td>1963</td>
<td>3040</td>
<td>1976</td>
<td>5083</td>
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<tr>
<td>1951</td>
<td>974</td>
<td>1964</td>
<td>3216</td>
<td>1977</td>
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<td>3734</td>
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<td>1953</td>
<td>1052</td>
<td>1966</td>
<td>4002</td>
<td>1979</td>
<td>5888</td>
</tr>
<tr>
<td>1955</td>
<td>2111</td>
<td>1968</td>
<td>4663</td>
<td>1981</td>
<td>5087</td>
</tr>
<tr>
<td>1956</td>
<td>2127</td>
<td>1969</td>
<td>4710</td>
<td>1982</td>
<td>4828</td>
</tr>
<tr>
<td>1957</td>
<td>2137</td>
<td>1970</td>
<td>4518</td>
<td>1983</td>
<td>5541</td>
</tr>
<tr>
<td>1958</td>
<td>2092</td>
<td>1971</td>
<td>5099</td>
<td>1984</td>
<td>5819</td>
</tr>
<tr>
<td>1959</td>
<td>2488</td>
<td>1972</td>
<td>4926</td>
<td>1985</td>
<td>5701</td>
</tr>
<tr>
<td>1960</td>
<td>2016</td>
<td>1973</td>
<td>5825</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1961</td>
<td>2320</td>
<td>1974</td>
<td>5428</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1962</td>
<td>2770</td>
<td>1975</td>
<td>3904</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### FIGURE 4
U.S. APPARENT CONSUMPTION 1950-1985

- **APPARENT CONSUMPTION**

### TABLE 5

U.S. APPARENT CONSUMPTION 1978-1985
(IN 1000'S OF METRIC TONS)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>CONSUMPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>5440</td>
</tr>
<tr>
<td>1979</td>
<td>5299</td>
</tr>
<tr>
<td>1980</td>
<td>4558</td>
</tr>
<tr>
<td>1981</td>
<td>4614</td>
</tr>
<tr>
<td>1982</td>
<td>4370</td>
</tr>
<tr>
<td>1983</td>
<td>5035</td>
</tr>
<tr>
<td>1984</td>
<td>5279</td>
</tr>
<tr>
<td>1985</td>
<td>5174</td>
</tr>
</tbody>
</table>

### FIGURE 5

U.S. ALUMINUM CONSUMPTION (1978-1985)

Rising U.S. Electricity Prices

The oil shocks of the 1970's in conjunction with rising U.S. electricity demand resulted in dramatic power rate increases for some U.S. regions. Since aluminum companies are highly electricity intensive, their production costs are more responsive to higher electricity rates than the production costs of manufacturing firms in general. The magnitude of price increases faced by individual plants largely depended on two factors. The first determinant was whether a smelter was serviced by a utility (or government marketing agency) that was involved with the construction of new nuclear generating facilities. The second determinant relates to whether a smelter was served by a utility dependent on oil or natural gas. Aluminum plants served by either type of utility faced the greatest increase in electricity rates.

The initial impact of rising domestic electricity prices was that U.S. aluminum companies slowed their construction of domestic aluminum capacity. During the 1970's, some proposed plants had to be indefinitely postponed because low cost electricity was no longer available. In some cases, these investment dollars were redirected into the building of aluminum capacity in other countries. Canada, Australia, and Brazil have captured the majority of U.S. investment. Although the construction of U.S. facilities slowed in the 1970's, it did not stop. 25 percent of U.S. capacity was built between 1965 and 1980. No new capacity has been built since 1980.

As the price of electricity rose still higher during the late 1970's and early 1980's, the viability of existing U.S. smelters was threatened. Because Canadian aluminum smelters are less dependent
on coal and nuclear energy, electric rates for Canadian producers did not increase as rapidly as did those faced by U.S. producers. More importantly, Alcan's 75 percent share of Canadian aluminum capacity is supplied with electricity from Alcan-owned hydroelectric facilities. Between 1979 and 1983, Alcan's electricity costs were unchanged. As a result of these factors, Canadian production costs were largely immune to the deleterious impact of rising oil prices.

Although some U.S. smelters own their own electricity source, the vast majority of electricity consumed by U.S. smelters is purchased from one or more of the dozen U.S. utilities, co-ops, and government agencies that serve aluminum companies. Thus, each U.S. aluminum region was impacted differently by rising energy costs. The following analysis examines how each of the six U.S. aluminum regions were affected by rising electricity costs.

Pacific Northwest

In the PNW, rates increased from less than 2.5 mills/KWH in 1978 to over 25 mills/KWH in 1984. This 1000 percent increase was largely due to cost over-runs from nuclear power plants under construction. In 1978, electricity costs contributed less than two cents per pound to PNW smelter production costs. By 1984, electricity costs accounted for 19.05 cents per pound (see figure 6). In January of 1987, one PNW smelter was permanently closed. A second smelter was temporarily closed and may be closed permanently. The other eight plants were operating at various
levels of capacity utilization.

Southeast

Southeast smelters served by the Tennessee Valley Authority witnessed similar circumstances. Official rates to TVA aluminum customers increased from approximately 20 mills/KWh in 1978 to over 37 mills/KWH in 1984. However, because of "take or pay" clauses, the effective rates were often much higher. For example, Reynolds's TVA smelter purchased power in 1982 for a price that effectively totaled over 88 mills/KWH (see figure 7).26 Although official rates increased by 57 percent between 1978 and 1984, the effective rate increase for the Reynolds's smelter exceeded 400 percent. In terms of the official rate structure, electricity accounted for 15 cents per pound in 1978 and 27.75 cents per pound in 1984. Depending on the smelter, actual electricity costs contributed as much as 66 cents per pound to total production costs. Given the fact that TVA rates were relatively high to begin with, plants served by the TVA were harder hit by rising electricity costs than were PNW plants served by BPA. One Southeast plant is permanently closed and the rest of the capacity functions only as "swing capacity".27

Gulf Coast

Historically, the Gulf Coast region depended on electricity generated from inexpensive natural gas. Because of the rapid price increases in natural gas that occurred in the 1970's, Gulf Coast smelters were hit early and hard. Unlike smelters located in the
TABLE 6

ELECTRICITY RATES AND ELECTRICITY COSTS FACED BY PNW ALUMINUM SMELTERS (1978-1985)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>MILLS/KWH</th>
<th>CENTS/LB.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>2.4</td>
<td>1.80</td>
</tr>
<tr>
<td>1979</td>
<td>3.0</td>
<td>2.25</td>
</tr>
<tr>
<td>1980</td>
<td>4.6</td>
<td>3.45</td>
</tr>
<tr>
<td>1981</td>
<td>6.1</td>
<td>4.57</td>
</tr>
<tr>
<td>1982</td>
<td>16.0</td>
<td>12.00</td>
</tr>
<tr>
<td>1983</td>
<td>22.2</td>
<td>16.65</td>
</tr>
<tr>
<td>1984</td>
<td>25.4</td>
<td>19.05</td>
</tr>
<tr>
<td>1985</td>
<td>21.0</td>
<td>15.75</td>
</tr>
</tbody>
</table>

FIGURE 6

IMPACT OF BPA RATES ON SMELTER ELECTRICITY COSTS

SOURCE: Bonneville Power Adm. DSI Historical Summary (1978-1985)

* Assumes electro-processing coefficient of 7.5 KWH/LB.
TABLE 7
ELECTRICITY RATES AND ELECTRICITY COSTS FACED BY TVA SMELTERS (1978-1985)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>MILLS/KWH*</th>
<th>CENTS/LB</th>
<th>MILLS/KWH*</th>
<th>CENTS/LB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>20.89</td>
<td>15.66</td>
<td>19.38</td>
<td>14.53</td>
</tr>
<tr>
<td>1979</td>
<td>23.69</td>
<td>17.76</td>
<td>23.86</td>
<td>17.89</td>
</tr>
<tr>
<td>1980</td>
<td>27.14</td>
<td>20.35</td>
<td>26.84</td>
<td>20.13</td>
</tr>
<tr>
<td>1981**</td>
<td>31.74</td>
<td>23.80</td>
<td>35.30</td>
<td>26.47</td>
</tr>
<tr>
<td>1982**</td>
<td>42.06</td>
<td>31.54</td>
<td>88.05</td>
<td>66.03</td>
</tr>
<tr>
<td>1983**</td>
<td>42.51</td>
<td>31.88</td>
<td>CLOSED</td>
<td>N/A</td>
</tr>
<tr>
<td>1984**</td>
<td>39.06</td>
<td>29.29</td>
<td>57.74</td>
<td>43.30</td>
</tr>
<tr>
<td>1985**</td>
<td>37.99</td>
<td>28.49</td>
<td>68.13</td>
<td>51.09</td>
</tr>
</tbody>
</table>

** Assumes Electro-processing Coefficient of 7.5 KWH/LB
** Take or pay clauses in effect.
+ Reynolds TVA Smelter was Closed in 1983


---

FIGURE 7
TVA ELECTRICITY RATES AND COSTS

* Assumes Electro-processing Coefficient of 7.5 KWH/LB
** Take or pay clauses in effect.
+ Reynolds TVA Smelter was Closed in 1983

Southeast and Pacific Northwest, Gulf Coast plants are served by several different private utilities. These utilities do not publish their rates the way that the BPA and the TVA publish theirs. A 1983 study indicates that Gulf Coast rates averaged less than PNW rates at that time. However, this was before low cost natural gas contracts expired for Kaiser's Chalmette Louisiana smelter. When that occurred, electric rates more than doubled from 18 mills/KWH to over 40 mills/KWH. Today, four out of five of that region's smelters have been permanently closed.\(^{28}\)

**Ohio Valley**

In contrast to the plants located in the PNW, Southeast, and Gulf Coast regions, smelters located in the Ohio Valley fared relatively well. The Ohio Valley region has historically been a high cost region because the majority of its power is generated from coal. However, coal generated electricity did not increase in price as rapidly as did that generated by natural gas or nuclear. As a result, Ohio Valley plants gained in relative regional competitiveness. Like Gulf Coast smelters, Ohio Valley plants are serviced by several utilities. Therefore, rates vary from smelter to smelter. Ohio Valley rates in 1983 ranged from a low of 18 mills/KWH to a high of 30 mills/KWH.\(^{29}\) On average, they were slightly less than PNW rates. One advantage that Ohio Valley smelters possess over other North American regions is that their cost of transporting aluminum ingot to fabricating facilities is the lowest of North America's six aluminum regions. In 1986, no Ohio
Valley plants were permanently closed.

**Northeast**

The U.S. aluminum region least affected by rising electricity costs was the Northeast. Alcoa and Reynolds each have a plant located in Messena, New York that is served with low cost hydro-power. These plants are protected by long-term contracts that have partially sheltered them from the impact of major rate hikes. Between 1978 and 1983, rates to these smelters averaged less than 10 mills/KWH. Since 1983, Northeast rates have averaged approximately 15 mills/KWH.\(^{30}\) In terms of electricity prices, this is the lowest priced aluminum region in the United States. During the recession of the early 1970's, Northeast plants operated at capacity.

**III. RISING U.S. ELECTRIC RATES: IMPLICATIONS FOR U.S.- CANADIAN ALUMINUM COMPETITION.**

In 1986, electricity costs contributed, on average, 15.2 cents per pound to U.S. variable aluminum production costs. In contrast, electricity costs in Canada only added 3.3 cents per pound (US$).\(^{31}\) Subtracting Canadian electricity costs from U.S. electricity costs tells us that Canada enjoys a 12.9 cent per pound cost advantage from the electricity component. Considering that the two countries have electro-processing coefficients that are approximately the same, the majority of the electricity cost differential is due to lower Canadian electricity prices. Figure 8 illustrates disaggregated 1986 variable production costs for the U.S. and

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**TABLE 8**

**U.S. - CANADIAN AVERAGE VARIABLE COSTS FOR APRIL 1986**
**(IN U.S. CENTS PER ROUND)***

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>MATERIAL</th>
<th>ENERGY</th>
<th>LABOR</th>
<th>OTHER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>23.4</td>
<td>15.2</td>
<td>10.1</td>
<td>2.2</td>
<td>50.9</td>
</tr>
<tr>
<td>CANADA</td>
<td>17.3</td>
<td>3.3</td>
<td>10.3</td>
<td>6.7</td>
<td>37.6</td>
</tr>
</tbody>
</table>

**FIGURE 8**

**U.S. - CANADIAN AVERAGE VARIABLE COSTS**

* These represent weighted average costs.

**SOURCE:** Mining Magazine *Venezuela's Aluminum Plans* Dec. 1986 Vol. 155, No. 6
Canada. Of the four cost categories listed, electricity costs have the greatest differential while labor costs show the least differential. These statistics support the contention that energy costs are the primary consideration when explaining Canada's lower production cost advantage.

The implication of the information presented in figure 8 is that when the price of aluminum dips below 50.9 cents per pound, the typical U.S. smelter is not covering average variable costs. Economic theory tells us that when average variable costs are not being met, the firm can minimize losses by ceasing to operate. Figure 9 depicts the monthly price of aluminum since 1984. This time period was chosen because U.S. aluminum production costs have stabilized since 1984 and in some cases have actually decreased. Note that the U.S. - Canadian aluminum price has dipped below 50.9 cents per pound (US$) for extended time periods. However, the price of aluminum has always exceeded the Canadian average variable cost of 37.6 cents per pound. Considering how the price of aluminum compares with U.S. and Canadian variable costs, it's not surprising that as of December 1985, all Canadian smelters were operating. In contrast, six U.S. smelters were permanently closed and five others were temporarily closed.32

IV. EXCHANGE RATES: AN ALTERNATIVE CONSIDERATION

Although the relative increase in U.S. power rates is partially responsible for the decline in U.S. aluminum competitiveness, it may not be the most important factor. During the same time period, the value of the U.S. dollar was also increasing. Since Canadian
## TABLE 9

### MONTHLY ALUMINUM PRICES FOR 1984 AND 1985

<table>
<thead>
<tr>
<th>MONTH</th>
<th>1984</th>
<th>1985</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>76.13</td>
<td>50.10</td>
</tr>
<tr>
<td>F</td>
<td>73.34</td>
<td>51.30</td>
</tr>
<tr>
<td>M</td>
<td>71.56</td>
<td>51.20</td>
</tr>
<tr>
<td>A</td>
<td>68.21</td>
<td>52.00</td>
</tr>
<tr>
<td>M</td>
<td>64.68</td>
<td>51.70</td>
</tr>
<tr>
<td>J</td>
<td>63.20</td>
<td>47.90</td>
</tr>
<tr>
<td>J</td>
<td>56.10</td>
<td>46.90</td>
</tr>
<tr>
<td>A</td>
<td>54.40</td>
<td>47.50</td>
</tr>
<tr>
<td>S</td>
<td>48.40</td>
<td>46.30</td>
</tr>
<tr>
<td>O</td>
<td>50.10</td>
<td>45.70</td>
</tr>
<tr>
<td>N</td>
<td>55.10</td>
<td>45.20</td>
</tr>
<tr>
<td>D</td>
<td>51.40</td>
<td>50.00</td>
</tr>
</tbody>
</table>

## FIGURE 9

### NEW YORK COMMEX ALUMINUM SPOT PRICES

![Bar Chart](image)

### SOURCE:
suppliers receive U.S. dollars for the aluminum they export to the U.S., the more the U.S. dollar appreciates vis-a-vis the Canadian dollar, the more aluminum Canadian suppliers will be willing to sell at any given U.S. price. This is because the price of aluminum in Canadian currency is actually increasing as the value of the U.S. dollar increases. When this occurs, Canadian production of aluminum will increase in response to this higher effective price. As Canadian production increases, the U.S. aluminum price will fall due to increased supply in the North American market. This makes it more difficult for U.S. firms to meet their average variable costs. Thus, some U.S. firms are forced to shut down.

Theoretically, exchange rates maintain purchasing power parity between the value of different currencies. Therefore, one of the most important forces driving exchange rates is the differential inflation rate between the relevant countries. In the case of the United States and Canada, the U.S. dollar has increased 27 percent against the Canadian dollar since 1978. If differential inflation rates caused the decline in the value of the Canadian dollar, then the Canadian price level should have increased relative to the U.S. price level by approximately 27 percent. In reality, Canadian prices increased only 6.2 percent relative to U.S. prices. Thus, Canadian producers exporting aluminum to the U.S. have benefited from the strong U.S. dollar since only a portion of their aluminum price gains have been offset by higher Canadian inflation.

Given the fact that Canadian inflation only explains 23 percent of the relative strength of the U.S. dollar, other factors must also be driving exchange rates. One possibility would be that U.S. interest
rates have been so high compared to Canadian interest rates that demand for the U.S. dollar by Canadian investors has buoyed the strength of the U.S. dollar. Theory states that this will only occur in the short-run because the inflow of outside capital will eventually force U.S. interest rates down until they reach parity with the Canadian interest rate. But this market mechanism will fail if there is strong central bank intervention by either country.

Since higher Canadian inflation did not offset the drop in value of the Canadian dollar that occurred between 1978 and 1986, the relative strength of the U.S. dollar could be an important factor explaining the rise in U.S. imports of Canadian aluminum. The purpose of this thesis is to evaluate how important the relative strength of the U.S. dollar has been in comparison with rising U.S. electricity prices in explaining U.S. aluminum import demand.
CHAPTER THREE
REVIEW OF LITERATURE AND THEORY

I. INTRODUCTION

This chapter can be topically divided into two important categories. These include the category of lost U.S. aluminum competitiveness and the category of import demand estimation. Since these two topics are fundamentally different in nature, they will be examined separately. Specifically, Sections II through IV of this chapter contain an overview of the literature pertaining to lost U.S. aluminum competitiveness while Section V of this chapter focuses on the theory of import demand estimation.

II. ALUMINUM STUDIES

There is a large body of current literature that addresses the recent decline in U.S. aluminum viability. From this, one school of thought emerges. This school maintains that although the world aluminum industry is currently experiencing a structural transition, lost U.S. competitiveness is largely attributable to the fact that electricity prices faced by U.S. aluminum companies have risen significantly faster than those faced by most foreign competitors.

Studies which support this contention can be broken into two classifications; descriptive and analytical. Descriptive studies typically document lost competitiveness by summarizing facts generated from other research. Often, the purpose of these studies is to promote the implementation of a particular policy solution. In contrast, analytical studies are typically conducted by private
research firms who are under contract with either aluminum companies or large government agencies to provide raw information. Firms that concentrate on generating raw data are less likely to include policy recommendations in their studies. It is usually the party that purchases this information that uses it for some normative purpose. The notable exception is the Bonneville Power Administration as it is both the producer and the consumer of its aluminum industry research.

III. DESCRIPTIVE RESEARCH

U.S. Department of Commerce - 1985

In January of 1985, this agency released a comprehensive study titled Energy and the Primary Aluminum Industry. The purpose of this report was three fold. This included the documentation of lost competitiveness, an examination of the forces responsible for lost competitiveness and a policy prescription for improved competitiveness. The following is an outline of their most important conclusions and recommendations:

Conclusions

1) The world aluminum industry is going through a period of substantial structural change which has adverse implications for the U.S. aluminum industry.

   a- Non-traditional aluminum producing countries are capturing an increasing share of world capacity due to their proximity to low cost production inputs. This trend is expected to continue.
b- Government ownership of free world capacity has substantially increased from 10 percent in 1960 to 24 percent in 1980. This increases the percentage of capacity that operates regardless of market conditions. The consequence is that this tends to depress the price of aluminum.

c- Between 1950 and 1980, demand for aluminum has grown rapidly. Because of market saturation, the rate at which apparent consumption is currently expanding has significantly slowed.

2) Power rates have increased substantially in the U.S. especially in the BPA region. Rates that U.S. smelters pay are now among the highest in the world. In addition to high rates, inconsistent and unpredictable U.S. rate policies have hindered industry attempts at long range planning.

Recommendations

1) "develop rate making procedures that will provide the industry with long-term rate stability without subsidization from other customers."

2) "decontrol transmission lines (specifically BPA and TVA service areas) so that surplus electricity can be wheeled to high cost or shortage areas."

3) "While the optimal solution is developing rates on a 'cost of service' principle, we recognize that other options may have to be considered. 'Creative' ratemaking is one such option...... One example is indexing the electricity rate to an agreed upon aluminum price."

Bureau of Mines

The U.S. Bureau of Mines publishes several important sources of information concerning U.S. aluminum. These include a Minerals Yearbook, a bimonthly Minerals and Materials survey, and periodic
Mineral Commodity Profiles. The Yearbook recapitulates important international and domestic facts relevant to specific commodities. This typically includes information concerning capacity, commodity price, strikes, production and production technology.

The bimonthly Minerals and Materials Survey is like the yearbook in that it also presents vital aluminum industry statistics. However, it differs in that it sometimes includes analytical research regarding the state of U.S. aluminum viability. Some selected conclusions reached by the Bureau of Mines in the June/July 1986 Bimonthly Survey include:

1) U.S. aluminum capacity has declined sharply (about 20 percent) since 1980.

   a- The product life-cycle of aluminum has reached the stage of maturity. Furthermore, during the 1980's and 1990's, decreased per capita aluminum consumption is expected as new plastics and ceramics are used to replace aluminum.

   b- Net imports of crude and semi-fabricated metal have more than doubled since the energy crisis of 1973. However, net exports of aluminum scrap also more than doubled during that time period.

   c- The production of aluminum is highly energy intensive. Approximately $150 \times 10^6$ Btu are needed to produce one metric ton of aluminum from bauxite. Only $24 \times 10^6$ are needed to produce one metric ton of steel from iron ore.

2) If disparities in energy costs between U.S. and international competitors continue to grow, the United States will continue to lose its domestic market to foreign producers.
IV. ANALYTICAL RESEARCH

Aluminum Commodity Profile-1983

The third important Bureau of Mines publication is known as the Aluminum Commodity Profile. The 1983 "Profile" was important because the analysis went beyond summarizing current statistics. Specifically, the 1983 Aluminum Profile includes estimates of future aluminum demand for both the U.S. and the world. Forecasts for each of the 10 major end-use categories were made for the years 1990 and 2000. Figure 10 illustrates projected U.S. aluminum demand for the year 2000 as compared to actual 1981 demand.

In these demand forecasts, the high forecast is approximately 100 percent greater than the low forecast. This suggests that U.S. aluminum producers face a great deal of uncertainty as to future market conditions. The 1983 Aluminum Profile attributes a portion of this uncertainty to the fact that aluminum consumption is strongly tied to future levels of other variables like GNP and defense spending which are unknown. The study also contends that future levels of aluminum consumption will depend largely on how successful other materials such as high strength plastics are in replacing aluminum.

In terms of future aluminum supply, the study does not present econometric forecasts. However, it provides an estimate that in the year 2000, domestic supply will account for 75 percent of the probable domestic demand. One reason for this optimistic projection is that this study expresses confidence that new
## TABLE 10

**PROJECTED U.S. ALUMINUM DEMAND BY END USE FOR THE YEAR 2000**

<table>
<thead>
<tr>
<th>END USE</th>
<th>1981</th>
<th>STATISTICAL PROJECTION</th>
<th>CONTINGENCY FORECASTS FOR 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>Metal:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>1,074</td>
<td>2,900</td>
<td>1,800</td>
</tr>
<tr>
<td>Transportation</td>
<td>911</td>
<td>2,200</td>
<td>1,800</td>
</tr>
<tr>
<td>Electrical</td>
<td>564</td>
<td>950</td>
<td>500</td>
</tr>
<tr>
<td>Containers</td>
<td>1,496</td>
<td>4,400</td>
<td>1,700</td>
</tr>
<tr>
<td>Durables</td>
<td>417</td>
<td>1,200</td>
<td>700</td>
</tr>
<tr>
<td>Machinery</td>
<td>356</td>
<td>890</td>
<td>600</td>
</tr>
<tr>
<td>Other</td>
<td>269</td>
<td>370*</td>
<td>400</td>
</tr>
<tr>
<td>Total</td>
<td>5,087</td>
<td>12,910</td>
<td>7,500</td>
</tr>
<tr>
<td>Nonmetal:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refractories</td>
<td>209</td>
<td>610</td>
<td>410</td>
</tr>
<tr>
<td>Chemicals</td>
<td>349</td>
<td>540</td>
<td>510</td>
</tr>
<tr>
<td>Abrasives</td>
<td>104</td>
<td>230</td>
<td>180</td>
</tr>
<tr>
<td>Total</td>
<td>662</td>
<td>1,380</td>
<td>1,100</td>
</tr>
<tr>
<td>Grand Total</td>
<td>5,749</td>
<td>14,290</td>
<td>8,600</td>
</tr>
</tbody>
</table>

* R² is less than .70

**FIGURE 10**


technologies for producing aluminum will be developed which will benefit U.S. producers. Although research continues, no method of producing aluminum has ever proven cost effective other than the original smelting process that was introduced in the late 1800's. In addition, it should be noted that this study was conducted prior to the permanent closing of several U.S. smelters. Thus, its outlook concerning U.S. supply may be more optimistic than current conditions warrant.

Battelle - 1983

In 1983, the financial plight of the PNW aluminum industry prompted the region's aluminum companies to contract with Battelle Laboratories to conduct an independent study of how the PNW aluminum industry affects the PNW economy. One objective of the Battelle study was to compare the relative competitive position of the six North American aluminum regions. Battelle's methodology was to calculate the cost of alumina, electricity, labor, and transportation for representative plants within each of the six regions. Battelle contends that although aluminum plants face other production costs, the major expenses are represented by these four categories. The results generated from this analysis are presented in table 11. Battelle states that in 1983, electricity costs were responsible for the majority of the variation in regional production costs. Because of Canada's particularly low electricity costs, their smelters enjoy a distinct production cost advantage.
TABLE 11
SELECTED PRODUCTION COSTS FOR NORTH AMERICAN ALUMINUM REGIONS
(Costs in Dollars Per Short Ton)

<table>
<thead>
<tr>
<th>Region*</th>
<th>Alumina</th>
<th>Labor</th>
<th>Shipping</th>
<th>Electricity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNW</td>
<td>370</td>
<td>251</td>
<td>103</td>
<td>388</td>
<td>1112</td>
</tr>
<tr>
<td>S.E.</td>
<td>370</td>
<td>251</td>
<td>32</td>
<td>472</td>
<td>1125</td>
</tr>
<tr>
<td>O.V.</td>
<td>370</td>
<td>251</td>
<td>26</td>
<td>384</td>
<td>1031</td>
</tr>
<tr>
<td>N.E.</td>
<td>370</td>
<td>251</td>
<td>41</td>
<td>160</td>
<td>822</td>
</tr>
<tr>
<td>G.C.</td>
<td>370</td>
<td>251</td>
<td>75</td>
<td>300</td>
<td>996</td>
</tr>
<tr>
<td>Canada</td>
<td>390</td>
<td>216</td>
<td>65</td>
<td>54</td>
<td>725</td>
</tr>
</tbody>
</table>

FIGURE 11
NORTH AMERICAN REGIONAL COMPETITIVENESS (1983)

$\$/short ton

* See figure 3 in Chapter One for definition of regions

SOURCE: Battelle The Direct Service Industries: Their Contribution to the Northwest Power System and Economy April 1983
Merner - 1982

In September of 1982, a study comparing 1979 and projected 1983 North American smelter power costs was conducted by Merner Aluminum Research. This was carried out on a plant by plant basis. The input prices used by Merner were obtained either directly from suppliers or from published information. The electro-processing efficiencies were developed from statistical analysis by Merner. The following is a brief summary of Merner's conclusions:

1) Alcan is developing an increasingly large power cost advantage over its U.S. competitors.

2) Assuming a 100 percent utilization rate, the U.S. aluminum industry's annual power bill will rise approximately one billion dollars between 1979 and 1983.

3) Smelters in the Ohio Valley region will no longer be at a production cost disadvantage with PNW smelters after 1983.

4) Power cost increases at TVA have slowed but they have already risen to a point to challenge the viability of older plants.

5) The industry's economic health is going to be more intimately involved with coal now that the aluminum industry has lost access to BPA's low cost hydropower.

6) The power cost advantage that U.S. producers once had over foreign competitors will become negligible by 1983 if one ignores especially high cost plants in Japan, Korea, and Taiwan.

7) Even eliminating the highest tier of North American power, electricity cost differentials still account for over one half of the potential variation in North American production costs (see figure 12).
TABLE 12
PRODUCTION COST VARIABILITY

<table>
<thead>
<tr>
<th>Units/Ton</th>
<th>$/Unit</th>
<th>c/lb. of Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor (hours)</td>
<td>7-18</td>
<td>14-19</td>
</tr>
<tr>
<td>Alumina (tons)</td>
<td>1.95</td>
<td>100-300</td>
</tr>
<tr>
<td>Electricity (Mwh)</td>
<td>14-21</td>
<td>3-40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIGURE 12
LOW TO HIGH VARIABILITY FOR SELECTED PRODUCTION COSTS


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Since Merner is primarily concerned with generating raw aluminum industry data, their 1982 study is not recommendation oriented.

BPA - 1985

The most comprehensive regional aluminum research in the U.S. is conducted by Bonneville Power Administration. The purpose of BPA's research is to enhance its success at rate case hearings and to provide forecasts of future energy demand by the ten aluminum smelters that it serves. BPA's analytical research is derived from econometric time series analysis, an aluminum smelter model (simulator), and an oligopoly game theory decision making model. In the latter two cases, the parameters which drive the models are generated from econometric time series analysis.

Technical information concerning any of BPA's models or concerning BPA's output can be found in the December 1985 BPA report titled *Documentation for Variable Industrial Rate Design Study*. Specific information about individual PNW plant labor and energy efficiencies along with projected production levels can also be found in this documentation.

In February of 1985, BPA released an Issue Alert titled *BPA's Direct Service Industries: Changing Conditions—Changing Needs?* In this report, BPA summarizes its findings regarding the PNW aluminum industry. The following is an outline of BPA's findings and recommendations:
CONCLUSIONS

1) At least five of the ten PNW smelters are at risk of being shut down.

2) Two factors are primarily responsible for the financial plight of the region's aluminum industry.
   a- demand for aluminum decreased 12 percent between 1980 and 1983. In contrast, world aluminum supply increased during that time period.
   
b- Once the cheapest power on earth, PNW power rates increased more between 1979 and 1984 than anywhere else in the world. Today, PNW power is relatively expensive when compared to that paid by other world producers (see figure 13).

Some PNW plants are relatively energy inefficient. Cheap electricity once negated this inefficiency. However, higher electricity prices have increased the penalty of inefficiency.

3) Lost PNW aluminum competitiveness is bad for the PNW economy.
   a- The PNW aluminum industry directly employed over 12,400 jobs in 1981. These jobs are now at risk.
   
b- Kaiser Aluminum has postponed a 600 million dollar PNW aluminum modernization project because of questionable PNW aluminum viability.
   
c- Rising electricity prices forced Alumax to abandon plans to build a PNW smelter and instead opt to build in Quebec.

4) Lost PNW aluminum competitiveness is bad for BPA.
   a- In 1984, BPA received 640 million from its Direct Service Industries. Loss of these revenues would have serious impacts on BPA's ability to meet treasury debt obligations. It would also mean rate increases for BPA's other customers.
### TABLE 13
PERCENTAGE BREAKDOWN OF VARIABLE PRODUCTION COSTS

<table>
<thead>
<tr>
<th>Region</th>
<th>Energy</th>
<th>Alumina</th>
<th>Labor</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNW (1984)*</td>
<td>32.1%</td>
<td>28.2%</td>
<td>16.7%</td>
<td>23.0%</td>
</tr>
<tr>
<td>World Average</td>
<td>29.0%</td>
<td>39.9%</td>
<td>17.0%</td>
<td>14.1%</td>
</tr>
<tr>
<td>New Smelter (1985)</td>
<td>11.8%</td>
<td>41.6%</td>
<td>10.6%</td>
<td>35.8%</td>
</tr>
</tbody>
</table>

* Excludes portion of Alcoa Wenatchee served by Rocky Reach Hydro.

### FIGURE 13
PRIMARY ALUMINUM VARIABLE COST COMPOSITION

* Excludes portion of Alcoa Wenatchee served by Rocky Reach Hydro.

SOURCE: Bonneville Power Adm. Issue Alert February 1985

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RECOMMENDATIONS

1) BPA recommended in this Issue Alert that public hearings be held to evaluate the five options listed below. Based on these hearings and BPA's own analysis, the publication contends that one or more of the five options should be implemented as BPA policy.

    a- Adopt a long term variable rate pricing structure for the DSI's.
    b- Provide seed money for aluminum plant modernization.
    c- Allow the DSI's to purchase power from other sources.
    d- Offer DSI's a rate reduction for increased interruptibility.
    e- Maintain the status quo.

BPA acted on these recommendations when it adopted a variable rate pricing structure (the price of electricity is tied to the price of aluminum). This rate structure was approved by the Federal Energy Regulatory Commission in June of 1986.

Aluminum Studies - Conclusion

While many articles contend that U.S. aluminum competitiveness has been hurt by poor market conditions, the most prevalent view is that rising U.S. electricity prices have contributed the most to lost competitiveness. With regard to how U.S. aluminum imports have been affected by the strong U.S. dollar, few articles have been published. Furthermore, the literature is void of any attempt to use an import demand function to study aluminum imports. Articles in the Wall Street Journal and in other business related publications do mention the impact of exchange rates on

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Canadian export performance, but these articles do not directly relate to aluminum nor are they quantitative in nature.

V. IMPORT DEMAND ESTIMATION

The purpose of this section is to examine the theory behind import demand estimation. Initially, a simple definition of import demand is presented. Then two different theoretical approaches to import demand are explained. Graphical exposition is used to supplement the discussion.

Definition of Import Demand

Net imports can be expressed in the following form: \( \text{Imports} = (\text{domestic consumption} - \text{domestic supply} - \text{exports} + \text{net inventory change}) \). In general, import demand is the portion of total demand that is not satisfied by domestic supply. Because of this simple arithmetic relationship, determining the level of import demand is a trivial matter. However, explaining the level of import demand is more involved because one has to both identify important variables which influence import demand and to quantify the impact of each variable. That is, an import demand function must first be specified and then be estimated.

Since import demand is a subset of total demand, an import demand function is very similar in composition to a domestic demand function. For example, both total demand and import demand are determined by income, product price, tastes, market size, and price of substitutes. However, an import demand function is slightly more complicated because various international factors must be
included in the model. These additional variables are almost exclusively price shifters. The most important examples include tariffs, quota's, and exchange rates.

Most import demand studies are conducted under the assumption that a given country faces a perfectly elastic import supply curve. In other words, it is assumed that a country can import as much of a good as it wants without affecting the world price of that good. Figure 13A illustrates how import demand is determined for a country facing a perfectly elastic import supply curve. When domestic demand shifts from $D$ to $D'$ to $D''$ etc., the increased demand is met entirely by imports. Since the import price of good $X$ remains at 30 regardless of quantity imported, the world price of good $X$ is independent of country Y's level of imports. Moreover, the domestic price for the good will also be constant at 30 so long as demand exceeds 20 units.

The fact that world price and import demand are independent of each other means that no simultaneous relationships need be modeled. As a result, unbiased coefficients can be directly estimated by applying ordinary least squares (OLS) to a single equation import demand model. Because of the simplicity of modeling and estimating a single equation import demand function, the assumption of a perfectly elastic import supply curve is used extensively. Recent examples in economic literature include among others; Stern (1979), Chambers (1981) and Nickerson (1986).

As with any demand function, the most important import demand variables are price and income. Since exchange rates, tariffs, and quotas all help determine price, these variables are also
where:

\[ S \] = domestic supply of good \( x \)
\[ S_f \] = import supply curve for good \( x \)
\[ D \] = domestic demand for good \( x \)
\[ \overline{ab} \] = imports when demand = \( D \)
\[ \overline{ac} \] = imports when demand = \( D' \)
\[ \overline{ad} \] = imports when demand = \( D'' \)
\[ \overline{efg} \] = effective supply curve for country Y
expected to test significant. The following import demand function not only depicts the theoretical makeup of the single equation model, it also illustrates the simplicity of the single equation model.

\[ M_{dt} = \beta_0 + \beta_1 P_{dt} + \beta_2 P_{ft} + \beta_3 Y_{ct} + \beta_4 Y_{tt} + \beta_5 T + \beta_6 R + \beta_7 X \]

where:

- \( M_{dt} \) = The import demand in period \( t \). The demand can be the aggregate import demand for all commodities or for a specific commodity.

- \( P_{dt} \) = The domestic price for the commodity group. The sign should be positive with respect to import demand due to substitution. When prices in the domestic economy increase, imports will increase as foreign goods are substituted.

- \( P_{ft} \) = Imported price / domestic price. The sign should be negative. As the relative prices of imports rise, the volume of imports should fall.

- \( Y_{ct} \) = Cyclical portion of the income variable (reflects business cycle activity). The sign of the \( D \) coefficient depends on the construction of the variable.

- \( Y_{tt} \) = Trend portion of the income variable. The sign of the trend income variable is indeterminant because it is dependent on the type of goods imported. It should be positive if "luxury" or "normal" goods are imported but should be negative if "inferior" goods are imported.
\( T \) = Tariff rate on the imported commodity. The coefficient sign is expected to be negative. This is due to the fact that as the tariff rate increases, the relative prices of imports are likewise increased.

\( R \) = The effects of trade restrictions (quota's). This is usually a dummy variable indicating whether the restriction is present in a period or not. The sign is expected to be negative if the trade restriction has a significant effect on trade.

\( X \) = Miscellaneous variables to better specify an import demand equation for a particular industry. Such variables include technology, quality, etc..

Although many import demand studies assume that the country being studied faces a horizontal import supply curve, this assumption is not always appropriate. In some cases, the relevant market is small enough that a given country may face a steep import supply curve. This is especially true in cases where one country dominates the consumption of a particular good within a given market. In this situation, the price of the imported good may be directly related to the quantity of the good being imported.

Figure 13B illustrates a two country market where the import supply curve for country Y is not perfectly elastic. Ceteris paribus, if demand for good x in country Y were to shift to the right, there would be an increase in imports. But if this were to occur, the market price for the product would also increase. This means that imports and market price are not independent. As a result, a partial equilibrium model would have to be constructed and estimated in
TABLE 13B
PARTIAL EQUILIBRIUM IN A TWO-COUNTRY MARKET

Where:

\[ D_z = \text{quantity demanded by country Z} \]
\[ D_y = \text{Quantity demanded by country Y} \]
\[ D_m = \text{total market demand} \ (D_z + D_y) \]
\[ S_z = \text{quantity supplied by country Z} \]
\[ S_y = \text{quantity supplied by country Y} \]
\[ S_m = \text{total market supply} \ (S_z + S_y) \]
\[ P = \text{market equilibrium price} \]
\[ \overline{ab} = \text{imports by country Y} \ (\text{exports by country Z}) \]
order to determine country Y's import demand. This type of model can be developed from figure 13B.

Market supply is obtained by summing country Y and country Z's domestic supply curves \((S_y + S_z)\). Likewise, market demand is obtained by summing country Y and country Z's domestic demand curves \((D_y + D_z)\). In figure 13B, the market supply and demand curves are designated \(S_m\) and \(D_m\). The equilibrium market price for good x occurs at the intersection of these two curves. In figure 13B, market supply equals market demand at a price of 40 and at a quantity of approximately 75 units.

Import demand for country Y is equal to \(D_y - S_y\) (or \(S_z - D_z\)). In order to isolate import demand, it is helpful to first break the market equilibrium model into its structural equations. These equations are listed below. Notice that the simultaneous nature of the model results from the inclusion of market price in each of the equations.

**Structural Equations**

\[
\begin{align*}
D_y &= f_1(P, \text{ exogenous demand variables}) \\
D_z &= f_2(P, \text{ exogenous demand variables}) \\
S_y &= f_3(P, \text{ exogenous supply variables}) \\
S_z &= f_4(P, \text{ exogenous supply variables}) \\
D_y + D_z &= S_y + S_z
\end{align*}
\]
After the above equations have been simultaneously solved, import demand can be determined by subtracting $S_y$ from $D_y$. However, it usually easier to estimate import demand by putting the structural equations into their reduced forms. Once this has been done, each of the reduced form equations will become a function of all the exogenous variables contained in the structural equations. The reduced form equations are presented below:

\[
P = g_1(\text{all exog. supply and demand variables for country Y and country Z})
\]

\[
D_y = f_1[g_1(\text{all exog. variables}), \text{exogenous demand variables for country Y}]
\]

\[
D_z = f_2[g_1(\text{all exog. variables}), \text{exogenous demand variables for country Z}]
\]

\[
S_y = f_3[g_1(\text{all exog. variables}), \text{exogenous supply variables for country Y}]
\]

\[
S_y = f_4[g_1(\text{all exog. variables}), \text{exogenous supply variables for country Y}]
\]

Since import demand for country Y is equal to $D_y - S_y$, and since $D_y$ and $S_y$ are both a function of all exogenous variables, import demand for country Y is also a function of all exogenous variables [$M_y = f_5(\text{all exog. variables})$]. Since ordinary least squares can be directly applied to each of the reduced form equations, it can also be directly applied to the import demand equation.
Reduced form import demand functions are not common in economics literature. One reason for this is that until recently, nearly all import demand functions were estimated using highly aggregated data. That is, import demand was seldom estimated for a single commodity. When all commodities are lumped together, it was often assumed that a country faced a perfectly elastic import supply curve. The reason for this is that the relevant market became the world market. Because there are many countries in the world market, it was easy to assume that no one country dominated the average price for all internationally traded commodities.

Now that trade is becoming a more important factor in the U.S. economy, less aggregated studies are proving to be more useful. With respect to aluminum, the United States controls so much of both world supply and demand that the assumption of a perfectly elastic import supply curve would be inappropriate. As a result, U.S. import demand for aluminum will be estimated in this study using a reduced form import demand model similar to the one described in this chapter.
CHAPTER FOUR
MODELING THE U.S. - CANADIAN ALUMINUM MARKET

I. INTRODUCTION

The objective of this chapter is to develop a model suitable for estimating U.S. import demand of Canadian aluminum. To accomplish this objective, the chapter is broken into two parts. First, two assumptions are presented that will facilitate the estimation procedure. Second, the import demand function to be employed in this thesis is derived.

II. ASSUMPTIONS OF THE MODEL

The first major assumption made in modeling U.S. imports of Canadian aluminum is that North America can be viewed as a separate aluminum market. According to BPA aluminum specialist Paul Spies, this assumption is often made in studies that examine U.S. and Canadian aluminum. The justification for viewing North America as a separate market relates to transportation costs. Specifically, it costs significantly less to transport aluminum from Canada to the U.S. than it does to transport aluminum to the U.S. from other potential sources. This is one reason that over 50 percent of Canadian aluminum exports are destined for the U.S. and why as much as 80 percent of U.S. imports of unwrought unalloyed aluminum originate in Canada.

To illustrate how U.S. and Canadian shipping costs compare, it
is helpful to break North America into six aluminum regions of which five are in the United States and one is in Canada. In 1982, Battelle Laboratories ranked these six regions in terms of what it cost them to ship aluminum to Toledo, Ohio. This specific city was selected because of its close proximity to where the majority of U.S. aluminum fabricating occurs. Battelle concluded that Canadian producers had higher transportation costs than three U.S. production regions, but they had lower transportation costs than those of the remaining two U.S. regions. On a weighted average basis, it costs Canadian producers approximately five dollars more per short ton than their U.S. counterparts to transport aluminum to Toledo.38

In contrast to Canada, other potential sources for U.S. aluminum imports are located in most instances thousands of miles away. Figure14 illustrates the estimated transportation costs for newly constructed smelters located in different world regions. These transportation costs are not based on aluminum shipments to Toledo, or necessarily even to the United States. However, table 14 indicates that the United States and Japan are the principal aluminum export markets. With the exception of Canada, non-U.S. producers face approximately the same shipping costs regardless of whether their primary export market is the United States or Japan. One reason for this is that Japan and the United States are both located long distances from Brazil, Australia and the Middle East. This gives Canadian producers a distinct edge because all but one of
### TABLE 14

**ESTIMATED PRODUCTION COSTS FOR NEW ALUMINUM SMELTERS**  
(IN 1982 U.S. DOLLARS)

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>U.S.</th>
<th>AUSTRALIA</th>
<th>BRAZIL</th>
<th>CANADA</th>
<th>MID. EAST</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAW MATERIAL</td>
<td>396</td>
<td>371</td>
<td>385</td>
<td>417</td>
<td>396</td>
</tr>
<tr>
<td>ELECTRICITY</td>
<td>440</td>
<td>240</td>
<td>240</td>
<td>260</td>
<td>150</td>
</tr>
<tr>
<td>LABOR</td>
<td>137</td>
<td>137</td>
<td>103</td>
<td>137</td>
<td>137</td>
</tr>
<tr>
<td>TRANSPORTATION</td>
<td>20</td>
<td>112</td>
<td>112</td>
<td>52</td>
<td>112</td>
</tr>
<tr>
<td>OTHER</td>
<td>374</td>
<td>408</td>
<td>388</td>
<td>402</td>
<td>408</td>
</tr>
<tr>
<td>CASH TOTAL</td>
<td>1367</td>
<td>1258</td>
<td>1248</td>
<td>1268</td>
<td>1203</td>
</tr>
<tr>
<td>CAPITAL RECOVERY</td>
<td>316</td>
<td>400</td>
<td>407</td>
<td>390</td>
<td>407</td>
</tr>
<tr>
<td>TOTAL COSTS</td>
<td>1683</td>
<td>1658</td>
<td>1665</td>
<td>1658</td>
<td>1610</td>
</tr>
</tbody>
</table>

**MAJOR EXPORT MARKET**  
N/A        JAPAN    JAPAN    U.S.    JAPAN

**FIGURE 14**

**SELECTED PRODUCTION COSTS FOR NEWLY BUILT SMELTERS**

![Bar chart showing production costs for new smelters by country and component](chart.png)


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their plants are located in the Province of Quebec which is geographically little more than an extension of the U.S.'s Northeast aluminum region (see figure 3 from Chapter Two). The result is that Canadian transportation costs are approximately 60 dollars per ton less than those faced by other non-U.S. producing regions.

All the costs presented in Table 14 relate to what production costs would be for new 1982 plants. Thus, these costs are not necessarily indicative of those experienced by plants currently operating in those regions. However, the transportation cost factor is probably representative of that experienced by new and old plants located in the same geographic area. Other costs, like electricity, vary significantly between new and old plants. Therefore, table 14 should not be used to draw conclusions about regional competitiveness in general.

Further evidence that transportation costs isolate the U.S. - Canadian market is that the New York COMMEX spot price differs from the London Metal Exchange price by as much as 60 dollars per short ton. The only logical explanation for this price differential is that it represents the transportation cost of shipping aluminum between the two markets. Any other cause for the price difference would be quickly erased by aluminum traders engaging in arbitrage.

As figure 14 illustrates, there are several nations that export aluminum. One indication that transportation costs have been an effective barrier is that the United States imports nearly all of its primary aluminum from Canada rather than from these other sources.

Making the assumption that North America is a separate
market allows us to derive the necessary import demand function from a two country partial equilibrium model rather than from a world partial equilibrium model. This means that only information affecting supply and demand for the U.S. and Canada need be considered. This makes the model both easier to derive due to fewer equations and easier to estimate due to fewer data requirements.

III. ASSUMPTION TWO

The second major modeling assumption is that the U.S.- Canadian aluminum industry is competitive. The reason for including this assumption is because it is very difficult to model non-competitive behavior. Firms in a non-competitive industry may not be profit maximizers. Rather, these firms may be market share maximizers or "satisficers". By the very definition of a non-competitive industry, at least some firms are large enough to affect price. Thus, the price of the product may not always be determined by the forces of supply and demand but by some alternative scheme such as price leadership. To capture non-competitive oligopolistic behavior, a theoretical structure such as game theory must be used. Use of a sophisticated technique like game theory is beyond the scope of this thesis.

Prior to the mid 1970's, the North American aluminum market was not at all characterized by competitiveness and this assumption would have been highly inappropriate. One historical indication of this non-competitiveness is the fact that in 1960 the top three U.S. aluminum producers accounted for over 87 percent of U.S. capacity (see figure 15). In addition, Canadian capacity was exclusively
### TABLE 15

1960 MARKET SHARE CONCENTRATION IN U.S. PRIMARY ALUMINUM

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>MARKET SHARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALCOA</td>
<td>34.5%</td>
</tr>
<tr>
<td>REYNOLDS</td>
<td>28.4%</td>
</tr>
<tr>
<td>KAISER</td>
<td>24.7%</td>
</tr>
<tr>
<td>OTHERS</td>
<td>12.4%</td>
</tr>
</tbody>
</table>

### FIGURE 15

![Pie chart showing market share concentration](image)

**SOURCE:** Electric Power Research Institute, *The U.S. Aluminum Industry 1983-2000, with Implications for Electricity Demand* January 1984

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controlled by Aluminum Company of Canada (ALCAN) and Reynolds Aluminum of Canada. The fact that four companies controlled so much of North American capacity led to price leadership. Alcoa was the undisputed price leader. Alcoa would publish a monthly list price and other companies would typically adopt the Alcoa price. However, the actual price paid by large aluminum consumers depended on their bargaining position and on current market conditions. These factors determined whether the list price was discounted or whether a premium was added to it.

The reason that so few companies could dominate such a large portion of the aluminum market relates to the fact that there has historically been two significant barriers that have inhibited the entry of new firms into the industry. First, a financial barrier exists because building an aluminum smelter requires tremendous fixed capital outlays. In 1987, a new smelter jointly owned by a U.S. aluminum company and the Province of Quebec will come on line. The cost of this plant is estimated to be between 1.2 and 1.5 billion U.S. dollars. Two other proposed Canadian plants have price tags over one billion U.S. dollars.40

One reason for such high capital costs is that there are huge economies of scale in aluminum smelting. As a result, minimum long-run average cost is only attainable if you are a very large company. Historically, Alcoa was able to exclude competitors simply because it was large enough to be very profitable even though marginal revenue was quite small. In addition to Alcoa's size, its vertical integration has contributed to its ability to be profitable at
very low aluminum prices.

A second barrier to entry was that the large established aluminum companies for many years actively tried to monopolize the industry. Predatory pricing was one method used by established firms to keep potential competitors out of the industry. Until the 1970's, aluminum was a high growth industry. Large producers responded to anticipated growth by consistently over-building their capacity. This allowed them to flood the market with aluminum during strategic times to keep the price of aluminum depressed so that new producers would be discouraged from entering the industry. In the 1945 antitrust case of *U.S. vs. Alcoa*, Judge Learned Hand ruled that, among other things, Alcoa had monopolized the industry by engaging in predatory pricing and by systematically over-building capacity.42

The competitive nature of the industry began to improve in the early 1960's and is still improving. This trend toward competitiveness can be attributed to several forces. First, the barrier to entry caused by high fixed costs has become less effective. One reason for this is that potential aluminum producers in the 1960's began to band together and form joint ventures. A major advantage of this arrangement is that groups can not only raise capital more easily, they can also combine their different technological and marketing specialties to more efficiently produce and market aluminum products. In fact, the two most structurally efficient aluminum plants in the U.S. are owned by Alumax which is 50 percent controlled by the U.S. firm AMAX, 45 percent by Mitsui &
Co., and 5 percent by Nippon Steel. New firms like Alumax have not only helped decrease market share concentration, but their superior efficiency allows them to compete on the basis of price with the more vertically integrated and established aluminum giants.

A second force responsible for increased competitiveness has been that while aluminum capacity continued to expand during the 1970's, growth in aluminum demand was slowing significantly. By the early 1980's, substantial excess capacity existed in the North American market. This excess capacity tended to keep the price of aluminum depressed. Large companies like Alcoa have some of the oldest and least efficient plants. Low aluminum prices have forced these companies to permanently close high cost facilities. In 1983, Reynolds Aluminum permanently closed 186,000 tons of capacity. In 1986, Alcoa permanently closed 189,000 tons of capacity. In fact, the majority of capacity that has been closed since 1978 has been by Alcoa, Reynolds, and Kaiser Aluminum. Thus, although new capacity hasn't been built in the U.S. since 1980, the market share held by smaller producers continues to increase relative to that held by the "big three". Compare figure 15 with figure 16 to see how the relative share of U.S. capacity controlled by the "big three" has consistently fallen since 1960.

A third factor contributing to increased competitiveness took effect when trading of aluminum futures began on the London Metal Exchange in 1978 and on the New York COMMEX in 1983. When demand for aluminum fell sharply in the late 1970's and early 1980's, aluminum producers were suddenly faced with huge
TABLE 16

MARKET SHARE CONCENTRATION IN U.S. PRIMARY ALUMINUM
1980 AND 1986

MARKET SHARE

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>1980</th>
<th>1986</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALCOA</td>
<td>31.5%</td>
<td>29.9%</td>
</tr>
<tr>
<td>REYNOLDS</td>
<td>17.7%</td>
<td>18.7%</td>
</tr>
<tr>
<td>KAISER</td>
<td>13.1%</td>
<td>10.3%</td>
</tr>
<tr>
<td>OTHERS</td>
<td>37.7%</td>
<td>41.2%</td>
</tr>
</tbody>
</table>

FIGURE 16

SOURCE1: Ibid.

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inventories. Many producers responded by selling their excess aluminum on the spot market. The huge swings in the price of aluminum that occurred during the early 1980's made the future's market attractive to aluminum buyers who wanted to "hedge" against the risk associated with price fluctuations.

The increasingly important role of this spot market has undermined the dominant position that the "list price" previously held and the price leadership built around it. The U.S. Department of Commerce in December of 1984 concluded that since 1978, large aluminum companies have lost complete control over the price of aluminum and that the list price of aluminum has been reduced to a token role. The divergence between the list price and the spot price has been dramatic. Between 1981 and 1985, the spot price averaged 21.5 cents per pound less than the list price. During the same period, the average list price was 78.4 cents per pound. This is a 27 percent divergence.

The cumulative impact of lower barriers to entry, chronic over capacity, and the trading of aluminum futures has been to make the aluminum industry more competitive. This does not mean that the aluminum industry is an example of perfect competition. Industrial giants like Alcoa still have the power to affect the market. However, financial losses in aluminum production during recent years have forced even Alcoa to act more like a profit maximizer. Since the time period covered in this thesis is 1978 through 1986, the industry is being studied during its most competitive stage.
III. MODELING U.S. DEMAND FOR CANADIAN ALUMINUM

The first step in deriving a U.S. import demand function for Canadian aluminum is to construct a partial equilibrium model for the North American aluminum market. Given the assumptions that have been made, total demand in this joint market is the horizontal summation of the U.S. and Canadian aluminum demand curves. Likewise, total supply in this market is the horizontal summation of the U.S. and Canadian aluminum supply curves. Equilibrium in the market will occur at the price where supply equals demand. These relationships can be expressed in the following model:

\[ D_{us} = f_1(P_{al}, P_{sub}, Y_{us}, \text{OTHER}) \]
\[ S_{us} = f_2(P_{al}, P_{Cus}, C_{us}) \]

\[ D_{can} = f_3(P_{al}, P_{sub}, Y_{can}, EX, T, \text{OTHER}) \]
\[ S_{can} = f_4(P_{al}, P_{Ccan}, C_{can}, EX, T) \]

\[ D_{us} + D_{can} = S_{us} + S_{can} \]

where:

- \( D_{us} = \) U.S. aluminum demand
- \( S_{us} = \) U.S. aluminum supply
- \( D_{can} = \) Canadian aluminum demand
- \( S_{can} = \) Canadian aluminum supply
- \( P_{al} = \) U.S. - Canadian aluminum market price
- \( P_{sub} = \) price of substitutes
- \( Y_{us} = \) U.S. income
- \( Y_{can} = \) Canadian income
- \( T = \) U.S. Tariff on imported Canadian aluminum
- \( P_{Cus} = \) U.S. aluminum production costs
- \( P_{Ccan} = \) Canadian aluminum production costs
- \( C_{us} = \) U.S. aluminum capacity
\[ C_{\text{can}} \] = Canadian aluminum capacity
\[ \text{EX} \] = Exchange rate (Can.$/U.S.$)

\[ \text{OTHER} \] = Other exogenous demand factors (market size, tastes). Since market size changes very slowly and tastes are difficult to measure, these variables can be dropped from the model.

To facilitate the derivation of import demand, it is helpful to convert the structural equilibrium model into its reduced form. By definition this requires that each endogenous variable be expressed as a function of all exogenous variables contained in the structural equations. The reduced forms of the structural equations are:

\[
P_{\text{al}} = g_1(\text{Cus}, \text{Ccan}, \text{PCus}, \text{PCan}, \text{Yus}, \text{Ycan}, \text{Psub}, \text{EX}, \text{T})
\]

\[
D_{\text{us}} = f_1[g_1(\text{Cus}, \text{Ccan}, \text{PCus}, \text{PCan}, \text{Yus}, \text{Ycan}, \text{Psub}, \text{EX}, \text{T}), \text{Yus}, \text{Psub}, \text{T}]
\]

\[
S_{\text{us}} = f_2[g_1(\text{Cus}, \text{Ccan}, \text{PCus}, \text{PCan}, \text{Yus}, \text{Ycan}, \text{Psub}, \text{EX}, \text{T}), \text{Cus}, \text{PCus}, \text{T}]
\]

\[
D_{\text{can}} = f_3[g_1(\text{Cus}, \text{Ccan}, \text{PCus}, \text{PCan}, \text{Yus}, \text{Ycan}, \text{Psub}, \text{EX}, \text{T}), \text{Ycan}, \text{Psub}]
\]

\[
S_{\text{can}} = f_4[g_1(\text{Cus}, \text{Ccan}, \text{PCus}, \text{PCan}, \text{Yus}, \text{Ycan}, \text{Psub}, \text{EX}, \text{T}), \text{Ccan}, \text{PCan}]
\]
From the reduced form equations, it is a simple step to derive U.S. import demand. By definition, U.S import demand is equal to the difference between U.S. demand and U.S. supply. This is represented by the following equation:

\[ M_{us} = D_{us} - S_{us} \]

where:
- \( M_{us} \) = U.S. aluminum imports from Canada
- \( D_{us} \) = U.S. demand for aluminum
- \( S_{us} \) = U.S. supply of aluminum

We can simplify this model by substituting the actual U.S. supply and demand equations into the import demand equation. This allows us to look at import demand as the sum of its components. After making this substitution, import demand simply becomes a function of all the exogenous variables contained in the structural equations.

IV. PREDICTING THE SIGNS ON THE COEFFICIENTS

Predicting the expected signs for the explanatory variables is facilitated by totally differentiating the import demand function. The total differential of import demand expresses a change in imports equal to the summation of the changes brought about by each
variable affecting imports. Mathematically, the total differential of import demand takes the following form:

\[
\begin{align*}
\frac{\partial D_{us}}{\partial g_1} \frac{\partial D_{us}}{\partial x_i} \frac{\partial D_{us}}{\partial x_i} - \frac{\partial S_{us}}{\partial g_1} \frac{\partial S_{us}}{\partial x_i} \frac{\partial S_{us}}{\partial x_i} \\
\frac{\partial P_{al}}{\partial g_1} \frac{\partial P_{al}}{\partial x_i} \frac{\partial P_{al}}{\partial x_i} - \frac{\partial S_{us}}{\partial P_{al}} \frac{\partial S_{us}}{\partial x_i} \frac{\partial S_{us}}{\partial x_i}
\end{align*}
\]

The following is a typical coefficient:

\[
\begin{align*}
\left[\begin{array}{c}
\frac{\partial D_{us}}{\partial S_{us}} \frac{\partial P_{al}}{\partial x_i} \\
\frac{\partial P_{al}}{\partial S_{us}} \frac{\partial P_{al}}{\partial x_i}
\end{array}\right] \frac{\partial D_{us}}{\partial x_i} + \left[\begin{array}{c}
\frac{\partial D_{us}}{\partial S_{us}} \frac{\partial P_{al}}{\partial x_i} \\
\frac{\partial P_{al}}{\partial S_{us}} \frac{\partial P_{al}}{\partial x_i}
\end{array}\right] \frac{\partial D_{us}}{\partial x_i}
\end{align*}
\]

This illustrates that each coefficient sign is potentially a result of the cumulative impact of four distinct forces. A given variable may affect supply and demand directly, or it may affect
supply and demand indirectly through the market price. Direct
effects on supply and demand cause those curves to shift while
indirect effects cause movement along the curves. In the case of
Canadian variables, unambiguous signs can be determined by working
through the partial differential associated with each Canadian
variable. The following is an example of how partially
differentiating U.S. import demand for aluminum with respect to
Canadian income leads to an unambiguous negative sign:

\[
\begin{bmatrix}
-\partial D_{us} & \partial S_{us} & \partial P_{al} \\
-\partial P_{al} & \partial P_{al} & \partial Y_{can} \\
0 & 0 & \partial Y_{can}
\end{bmatrix}
\begin{bmatrix}
\partial D_{us} \\
\partial S_{us} \\
\partial P_{al} \\
\partial Y_{can}
\end{bmatrix} +
\begin{bmatrix}
-\partial D_{us} & \partial S_{us} \\
-\partial P_{al} & \partial P_{al} \\
0 & 0 \\
\partial Y_{can} & \partial Y_{can}
\end{bmatrix}
\begin{bmatrix}
\partial D_{us} \\
\partial S_{us} \\
\partial P_{al} \\
\partial Y_{can}
\end{bmatrix}
\]

\[dY_{can} = -dY_{can}\]

With U.S. variables, the signs are unambiguous if one assumes
that a variable's direct effect on imports is always larger than its
indirect effect(s). For example, an increase in U.S. production costs
will cause U.S. supply to decrease (direct effect). A decrease in U.S.
supply will also cause the market price of aluminum to increase.
This will discourage U.S. consumption (indirect effect). The net
effect on import demand theoretically depends on the relative
magnitude of these two forces. In general, one would expect the
impact on U.S. supply to be greater than the impact on U.S. demand.
As a result, U.S. imports for aluminum would increase. Given the
reasonableness of the assumption explained above, it will be
employed so that unambiguous signs can be determined for the U.S.
variables.
Expected Coefficient Signs

$C_{can} = \text{Canadian capacity.}$ The expected sign attached to this variable's coefficient is positive. As Canadian capacity increases, the market price is driven down. This stimulates U.S. demand. Since the price decrease will cause U.S. supply to fall, higher U.S. demand is satisfied by higher U.S. imports.

$P_{C_{can}} = \text{Canadian production costs.}$ The signs attached to the various Canadian production costs should all be negative. As Canadian production costs increase, it forces up the market price of aluminum. This will cause U.S. demand to fall in response to the higher price and it will cause U.S. supply to increase (at least in the long-run). Both factors will serve to decrease U.S. imports.

$Y_{can} = \text{Canadian income.}$ The sign for Canadian income should be negative. When Canadian income increases, Canadian demand for aluminum increases which theoretically will force up the market price. This will cause U.S. demand to decrease and U.S. supply to increase. Both factors cause U.S. imports of aluminum to fall.

$EX = \text{Ratio of Canadian dollars per U.S. dollar.}$ The correct sign for the exchange rate coefficient is positive. If the U.S. dollar increases relative to the Canadian dollar, it impacts U.S. imports the same way that a decrease in Canadian production costs would. This is true by definition since a relative increase in the U.S. dollar translates into lower Canadian production costs.

$T = \text{U.S. tariffs on aluminum imports.}$ The correct sign for the tariff variable is negative. Higher tariffs cause the effective price of imported aluminum to rise relative to that of domestic aluminum. This tends to both decrease U.S. aluminum demand and increase U.S. aluminum supply. These factors jointly cause imports to fall.

$C_{us} = \text{U.S. aluminum capacity.}$ One would expect an inverse relationship between changes in U.S. capacity and U.S. imports. When U.S. aluminum capacity increases, the gap between U.S. supply and demand decreases. This, results in lower imports.
\( PC_{us} \) = U.S. aluminum production costs. The relationship between domestic production costs and imports is expected to be direct. As U.S. production costs increase, the marginal producer is forced to shut down. This reduces U.S. aluminum supply which means that more aluminum will have to be imported to maintain the current level of domestic demand.

\( Y_{us} \) = U.S. income. The sign is expected to be positive since the marginal propensity to import for a country is typically positive. As U.S. income increases, U.S. demand for aluminum also increases. Unless the increase in U.S. demand is accompanied by a larger increase in U.S. supply, net U.S. imports will increase.

\( P_{sub} \) = Price of aluminum substitutes. According to various sources, copper and iron are currently the two closest substitutes for aluminum. The expected sign for their coefficients would be positive. If the price of copper or iron increases, then aluminum will be substituted in their place. This will drive up domestic demand for aluminum and thus imports.
CHAPTER FIVE
ESTIMATING U.S. IMPORT DEMAND FOR ALUMINUM

I. INTRODUCTION

The purpose of this chapter is to address the question posed in the hypothesis statement. Namely, have rising domestic electricity rates been the most important factor in determining U.S. import demand for Canadian aluminum or have exchange rates played a more important role? In order to test the relative importance of these two variables, it is necessary to first examine any characteristics about the data that would affect the test results. After various data considerations have been examined, the aluminum import demand function will be estimated. At that point, the regression results will be analyzed and then conclusions regarding the hypothesis statement will be presented.

II. DATA

Although U.S. aluminum competitiveness began to deteriorate in the late 1970's, the impact on U.S. imports did not occur until the early 1980's (see figure 17). One explanation is that when aluminum futures started trading on the London Metal Exchange (LME) in 1978, speculation in the market boosted the price of aluminum which allowed many U.S. smelters to produce profitably even though their production costs were rapidly rising. In order to avoid the initial market disruptions that resulted when aluminum began trading on the LME, U.S. import demand is estimated from January 1979 through March 1986. Because only a seven year time period is
TABLE 17

U.S. IMPORTS OF CANADIAN ALUMINUM (1978 - 1985)
IN MILLIONS OF POUNDS

<table>
<thead>
<tr>
<th>YEAR</th>
<th>IMPORTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>338.3</td>
</tr>
<tr>
<td>1980</td>
<td>484.9</td>
</tr>
<tr>
<td>1981</td>
<td>552.1</td>
</tr>
<tr>
<td>1982</td>
<td>478.9</td>
</tr>
<tr>
<td>1983</td>
<td>593.8</td>
</tr>
<tr>
<td>1984</td>
<td>681.5</td>
</tr>
<tr>
<td>1985</td>
<td>794.7</td>
</tr>
</tbody>
</table>

FIGURE 17

U.S. IMPORTS OF CANADIAN ALUMINUM


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covered, monthly data is used so that sufficient observations are available.

Data Problems

Preliminary evaluation of the data set indicates that certain problems are associated with it. The following discussion addresses these problems and details how their impact can be minimized.

Autocorrelation

The use of monthly data introduces an element of randomness to the dependent variable which is difficult to model. Specifically, there are numerous factors which determine when a shipment of aluminum actually enters the United States. Unfortunately, the impact on monthly imports of a shipment entering at the end of one month rather than the first of another can be substantial since one shipment may be a significant portion of the total aluminum shipped for that month.

In order to make the dependent variable less erratic, a three month moving average was used to initially estimate the model. While time series data often exhibits autocorrelation, transforming the data into a moving average makes it inherently autocorrelated. Autocorrelation exaggerates the size of the standard coefficient errors which makes the explanatory variables appear to be less significant than they really are. To correct for autocorrelation, the two stage Cochrane-Orcutt method was applied to the three month moving average model. This approach produced a Durbin-Watson
statistic of 1.61. The implication of a 1.61 Durbin-Watson is that some autocorrelation is still present even after the data has been corrected. Thus, the significance of the estimated coefficients may be understated.

When the two stage Cochrane-Orcutt correction technique is applied to unaveraged data, a Durbin-Watson statistic of 2.0 is generated which indicates that using unaveraged data reduces the threat of autocorrelation. However, the unaveraged model explains nearly 30 percent less of the dependent variable compared to the moving average model. As a result, only regression results from the moving average model will be presented in this chapter.

Multicollinearity

To test the data set for the presence of multicollinearity, the simple correlation coefficient between each of the model's variables was calculated. These are presented in Table 17A. As this table illustrates, the correlation is very strong in some cases. Unfortunately, there are no firm rules for assessing the impact of multicollinearity on the size, sign or t statistic of a given coefficient. One common consequence of multicollinearity is that the significance of the coefficients attached to the offending variables is understated. Another potential implication is that the coefficients may be adversely affected, sometimes to the extent that the coefficient sign changes.

Since table 17A indicates that the degree of multicollinearity is serious, the next step is to minimize its influence. Due to the uncertainty of how a given model will be affected by the presence of
# TABLE 17A

**CORRELATION COEFFICIENT MATRIX**  
(Nominal Data)

<table>
<thead>
<tr>
<th></th>
<th>EX</th>
<th>Lus</th>
<th>L_can</th>
<th>Yus</th>
<th>Y_can</th>
<th>Cus</th>
<th>C_can</th>
<th>Al</th>
<th>T</th>
<th>Eus</th>
<th>E_can</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX</td>
<td>1.0</td>
<td>.84</td>
<td>.86</td>
<td>.77</td>
<td>.44</td>
<td>-.59</td>
<td>.90</td>
<td>-.14</td>
<td>.16</td>
<td>.63</td>
<td>.73</td>
</tr>
<tr>
<td>Lus</td>
<td>.84</td>
<td>1.0</td>
<td>.96</td>
<td>.51</td>
<td>.07</td>
<td>.18</td>
<td>.93</td>
<td>-.10</td>
<td>.51</td>
<td>.80</td>
<td>.80</td>
</tr>
<tr>
<td>L_can</td>
<td>.86</td>
<td>.96</td>
<td>1.0</td>
<td>.59</td>
<td>.15</td>
<td>-.25</td>
<td>.89</td>
<td>-.21</td>
<td>.39</td>
<td>.85</td>
<td>.84</td>
</tr>
<tr>
<td>Yus</td>
<td>.77</td>
<td>.51</td>
<td>.59</td>
<td>1.0</td>
<td>.85</td>
<td>-.63</td>
<td>.56</td>
<td>.00</td>
<td>-.07</td>
<td>.43</td>
<td>.65</td>
</tr>
<tr>
<td>Y_can</td>
<td>.44</td>
<td>.07</td>
<td>.15</td>
<td>.85</td>
<td>1.0</td>
<td>-.66</td>
<td>.20</td>
<td>.14</td>
<td>-.31</td>
<td>.00</td>
<td>.30</td>
</tr>
<tr>
<td>Cus</td>
<td>-.59</td>
<td>-.18</td>
<td>-.25</td>
<td>-.63</td>
<td>-.66</td>
<td>1.0</td>
<td>-.46</td>
<td>.16</td>
<td>.44</td>
<td>-.09</td>
<td>-.25</td>
</tr>
<tr>
<td>C_can</td>
<td>.90</td>
<td>.93</td>
<td>.89</td>
<td>.56</td>
<td>.20</td>
<td>-.46</td>
<td>1.0</td>
<td>-.61</td>
<td>.41</td>
<td>.67</td>
<td>.71</td>
</tr>
<tr>
<td>Al</td>
<td>-.14</td>
<td>-.10</td>
<td>-.21</td>
<td>.00</td>
<td>.14</td>
<td>.16</td>
<td>-.06</td>
<td>1.0</td>
<td>.56</td>
<td>-.36</td>
<td>-.29</td>
</tr>
<tr>
<td>T</td>
<td>.16</td>
<td>.51</td>
<td>-.39</td>
<td>-.07</td>
<td>-.31</td>
<td>.44</td>
<td>.41</td>
<td>.56</td>
<td>1.0</td>
<td>.27</td>
<td>.14</td>
</tr>
<tr>
<td>Eus</td>
<td>.63</td>
<td>.80</td>
<td>.85</td>
<td>.43</td>
<td>.00</td>
<td>-.98</td>
<td>.67</td>
<td>-.36</td>
<td>.27</td>
<td>1.0</td>
<td>.83</td>
</tr>
<tr>
<td>E_can</td>
<td>.73</td>
<td>.80</td>
<td>.84</td>
<td>.65</td>
<td>.30</td>
<td>-.25</td>
<td>.71</td>
<td>-.29</td>
<td>.14</td>
<td>.83</td>
<td>1.0</td>
</tr>
</tbody>
</table>
multicollinearity, several schools of thought exist regarding how the problem should be handled. One solution to multicollinearity is to omit the least important offending variables. Thus, if only two variables are highly correlated, the problem of multicollinearity will be solved if one of the variables is excluded. Unfortunately, this approach introduces specification bias into the model. The degree of specification bias is determined by the importance of the variables excluded and by the degree of correlation between the problem variables.

The method of excluding variables is one approach used in this thesis to correct for multicollinearity. Initially, the model is estimated using all the variables. After excluding the worst of the multicollinear variables, the model is estimated a second time. In order to maintain a credible model, essential import demand variables will not be excluded. These include U.S. income, U.S. - Canadian exchange rates, U.S. aluminum tariffs, and U.S. electricity prices. Other variables are excluded in the second regression only if they fail the Klein rule. Klein argues that multicollinear variables should only be excluded when the $r^2_{x_i|x_j}$ is greater than or equal to the $R^2$ of the model.46

In addition to excluding variables, this thesis uses the technique of principal components to control for multicollinearity. Rather than excluding problem variables, this method identifies the different sources of variation that are contained within the variables. A unique variable is then generated for each "latent"
source of variation. These new variables are called the principal components. The dependent variable is then regressed on the principal components. At that point, the OLS coefficients associated with the components can be used to derive unbiased coefficients for the original variables. These constructed coefficients are technically not affected by the presence of multicollinearity since the principal components that they are derived from are by definition not multicollinear.

III. THE MODEL

The model being estimated in this chapter is simply an application of the model developed in Chapter Four. Other than using averaged data, the only variation is that production costs have been disaggregated into their various components. This breakdown is necessary due to the fact that the hypothesis being tested focuses on the role of electricity prices and exchange rates in determining aluminum imports. If production costs were not disaggregated, it would be impossible to make the necessary comparison.

MODEL

\[ M_{us} = A_0 + A_1 EX + A_2 E_{us} + A_3 E_{can} + A_4 C_{us} + A_5 C_{can} + A_6 T + A_7 L_{us} + A_8 L_{can} + A_9 Y_{us} + A_{10} Y_{can} + A_{11} A_{I} + U \]
where:

\[ M_{us} = \text{Three month moving average of U.S. imports of unwrought unalloyed Canadian aluminum.} \]

\[ EX = \text{Three month moving average of U.S.-Canadian exchange rate. Specified as Canadian dollars per U.S. dollar.} \]

\[ E_{us} = \text{Three month moving average of power rates paid by PNW aluminum smelters. This is a proxy for average rates paid by U.S. smelters. Although the electricity price trend was similar for all U.S. aluminum regions, PNW rate increases were the most pronounced. As a result, using PNW rates as a proxy will to some extent overstate the U.S. average.} \]

\[ C_{us} = \text{Three month moving average of U.S. primary aluminum capacity in million tons/year.} \]

\[ C_{can} = \text{Three month moving average of Canadian aluminum capacity in million tons/year.} \]

\[ T = \text{Three month moving average ad valorem rate of tariff imposed by the U.S. on imported aluminum.} \]

\[ L_{us} = \text{Three month moving average of U.S. aluminum smelter wage rates.} \]

\[ L_{can} = \text{Three month moving average of Alcan smelter wage rates.} \]

\[ Y_{us} = \text{Three month moving average of U.S. industrial production index.} \]

\[ Y_{can} = \text{Three month moving average of Canadian industrial production index.} \]
$E_{can} =$ Three month moving average of Alcan power rates

$Al =$ Three month moving average of PNW alumina prices. This is used as a proxy for the North American alumina price. Battelle assumed in 1983 that U.S. alumina prices are relatively constant between U.S. regions. They also contend that while Canadian alumina may be more expensive than U.S. alumina, the two alumina prices move together.

$U =$ Stochastic error term
IV. OLS IMPORT DEMAND ESTIMATION

When all import demand variables are included in the regression procedure, the following results are generated:

**REGRESSION RESULTS**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Beta-coef.</th>
<th>T-stat</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.1037E+09</td>
<td>7.137</td>
<td>.383</td>
<td>N/A</td>
</tr>
<tr>
<td>Yus(-1)</td>
<td>0.1168E+07</td>
<td>.6043</td>
<td>1.32</td>
<td>2.77</td>
</tr>
<tr>
<td>Ycan(-1)</td>
<td>-0.9431E+06</td>
<td>-.4296</td>
<td>-1.42</td>
<td>-2.30</td>
</tr>
<tr>
<td>EX(-3)</td>
<td>0.2899E+07</td>
<td>.0134</td>
<td>.043</td>
<td>.075</td>
</tr>
<tr>
<td>Eus(-3)</td>
<td>0.8119E+06</td>
<td>.5111</td>
<td>2.60*</td>
<td>.228</td>
</tr>
<tr>
<td>Ecan(-3)</td>
<td>0.5582E+09</td>
<td>.0725</td>
<td>.377</td>
<td>.173</td>
</tr>
<tr>
<td>Cus(-2)</td>
<td>-0.4586E+05</td>
<td>-.3574</td>
<td>-1.13</td>
<td>-4.72</td>
</tr>
<tr>
<td>Ccan(-2)</td>
<td>0.1945E+05</td>
<td>1.1664</td>
<td>1.16</td>
<td>4.90</td>
</tr>
<tr>
<td>T(-1)</td>
<td>0.3478E+07</td>
<td>.1048</td>
<td>.425</td>
<td>.202</td>
</tr>
<tr>
<td>Lus(-2)</td>
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<td>-1.0537</td>
<td>-1.37</td>
<td>-2.56</td>
</tr>
<tr>
<td>Lcan(-2)</td>
<td>0.1284E+06</td>
<td>.0243</td>
<td>.058</td>
<td>.032</td>
</tr>
<tr>
<td>AI</td>
<td>0.8069E+06</td>
<td>.2839</td>
<td>2.20*</td>
<td>.533</td>
</tr>
</tbody>
</table>

\[ R^2 = .90 \]

Durbin-Watson = 1.61

* Denotes significance at the 95% level
Although the high R² indicates that this model explains a significant portion of U.S. import demand for Canadian aluminum, few variable coefficients tested significant. This is probably due to the serious multicollinearity present in the model. However, autocorrelation could also be a contributing factor. Because so few variables tested significant and because the model is known to be multicollinear, few meaningful conclusions regarding individual coefficients can be made. However, the t statistics attached to U.S. electricity prices and North American alumina prices would suggest that these two variables are significant.

To determine whether exchange rates have been an important determinant of U.S. import demand for Canadian aluminum, all the non-essential variables that do not meet the Klein rule should be excluded. The correlation coefficient matrix presented in table 17A shows three variables with simple correlations above the model's .90 R². The variables not meeting the Klein rule include U.S. capacity, Canadian capacity, and Canadian income.

Fortunately, excluding these three variables does not seriously compromise the model. In long-run models, U.S. and Canadian capacity would not be included anyway because in the long-run there are no fixed inputs (no fixed costs). If the seven year period covered in this thesis is sufficient to represent the long-run, excluding U.S. and Canadian capacity may actually improve the model's specification.

Canadian wage rates influence U.S. aluminum imports from
Canada because their wage rates help determine the market price. One could argue that the reason U.S. and Canadian wage rates are so correlated (.96) is because the two variables are not independent. Because of the very strong unionization of North American aluminum workers, there is really a North American wage rate rather than a U.S. wage rate and a Canadian wage rate. Thus, using both U.S. wage rates and Canadian wage rates as independent variables is essentially the same as including one variable twice in the model. Since the U.S. produces over twice as much aluminum as Canada, it makes sense to drop the Canadian wage rate.

After dropping U.S. capacity, Canadian capacity, and Canadian wages rates from the model, the following results were generated:

\[
\begin{array}{|c|c|c|c|c|}
\hline
\text{Variable} & \text{Coefficient} & \text{Beta-coef.} & \text{T-stat} & \text{Elasticity} \\
\hline
\text{Constant} & 0.1037E+09 & 7.137 & .383 & \text{N/A} \\
\text{Yus(-1)} & 0.1318E+07 & .6821 & 1.47 & 3.13 \\
\text{Ycan(-1)} & -0.1194E+07 & -.5441 & -1.64 & -2.92 \\
\text{EX(-2)} & 0.1394E+09 & .6449 & 2.03^* & 3.62 \\
\text{Eus(-3)} & 0.8281E+06 & .5213 & 2.31^* & .232 \\
\text{Ecan(-3)} & -0.4531E+09 & -.0587 & -.301 & -.141 \\
\text{T(-1)} & -0.1853E+07 & -.0558 & -.296 & -.107 \\
\text{Lus(-2)} & -0.1198E+07 & -.2025 & -.402 & -.493 \\
\text{Al} & 0.7476E+06 & .2638 & 1.80 & .495 \\
\hline
\end{array}
\]

\[R^2 .89\]
Exchange Rates and Electricity Prices

The second regression suggests that both U.S. electricity prices and the U.S. - Canadian exchange rate have been important variables explaining U.S. import demand for aluminum. First, these two variables are the only ones that tested significant (95% level) in the regression. Second, the beta-coefficients attached to these variables are both relatively high compared to those associated with most of the other variables. Beta coefficients are derived from standardized data. Standardizing the data puts everything into a common unit of measurement. This means that beta-coefficients can be directly compared in order to determine the relative importance of one variable with any other variable.

A comparison of the U.S. electricity beta-coefficient (.64) and the U.S.-Canadian exchange rate beta-coefficient (.52) suggests that exchange rates have played a more important role in determining U.S. aluminum imports than have rising U.S. electricity prices. This seems to validate the thesis hypothesis.

Comparing Elasticities

On a priori grounds, one would expect imports to be more responsive to exchange rate fluctuations than to movements in domestic electricity prices. Since electricity prices make up approximately 30 percent of U.S. aluminum production costs today, electricity prices would have to rise over three percent before production costs increased one percent. Moreover, electricity prices had to rise substantially in some U.S. regions before smelters
located there began to see their competitiveness threatened. For example, when the price of electricity doubled in the PNW between 1978 and 1980, it made PNW electricity costs approximately three cents per pound greater than Alcan electricity costs. However, PNW producers were still competitive because they had lower production costs in some other cost categories like alumina.47

A related consideration is that U.S. electricity rates increased the most prior to 1983 while the U.S. dollar has gained the most against the Canadian dollar since 1983 (see figures 2 and 6). In other words, the impact of a strong U.S. dollar on U.S. aluminum production may have occurred after the industry was already severely weakened by rising domestic electric rates. Thus, the relative timing of the two variables may have been a factor causing aluminum imports to be more sensitive to exchange rate fluctuations.

Even after these facts have been considered, it is difficult to explain why the elasticity for exchange rates (3.63) is approximately 16 times greater than the elasticity for U.S. electricity prices (.23). Perhaps the specification bias introduced by excluding variables and the multicollinearity still present in the model have worked to overstate the responsiveness of U.S. imports to exchange rate fluctuations.

Summary of OLS Results

The objective of this section was to use ordinary least squares to estimate unbiased import demand parameters. Because of serious
multicollinearity within the data set, the Klein rule was used to exclude some non-essential variables. Regression results from this model indicate that both exchange rates and U.S. electricity prices are significant at the 95 percent confidence level. In addition, the OLS beta-coefficients suggest that exchange rates have been more important than U.S. electric rates in explaining U.S. import demand for aluminum.

The OLS results presented in this section are generally consistent with economic theory. All variables that were even remotely significant (60% level) had the proper signs. The only surprising result was that the differential between the exchange rate elasticity and the U.S. electricity price elasticity was larger than expected.

V. ESTIMATING UNBIASED BETA-COEFFICIENTS WITH PRINCIPAL COMPONENTS

An alternative to OLS estimation is to use the technique of principal components. This method avoids specification bias if the principal components are generated from all the variables in the theoretical model. As previously stated, this technique also avoids the impact of multicollinearity because each component represents a unique source of variation.

Principal components are constructed from normalized data. Thus, when the principal component coefficients are converted back to actual variable coefficients, the derived coefficients are standardized into a common unit of measure. As a result, the reconverted coefficients for exchange rates and U.S. electricity prices can be directly compared to determine their relative
importance.

In order to use the most complete information set possible, nine principal components were created. This is only two less than the number of variables in the model. To insure that each unique source of variation within the data set is represented by a unique principal component, it would be desirable to use as many principal components as there are variables. However, the software available to the author did not allow for more than nine components to be created. More importantly, nine principal components explain almost 100 percent of the total variation contained in the data set (see table 17B). Therefore, using nine principal components rather than eleven is probably inconsequential. This is especially true since only three principal components tested significant when they were used as independent variables to explain U.S. aluminum imports.

The fact that two variables are highly multicollinear suggests that a single principal component will largely capture the impact of both variables. Table 17C contains the factor loadings for each principal component. These factor loadings show how much of a variable's variation is contained in each principal component. Notice how the first principal component explains a large portion of $EX, L_{us}, L_{can}, Y_{us}, C_{can} E_{us}$ and $E_{can}$. This is not particularly surprising since these variables are all highly multicollinear.

The fact that many variables are largely explained by only a few principal components has led some people to try to attribute economic meaning to the various components. For example, some people might contend that PC 1 really is a representation of, for
<table>
<thead>
<tr>
<th>principal Component</th>
<th>% of Total Variation Explained</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC 1</td>
<td>53.89</td>
</tr>
<tr>
<td>PC 2</td>
<td>79.23</td>
</tr>
<tr>
<td>PC 3</td>
<td>92.15</td>
</tr>
<tr>
<td>PC 4</td>
<td>96.53</td>
</tr>
<tr>
<td>PC 5</td>
<td>97.94</td>
</tr>
<tr>
<td>PC 6</td>
<td>98.86</td>
</tr>
<tr>
<td>PC 7</td>
<td>99.45</td>
</tr>
<tr>
<td>PC 8</td>
<td>99.74</td>
</tr>
<tr>
<td>PC 9</td>
<td>99.87</td>
</tr>
</tbody>
</table>
### TABLE 17C

**FACTOR LOADINGS**

<table>
<thead>
<tr>
<th>Variable</th>
<th>PC 1</th>
<th>PC 2</th>
<th>PC 3</th>
<th>PC 4</th>
<th>PC 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX</td>
<td>-.923811</td>
<td>.290569</td>
<td>.010661</td>
<td>-.185360</td>
<td>-.080304</td>
</tr>
<tr>
<td>Lus</td>
<td>-.965435</td>
<td>-.205432</td>
<td>.003394</td>
<td>.009514</td>
<td>.087010</td>
</tr>
<tr>
<td>Lcan</td>
<td>-.983640</td>
<td>-.016801</td>
<td>-.077616</td>
<td>.063411</td>
<td>.035617</td>
</tr>
<tr>
<td>Yus</td>
<td>-.646472</td>
<td>.676090</td>
<td>.253186</td>
<td>.206637</td>
<td>.067911</td>
</tr>
<tr>
<td>Yean</td>
<td>-.192393</td>
<td>.869253</td>
<td>.382444</td>
<td>.163536</td>
<td>-.149404</td>
</tr>
<tr>
<td>Cus</td>
<td>.107007</td>
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<td>-.013158</td>
</tr>
<tr>
<td>Ccan</td>
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<td>.051453</td>
</tr>
<tr>
<td>AI</td>
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<td>-.108258</td>
<td>.960868</td>
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<td>.196212</td>
</tr>
<tr>
<td>T</td>
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<td>.452440</td>
<td>-.047056</td>
<td>-.214359</td>
</tr>
<tr>
<td>Eus</td>
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<td>Ecan</td>
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<td>.296364</td>
<td>.052463</td>
<td>.186287</td>
<td>.129760</td>
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</tbody>
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<table>
<thead>
<tr>
<th></th>
<th>PC 6</th>
<th>PC 7</th>
<th>PC 8</th>
<th>PC 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX</td>
<td>-.009244</td>
<td>-.000475</td>
<td>.142278</td>
<td>-.024022</td>
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<td>Lus</td>
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<td>.068317</td>
<td>-.014280</td>
<td>.006017</td>
</tr>
<tr>
<td>Lcan</td>
<td>-.072239</td>
<td>.045034</td>
<td>-.048729</td>
<td>.030800</td>
</tr>
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<td>Yus</td>
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<td>.019816</td>
<td>.068347</td>
</tr>
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<td>-.028452</td>
<td>.038627</td>
<td>-.024014</td>
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<tr>
<td>Ccan</td>
<td>.051453</td>
<td>.014041</td>
<td>.135834</td>
<td>-.057705</td>
</tr>
<tr>
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<td>.031261</td>
<td>-.059616</td>
<td>-.023651</td>
<td>-.011443</td>
</tr>
<tr>
<td>T</td>
<td>.129185</td>
<td>.046677</td>
<td>.013229</td>
<td>.031103</td>
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<tr>
<td>Eus</td>
<td>.190375</td>
<td>-.018090</td>
<td>-.004090</td>
<td>-.024777</td>
</tr>
<tr>
<td>Ecan</td>
<td>.030671</td>
<td>.153625</td>
<td>.036720</td>
<td>.050364</td>
</tr>
</tbody>
</table>
REGRESSION RESULTS  
(Using Principal Components as Explanatory Variables)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta-coef.</th>
<th>T-stat</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
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<td>18.85</td>
<td>0.000</td>
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<tr>
<td>PC 1</td>
<td>-0.79</td>
<td>-4.38</td>
<td>0.000</td>
</tr>
<tr>
<td>PC 2</td>
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<td>1.31</td>
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</tr>
<tr>
<td>PC 4</td>
<td>-0.12</td>
<td>-1.13</td>
<td>0.259</td>
</tr>
<tr>
<td>PC 5</td>
<td>0.088</td>
<td>1.28</td>
<td>0.202</td>
</tr>
<tr>
<td>PC 6</td>
<td>0.25</td>
<td>3.33</td>
<td>0.001</td>
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<tr>
<td>PC 7</td>
<td>-0.026</td>
<td>-0.395</td>
<td>0.694</td>
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<td>PC 8</td>
<td>-0.034</td>
<td>-0.543</td>
<td>0.589</td>
</tr>
<tr>
<td>PC 9</td>
<td>0.046</td>
<td>0.929</td>
<td>0.356</td>
</tr>
</tbody>
</table>

\[ R_2 = .90 \]
\[ \text{Durbin-Watson} = 1.62 \]

instance, U.S. exchange rates. However, using principal components in this fashion is highly speculative. In this thesis, principal components is used only as a tool to double check the validity of the OLS parameters that have already been estimated.
Using the factor loadings in table 17C and the OLS coefficients attached to the principal components, approximations for unbiased beta-coefficients can be derived using the following formula:

\[ \hat{b}_1 = \sum (\beta_1 \cdot \phi_{11} + \beta_2 \cdot \phi_{22} + \ldots + \beta_n \cdot \phi_{nn}) \]

where:

- \( \hat{b}_1 \) = The coefficient attached to the first principal component once the dependent variable has been regressed on the principal components.
- \( \phi_{11} \) = The loading for the first variable and the first principal component.

The major drawback encountered when using principal components is that there is no straightforward method to accurately estimate the significance of the derived coefficients. Since it has already been determined by OLS estimation that the coefficients for U.S.-Canadian exchange rates and U.S. electricity prices are significant at the 95 percent confidence level, these coefficients will also be significant when derived from principal components. Assuming the same data set is used, the only difference between OLS coefficients and those derived from principal components is that the latter have been corrected for multicollinearity.

A second alternative is to derive the coefficients from only those principal components that tested significant (PC 1, PC 2, PC 6). If a variable is not significant, it will have a very small
coefficient. In the extreme case, if a variable contributed nothing to the significant components, then the derived coefficient will be zero by definition. In the results presented on the next page, Coefficient A is derived from only those principal components that tested significant at the 90 percent confidence interval. Coefficient B is derived from all the principal components. In most cases, there is very little difference between the two coefficients.

**DERIVED BETA-COEFFICIENTS**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient A*</th>
<th>Coefficient B+</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX</td>
<td>.8149</td>
<td>.8264</td>
</tr>
<tr>
<td>Lcan</td>
<td>.7440</td>
<td>.7314</td>
</tr>
<tr>
<td>Lus</td>
<td>.6835</td>
<td>.6893</td>
</tr>
<tr>
<td>Yus</td>
<td>.6922</td>
<td>.7059</td>
</tr>
<tr>
<td>Ycan</td>
<td>.3924</td>
<td>.4173</td>
</tr>
<tr>
<td>Cus</td>
<td>-.3871</td>
<td>-.4045</td>
</tr>
<tr>
<td>Ccan</td>
<td>.7475</td>
<td>.7789</td>
</tr>
<tr>
<td>AI</td>
<td>-.1358</td>
<td>.0199</td>
</tr>
<tr>
<td>T</td>
<td>.2031</td>
<td>.2628</td>
</tr>
<tr>
<td>Eus</td>
<td>.7029</td>
<td>.6184</td>
</tr>
<tr>
<td>Ecan</td>
<td>-.6309</td>
<td>-.6415</td>
</tr>
</tbody>
</table>

* Constructed from principal components significant at the 90% level or above.

+ Constructed from all principal components. Thus, significance of constructed coefficients is indeterminant.
With the exception of the Canadian income, U.S. tariff, and Canadian wage rate coefficients, all the signs match a priori predictions. Because the Canadian economy is so linked to the U.S. economy, it is possible that the positive sign attached to the Canadian income coefficient reflects the fact that the Canadian economy is doing well when the U.S. economy is doing well. Thus, U.S. imports tend to increase as Canadian income increases. This is partially substantiated by the fact that the simple correlation coefficient between the two countries' incomes is .85.

The positive sign attached to the tariff variable might be attributed to the fact that U.S. tariff policy changed during the time period under study. Specifically, as U.S. imports for Canadian aluminum began to increase during the late 1970's, a higher tariff was imposed on aluminum. As a result, the magnitude of the U.S. aluminum tariff is directly correlated with rising U.S. aluminum imports.

The positive sign attached to Canadian smelter wage rates can be partially explained by the fact that relative to U.S. producers, Alcan enjoyed some very profitable years during the time period under study. Labor unions representing Canadian smelter employees may have been able to successfully exploit this fact during contract negotiations. Since U.S. and Canadian labor costs have both increased dramatically during the time period being studied (simple correlation of .96), the fact that Canadian wage rates were increasing did not translate into lost Canadian aluminum competitiveness. However, it did result in a direct relationship between those rates and U.S. aluminum imports.
Of the eleven variables used in this model, the beta-coefficient attached to the exchange rate variable is the largest (.83). This would suggest that exchange rates have been the most important factor in determining U.S. imports of Canadian aluminum. The size of the beta-coefficients for U.S. electricity prices (.62) indicates that it was nearly as important. The beta-coefficients on U.S. wage rates (.69), and U.S. income (.70) indicate that these variables may have also been very important. However, it should be noted, that only U.S. electricity prices and U.S. - Canadian exchange rate coefficients tested significant using OLS. Thus, it is only safe to draw conclusions about those two variables.

In order to see if the principal component results support the OLS results, it is helpful to compare the beta-coefficients generated by the two different techniques. Table 17D illustrates how the beta-coefficients compare.

Regardless of the technique, the beta-coefficient for exchange rates is larger than the beta-coefficient for U.S. electricity prices. The principal component results suggest that exchange rates are even more important than what was suggested by the OLS results.
### TABLE 17D

A COMPARISON OF PRINCIPAL COMPONENT AND OLS BETA-COEFFICIENTS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta-Coefficients (OLS)</th>
<th>Beta-Coefficients (Principal Components)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX</td>
<td>.6449</td>
<td>.8264</td>
</tr>
<tr>
<td>Lus</td>
<td>-.2025</td>
<td>.6893</td>
</tr>
<tr>
<td>Yus</td>
<td>.6821</td>
<td>.7059</td>
</tr>
<tr>
<td>Ycan</td>
<td>-.5441</td>
<td>.4173</td>
</tr>
<tr>
<td>Al</td>
<td>.2638</td>
<td>.0199</td>
</tr>
<tr>
<td>T</td>
<td>-.0558</td>
<td>.2628</td>
</tr>
<tr>
<td>Eus</td>
<td>.5213</td>
<td>.6184</td>
</tr>
<tr>
<td>Ecan</td>
<td>-.0587</td>
<td>-.6415</td>
</tr>
</tbody>
</table>

### VI. CONCLUSION

Empirical evidence presented in this chapter suggests that between 1979 and 1986, the rising strength of the U.S. dollar played at least as important of a role in determining U.S. aluminum imports as did rising U.S. electricity prices. This conclusion is supported both by OLS beta-coefficient estimates and by beta-coefficients derived from principal components. Because the data set used in this thesis is characterized by strong multicollinearity, the coefficients derived from principal components are probably more accurate than those estimated by ordinary least squares. This is
because principal component beta-coefficients are typically less affected by multicollinearity than are those generated by ordinary least squares.

VII. FUTURE RESEARCH

Additional research could be directed down two possible paths. The first type of research could directly extend the work carried out in this thesis. For example, it has been established that an over-valued U.S. dollar has been partially responsible for the decline in U.S. aluminum competitiveness. However, no attempt has been made to quantify the total cost borne by the domestic aluminum economy that has resulted from an over-valued U.S. dollar. These costs include lost jobs, lost state and local tax revenues, revenues lost by utilities, in addition to various psychological costs due to lost jobs etc.. If the cost on the domestic aluminum economy of having an over-valued U.S. dollar could be estimated, then this would facilitate the process of determining whether the U.S. has benefited or has been penalized by its over-valued currency.

If the U.S. dollar significantly declines against the Canadian dollar in the near future, it would be interesting to test whether U.S. aluminum imports also decline in response to the weakening U.S. dollar. Conclusions reached in such a study could be used to further examine the responsiveness of U.S. aluminum imports to changes in the U.S. - Canadian exchange rate.

Another type of study might try to determine how large a tariff the U.S. must impose on imported aluminum before it would have a substantial impact on reducing U.S. aluminum imports. One
fact brought out in this thesis is that U.S. aluminum tariffs have been virtually ineffective between 1978 and 1986 at moderating the level of U.S. aluminum imports.

A second avenue of research might focus on new developments in the U.S. aluminum industry. For example, this thesis examines the U.S. aluminum industry prior to the summer of 1986 when the Federal Regulatory Energy Commission granted BPA the right to tie electricity prices to the world aluminum price. It would be interesting to determine the impact that this new pricing policy is having on PNW aluminum viability. Moreover, it would be useful to question the economic justification of this variable rate pricing scheme. Does economic theory support this type of solution to the U.S. aluminum problem?

One last consideration regarding future research is the fact that U.S. electricity rates have stabilized. In the near future, it is unlikely that electric rates charged to U.S. aluminum firms will rise significantly faster than those charged to Canadian smelters. In fact, the recent trend has witnessed a slight drop in rates charged to U.S. smelters. Moreover, new smelters coming on line in Canada are paying rates of approximately 17 mills/kwh which is much closer to the U.S. average than to the Alcan average. As a result, additional aluminum capacity in Canada will not enjoy the tremendous electricity cost advantage available to Alcan.

In contrast, new smelters being built and operated in other countries like Venezuela are beginning to establish such a cost advantage over most North American smelters that they could threaten the concept of a North American market. Specifically, their
lower costs could overcome the barrier posed by transportation costs. Currently, these new producing countries lack the capacity to replace the role played by U.S. producers and Canadian producers. However, the rapid expansion in aluminum capacity that is now occurring in these countries could change that scenario (see figure 19). Future research regarding U.S. aluminum viability will need to consider the consequences to U.S. producers resulting from the continued expansion of low cost smelters in new aluminum smelting countries.
TABLE 18
IMPORTS AND CAPACITY COMPARISONS FOR SELECTED REGIONS

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>IMPORTS (METRIC TONS)</th>
<th>CAPACITY (1000 METRIC TONS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUSTRALIA</td>
<td>0</td>
<td>1,346</td>
</tr>
<tr>
<td>BAHRAIN</td>
<td>0</td>
<td>12,403</td>
</tr>
<tr>
<td>BRAZIL</td>
<td>0</td>
<td>41,737</td>
</tr>
<tr>
<td>VENEZUELA</td>
<td>9,165</td>
<td>7,517</td>
</tr>
</tbody>
</table>

FIGURE 18
1978 AND 1985 CAPACITY FOR NEW LOW COST PRODUCERS

END NOTES


11Ibid., p. 1.


14Ibid., p. 9.


17Ibid., pp. 14-20.

18Ibid., p. 12.


24 Bonneville Power Administration, DSI Historical Summary Prepared by: Division of Economic Forecasting / Aluminum Studies. (November 1986), pp. 3-6. Note: electricity costs derived assuming average regional electro-processing coefficient of 7.5 kwh/lb.


27 Kennedy, Energy and Primary Aluminum p. 25.

28 Ibid., p. 27.

29 Merner, Projected Power Cost for Aluminum p. 4.

30 Battelle, The Direct Service Industries p. 7.25.

31 Mining Magazine "Venezuela's Aluminum Plans" p. 543.


34 Paul Spies, Personal Communication, (December 1986).


41 Kennedy, *Energy and Primary Aluminum* p. 6A.


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