T-4657

TESTING COURNOT BEHAVIOR WITH CONJECTURAL VARIATION IN THE EUROPEAN MARKET FOR IRON ORE

by

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A thesis submitted to the Faculty and Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Master of Science (Mineral Economics).

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ABSTRACT

This thesis, assuming the European market for iron ore is an oligopoly, tests two hypotheses. The first is that all participants in the European iron ore market play a Cournot game in quantities; and the second is that at least one of the players, presumably Brazil, is acting as a Stackelberg leader.

The oligopolistic nature of the European iron ore market is discussed along with the two models, the Cournot model and the Stackelberg model. The test variable, conjectural variation, is then derived from the two models. Conjectural variation describes the expectations of one country about the reaction of the other countries to a change in its output. The test variable is shown to depend on price elasticity of demand, market share, price, and marginal cost.

The results indicate that Brazil acts as a Stackelberg leader in that it considers, or takes into account, the reactions of other countries to a change in its output. Brazil thereby has an additional factor to take into consideration when making its profit maximizing decision.

The other countries, however, seem to play a Cournot game. They apparently do not consider, or anticipate, any changes in the output of their competitors when they alone change their output. They consider only the *level* of competitor output, and regard that output as given, in a known Cournot manner.

The major factor explaining the changes in the conjectural variation is market share. An increasing market share, according to the study, causes the conjectural variation to move away from a Cournot situation toward a Stackelberg situation.

Brazil increased its output capacity and market share during the late 1980s and early 1990s. This has led to a strengthened Brazilian position in the European market. There are reasons to believe that Brazil is trying to increase its strength even further both in the European market and, more importantly, in the Japanese market. The capacity of the large Carajás operation is increasing and the production cost in this operation is significantly below the cost of production elsewhere in the world. Brazil's cost of production is currently so low that even if the cost of transportation is included, Brazil might be able to supply the Japanese market at a lower c&f (cost and freight) price than, for example, Australia. It is therefore possible that Brazil could develop its position as a Stackelberg leader in the world market for iron ore. This does not mean, however, that Brazil is expected to "take over" the world market by simply out competing other suppliers. Some of the possible actions that a small mining operation could take to survive might be engaged in short-term contracts with traditional or nearby customers, or to devote itself to product differentiation. Future buyer diversification, either for strategic reasons or for technological reasons, also favor small mine operations.

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ACKNOWLEDGMENTS

First, I would like to thank my advisor Dr. John E. Tilton, professor of economics at the Colorado School of Mines, for his help, support, and valuable comments during the process of writing this thesis. Without his help, this would still just be an idea for a topic. I am also very grateful for help and support from Dr. Marian Radetzki, professor of economics at Luleå University in Sweden. Thanks to him I got the opportunity to work and study at the Colorado School of Mines.

My sincere thanks go also to Vattenfall in Sweden and the Wallander Foundation, for their financial help, which made it possible for me to spend a year in Colorado.

A number of other people have helped me in many ways: the two members of the committee, Dr. Rodderick G. Eggert and Dr. Wade Martin, both at CSM; the members of my advisory board, Dr. David Humphreys at RTZ in London and professor Thorvaldyr Gylfason at the University of Reykjavik. Thanks to you all.

I also wish to thank my friends who participated in meetings and seminars concerning my thesis. Their comments and suggestions were of great value to me.

The final, but deep sincere, thanks goes to Mrs. Lita Dunham for her tremendous work in editing this thesis.

Chapter 1
INTRODUCTION

From the 1970s we have seen a tremendous change in the European market for iron ore. Long a small producer, Brazil, for example increased its European market share to 40 percent in the early 1990s. During the 1980s, Brazil played a significant role in the yearly price negotiations for the European market. The large increase in Brazilian production is mostly due to the large CVRD operation in Carajás, and although Brazil has been able to increase its output in an occasionally growing market, other countries and mines have seen their outputs and market shares decrease. Scandinavia, with Sweden as its major producer, has experienced not only a large decrease in production, but has also seen its position as a dominant part in the price negotiations diminish. This shift in competitiveness, production, market shares, and the changing roles in price negotiations leads to some interesting questions.

Is Brazil playing a dominant role in the European market for iron ore? If it is, in what sense? Does it set the price to maximize its own profit, or does it adjust its output in order to gain market share? If Brazil is dominant, to what extent does it control the situation? What role do the other iron ore producing countries play? Do they just sit by and observe the price and/or the output from their respective competitors and adjust their own output after these observations, or do they play a more active role?

Purpose

Under the assumption that the European iron ore market can be described as being an oligopolistic market, two hypotheses will be tested:

a) H_0: All participants in the European iron ore market are playing a Cournot game.

b) H_0: At least one of the players can be regarded as a Stackelberg leader.

Although I will test the last hypothesis for every country, I will emphasize Brazilian market behavior.

The outcome of the tests is important. If we can observe at least one leader, what can be expected of this leader in the future? Can this leader, for example, be expected to use its leadership to increase its power on the European market, and is it even possible that a leader can use its power on the Australian market? Furthermore, if we can observe at least one leader, i.e., if we can reject the Cournot hypothesis, we can safely conclude that the price is lower than in the strict Cournot case (Anderson and Engers 1992, and Economides 1992). The Stackelberg model is more competitive since each leader selects output in order for the followers to cut back. The implications for profit are more unsure. According to Anderson and Engers, certain conditions must be fulfilled to conclude that the profit to the Stackelberg leader is higher than the profit from the Cournot outcome. Economides showed, however, that the Stackelberg model generates higher consumer surpluses than the Cournot model. He showed that although the Stackelberg model leads to fewer firms, it does generate increased social welfare.

Methodology

The test variable to be used here is the conjectural variations, a parameter that measures the expected reactions from other firms to a specific firm's decision regarding quantity and/or price. I will use estimates of the conjectural variations for different firms or groups of firms through the 1980s and beginning of the 1990s.

Other Studies of the Iron Ore Market

Other studies of the iron ore market structure are rare but do exist. Different assumptions and hypotheses about the market structure have been used in these studies, but only one, by Peter Gooday (1992), actually tried to test a market structure hypothesis. Gooday studied price formation in the Japanese market and assumed a bilateral monopoly situation in the trade between Australia and Japan. The study followed the theory of bilateral monopoly export trade developed by Smith (1977). Under the assumption of bilateral monopoly, Gooday calculated the upper and lower price bounds for the price negotiations. After identification of these bounds, he compared them with the actual outcome of the negotiations from 1980 to 1990.

The study shows that the model of bilateral monopoly might be appropriate for the iron ore trade between Australia and Japan. It also indicates that, although a monopoly structure, neither of the parties, the Japanese steel mills and the Australian iron ore producers, used their short term market power during those years. This study, however, considers only a part of the total market for iron ore, the Japanese market. The European market is treated as a marketplace where the world price of iron ore is settled. The European market price is treated as an exogenous variable, and the price formation in the European market is largely ignored.

One large study of the world market for iron ore by Manners (1971) did not classify the market structure. Manners instead chose to examine the market by (1) the market places, (2) the market regions, and (3) the market supply areas. He identified a number of market places where bargaining for ore was conducted and deals concluded. The market regions described the relationship between neighboring market places, and the relationship between different market regions was described by the market supply area.

In an attempt to build an econometric model, Priovolos (1987) described the world for iron ore as a bilateral oligopolistic market. In his model he then used the theory of bilateral monopoly and the analysis of collusion and bargaining between negotiating parties. He employed a two-stage game where the parties first negotiated a quantity and then determined a price that would maximize the joint profit. As an upper bound for the price, he used the price that would put the buyer out of business, and as a lower bound, he used the price that would put the seller out of business. The players in this model were then assumed to select their strategies on a probabilistic basis. The model was then linked in the overall model of the iron ore industry.

The model developed in the pages that follow attempts to fill in the gap between the studies of the world market for iron ore and the studies concerned only with the Japanese market.

Scope

This study will deal with the European market only. The major suppliers to this market are Africa, Australia, Brazil, Canada, and Scandinavia. Only what these regions supply to the European market is considered in the analysis. While Africa and Scandinavia are not countries, in both we find one dominant country — South Africa in Africa, and Sweden in Scandinavia.

It would be preferable to use companies instead of countries in the analysis, but company-specific data are not available. In almost every country, however, we can observe a dominant company — CVRD in Brazil, and LKAB in Sweden for example — so the use of countries instead of companies should not severely impact the results.

Finaly the study covers the years 1984 to 1992, a time with turbulent prices, changing market situations, and unsure participants and timing of price negotiations.

Outline

Chapter 2 describes of the European iron ore market. The idea that the world market is separated into two markets with different structures is discussed. The changing market shares and the price over time are described along with a description of the price formation and the price negotiations.

The models used in the analysis are described in chapter 3. The first section of chapter 3 describes oligopoly and discusses recent research in industrial organization leading towards the two models used in the analysis.

Chapter 4 describes and develop the test variable, conjectural variation, and chapter 5 describes the actual test procedure. Chapters 6 and 7 summarize the results and discuss the conclusions.

Chapter 2
BACKGROUND

Two Markets, Two Market Structures

Disregarding the difference in iron ore qualities, there are basically two markets for internationally traded iron ore, the Japanese market and the European market. Japanese and European steel makers dominate the demand side of the market and Brazilian and Australian producers dominate the supply side. Price negotiations normally take place once a year in both markets. The two "different" markets have different times for negotiations. The price on the European market, normally between Brazil and steel mills in Europe, is most often negotiated in December and January, while the price on the Japanese market, between Japan and Australia, is negotiated in March and April. This difference in time means that the Japanese steel mills and producers in Australia often are faced with a European market price when they start to negotiate, making the analysis of this market in some sense easier. Faced with this European price and considering the relative size of the Japanese consumers and Australian producers, the model of bilateral monopoly has been shown to fit quite well (Gooday 1992).

The European market is more complicated. There is no recent Japanese price to guide negotiations, and the Brazilian market share on the European market is smaller than the Australian market share on the Japanese market. This smaller Brazilian significance on the European market is reflected by the fact that a small mine in Mauritania signed the first contract of importance in 1993 (traditionally this is the role of Brazil). The European market seems thus more competitive, and the model of bilateral monopoly appears less appropriate for the European market.

The European Market

The major exporting countries and regions supplying Europe with iron ore are Africa, Australia, Brazil, Canada, and Scandinavia. Together they supply about 90 percent of the European market (table 1). Brazil, followed by Australia, has experienced the largest increase in the European market share. Brazil has increased its market share from 30 percent in 1984 to 40 percent in 1993. This increase has been offset by a decrease in the African market share. This does not mean, however, that African production has decreased. Most of the increasing market share in Brazil is due to its ability to increase supply in a growing market. Scandinavia and Canada have also experienced a decrease in their market shares, though their shares remain around 10 to 12 percent.

Prior to and during the observed period, Brazil opened and developed the large Carajás operation. With this operation, Brazil could supply the world with high quality ore at a very low average production cost (half the Canadian cost and a third of the Scandinavian cost). This seems to be the major reason behind the increasing Brazilian market share in both the European and Japanese markets.

Table 1. European Market Shares of Selected Countries, 1984-1993 (%)

From	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Brazil	30	31	31	34	33	34	41	38	41	40
Australia	13	14	13	14	16	15	14	16	17	18
Africa	24	20	20	19	19	20	15	12	11	14
Scandinavia	13	12	12	11	10	10	10	10	11	9
Canada	11	14	15	14	13	12	11	13	12	10
Others	8	9	9	9	8	9	9	10	9	9

Source: Swedish Geological Survey. 1989-1993, *Järnmalmsrevy* [Iron Ore Review] United Nations. Trade and Development Board. 1994. *Review of Iron Ore Statistics,* Iron ore statistics 1986-1993.

Prices decreased between 1984 and 1989. The prices recovered slightly during 1989-1991, but started to decrease again after 1992. The price trend for an extended time can be seen in figure 1. The price trend remained relatively stable before 1975 and it was around this period the Carajás operation started. Also, it was the Brazilian company CVRD that signed the first contract of importance, i.e. Brazil set the benchmark price for deliveries in 1976-1978.

Canada signed the first contract of importance in 1979, and managed to raise the price. After that, in 1980 and 1982, it was again Brazil who accepted a price decrease. This is, however, just part of the story. When the Brazilian company CVRD again signed the first contract for deliveries in 1989-1992, they managed to negotiate a price increase. For deliveries in 1993 and 1994 there was a sharp decrease in price, this time not due to Brazilian negotiations, but to SNIM in Mauritania and Hamersly in Australia. Both signed the first contracts allowing a significant reduction in price.

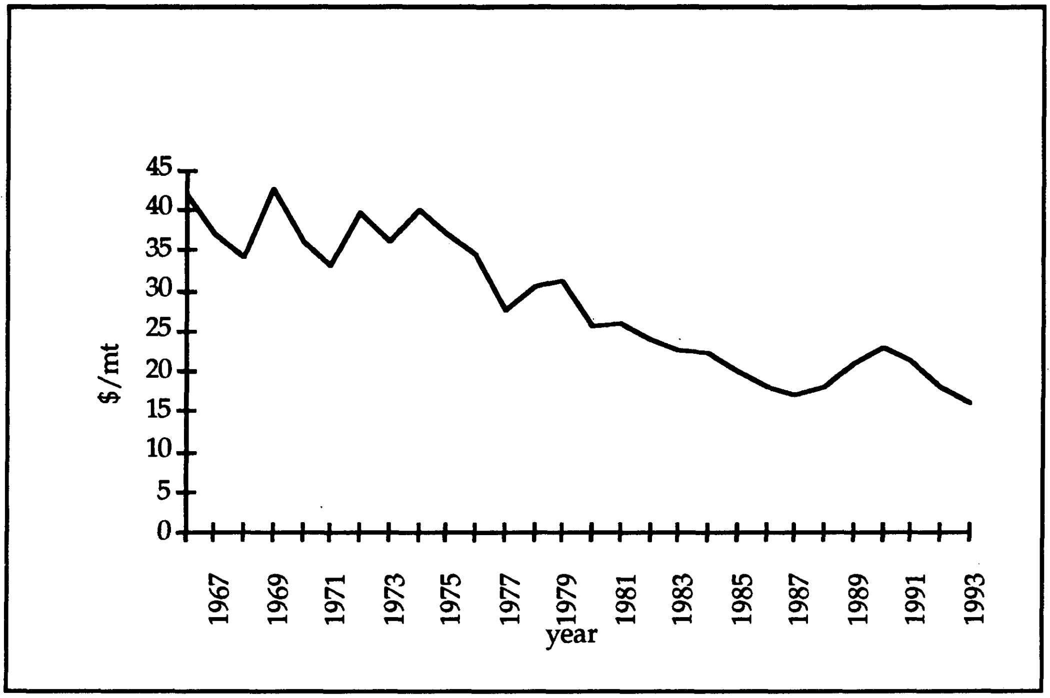

Figure 1. Average Price (f.o.b.) for Brazilian Ore in $/metric ton for the years 1967 to 1994.
Source: Swedish Geological Survey. 1989-1993, *Järnmalmsrevy* [Iron Ore Review]

Price Formation

Prices of iron ore are settled in annual negotiations that start at specific times of the year. The negotiations usually take place on the European and Japanese market independently. On the European market, the reference price is usually set by Brazil's CVRD and German steel mills. This price is regarded as a benchmark for other suppliers to the European market who adjust their f.o.b prices to compete on a c&f Rotterdam basis. Although the price negotiations in the Japanese and European markets are regarded as independent, a rather close interaction can be observed after 1988. According to the TEX reports from 1992-93, there have been small and almost unchanged price differences (f.o.b) between Australian deliveries to Japan and Brazilian deliveries to Europe after 1988. However, relatively large differences in prices can be observed between Australian deliveries to Japan and Brazilian deliveries to Japan. The price charged by Brazil on the European market is also relatively low compared to the price charged to the Japanese market.

Negotiations on the European market have tended to be delayed in recent years. Brazil always gets the first opportunity to negotiate price with German steel mills. During the mid-1980s and beginning of the 1990s they have, however, frequently "missed" this opportunity. In some cases the Japanese market has settled price before the European market, and in other cases (as, for example, in 1992) other suppliers in Europe have been able to set prices in Europe before Brazil (table 2).

Although in recent years the Japanese market has been settled before the European, there is a Brazilian dominance on the European market. This dominance, however, was broken by surprise by a relatively small mine in Mauritania (SNIM) who settled the first price for deliveries in 1993 to France.

Table 2. Iron Ore Market Price Setting in Japanese and European Markets, 1984-1992 (and partly for 1993, 1994).

Year	Japanese Market Date	Japanese Market Setter	Japanese Market Change	European Market Date	European Market Setter	European Market Change
1984	01/20/84	CVRD	-11.6%	**12/07/83**	**QCM/Germany**	**-8.5%**
1985	01/31/85	MMTC	0.0%	**12/07/84**	**QCM/Germany**	**0.0%**
1986	02/14/86	MMTC	-1.9%	**12/03/85**	**QCM/Germany**	**-1.1%**
1987	**02/20/87**	**Newman**	**-5.0%**	03/05/87	QCM/Holland	-9.3%
1988	**12/22/87**	**Hamersly**	**-4.0%**	12/24/87	Hamersly/Britain	8.6%
1989	**12/14/88**	**Hamersly**	**13.0%**	12/19/88	CVRD/Germany	13.0%
1990	**01/24/90**	**Hamersly**	**16.0%**	01/27/90	CVRD/Germany	16.0%
1991	**01/30/91**	**Hamersly**	**7.9%**	01/31/91	CVRD/Germany	7.9%
1992	**12/17/91**	**Hamersly**	**-4.9%**	**12/17/91**	**CVRD/Germany**	**-4.9%**
1993				**12/22/92**	**SNIM/France**	**-11%**
1994	**Feb.. 1994**	**Hamersly**	**-9.5%**			

Note: The first settlement each year is shown in **bold**.
Source: World Bank, 1992.
Swedish Geological Survey, 1992, *Järnmalmsrevy 1992.* [Iron Ore review, 1992]
United Nations. Trade and Development Board. 1994. *Review of the current situation and outlook for iron ore - 1994.*

It is important to note that many negotiations are annual renegotiations of prices for delivery in the future that are already contracted. Most of the trade in iron ore in the last 25 years has taken place under long-term contracts lasting at least five years (Rogers and Robertson 1987). In the iron ore industry these contracts generally state the yearly quantities with some degree of flexibility, usually between plus or minus 10 percent to 25 percent. The contracts also most often state that the prices for the contracted quantities are to be renegotiated on a yearly basis.

Shorter contracts do exist. The shortest are annual, because of the time of mining, processing and shipping. Annual arrangements are most often used by the Swedish iron ore producer LKAB, whose output is mainly sold to

Western Europe. Medium contracts, between two and five years, are unusual. The only examples of medium contracts are to be found between Japan and India.

The relatively small number of buyers and sellers in the iron ore market leads to a high degree of mutual dependence. This dependence is strengthened by the segmentation of the market, a result of long-term relationships and the heterogeneity of the ore. The requirements of a steel mill might be very specific, further limiting the number of suppliers. In addition, the fact that iron ore makes up only a small portion of the price of steel, and that there are no immediate substitutes for iron ore, results in a relatively low price elasticity of demand for iron ore.

The supply of iron ore is also relatively short run inelastic with respect to price. The output is limited by the existing output capacity and development of new capacity, which often includes investments in new mines, processing facilities and infrastructures, all very capital intensive and taking many years to complete. These high initial capital costs also discourage output reduction in times of decreasing demand. Investments in existing capacities can be regarded as being sunk costs, i.e., costs of investments that can produce a stream of benefits over a long horizon but can never be recouped (Tirole 1990). There are therefore reasons to believe that an existing mine has incentives to operate at capacity regardless of short-run variations in price.

The observed short-run instability of iron ore production and price is very likely the result of relatively high income elasticity of demand, and the use of long-term contracts is argued to be one factor in stabilizing the market (Rogers and Robertson 1987). The instability creates problems for both producers and consumers, and the use of long-term contracts is one way to decrease uncertainties in iron ore trade.

This background on the European market makes it reasonable to assume that the strategic variable in competition is quantity rather than price. Each mine, company, or country is thereby focusing on the quantity reaction from its competitors instead of focusing on the price reactions. Instead of having the quantity clearing the market after a price settlement, the iron ore market lets the price clear the market after contracting quantity.

What is observed is the price negotiations, but before these negotiations every mine has a certain output capacity that it wants to sell on the market. So the outcome of the negotiations reflects the price of a certain quantity that is set before the price settlement. If a leader can be identified on the market, this leader might be able to foresee its competititors' quantity reactions, it has thereby an indirect ability to influence the price.

Chapter 3
THE MODELS

Oligopoly in General and Recent Research

Oligopoly, or competition among the few, is one of the most common, but least analyzed market structures. It is difficult to analyze because of the uncertainty and the involvement of game theory. These "additional" problems arise from the fact that a firm working under oligopoly can (must) take into account its rival's actions in making its own decisions about price and/or quantity. A firm in a perfectly competitive market does not have this problem because no single firm can affect the market price, and a monopolist has no rivals to worry about.

Analysis of oligopoly usually starts with the four *basic* models of oligopoly behavior: the Cournot model, the Bertrand model, quantity leadership and price leadership. The last two models are most often analyzed using the Stackelberg model.

There are, of course, other oligopoly models including, for example, the Chamberlin model (developed in 1933) and the kinked demand curve model (developed by Paul Sweezy in 1939). These models are nice tools in showing, for example, why a market is rigid in prices. This is not the case for the iron ore market, neither prices nor quantities are rigid, and there is no evidence of monopoly profits as is suggested by the Chamberlin model. Another important model is the model of price leadership which is developed in two ways, dominant firm leadership and barometric firm leadership. The first assumes that the leader sets the price, which is followed by the competitive fringe. The fringe supplies what it can at that given price and the leader supplies the "residual." In the other model one company is regarded as the barometer of market conditions, lowering the price when the market is depressed and raising the price successfully when the market has "improved." The dominant firm model of price leadership might be appropriate to use in this analysis. Although this model has a different objective function (different from the Stackelberg model of price leadership), the first order condition is very similar to the first order condition in the Stackelberg case. In order to simplify the analysis, and because of the connections with Cournot and Bertrand, I will use the Stackelberg model in my analysis. I will, however, show the similarities in the section that presents and deals with the Stackelberg model.

The four basic models — Cournot, Bertrand, and Stackelberg's two models — differ (from a game theoretical viewpoint) by the definition of strategy, price or quantity, and by the information "available," i.e., what one player knows about its rivals' actions. In general, these models are treated as being "one-shot games," i.e., the players meet only once and simultaneously and noncooperatively set the price and/or quantities for a given time. It does not exclude the two-stage game where firms first choose quantity and then charge a price or the reverse. If, for example, companies compete in quantities, i.e., make a quantity precommitment prior to setting the price, we assume that the price is set as to clear the market.

Because of this "one-shot limitation" it is natural to demand that the strategic variable used in the model is not being readjusted immediately. Once chosen, we expect the selected value of the strategic variable to persist for some time in order for the one-shot analysis to hold (Varian 1992).

The Cournot model, developed in the mid-nineteenth century, uses quantity as the strategic variable. The quantity is most often the capacity. In the model, one firm makes its profit-maximizing output decision assuming that the output decisions of the other firms will be unaffected. In the next period the first firm might observe some changes made by the other firms, and, with these changes taken as given, the firm maximizes profit by choosing a new output (capacity), again, without expecting any output changes from the other firms. The equilibrium in the Cournot model is derived in the next section.

The Cournot model was first criticized by Bertrand in 1883 when he developed the Bertrand model for oligopolistic behavior. In this model it is the price rather than the quantity that is taken as the strategic variable. Again, the decision taken by one firm is not expected to change the decisions of other firms. One firm might therefore believe that it can capture the entire market by setting a lower price than the other firms', a belief that, of course, is shared by the other firms.

This common belief leads to the Bertrand paradox solved by Edgeworth in 1897. The Bertrand paradox leads to a competitive outcome independent of the number of firms in the industry[1]. We get a solution closer to the theory

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[1]See, for example, Tirole 1990, 211.

of imperfect competition, i.e., price above marginal cost, when we instead regard capacity constraints, i.e., one single firm cannot supply the whole industry. This means that not all consumers who want to buy from a "low-cost" producer are able to do so. Other firms are thereby faced with *residual* demand.

The equilibrium outcome of this game depends on the rationing rule, i.e., how the residual demand is divided among the companies. There are two major rationing rules, the efficient rationing rule and the proportional rationing rule. Under the efficient rule the most "eager" or the customer with the "first contract" is served by the low-cost producer, leaving the rest of the demand to the other producers. It is called efficient because it maximizes consumer surplus. Efficient rationing is also called parallel rationing because of geometrical reasons: after the low-cost producer has "dumped" his capacity on the market, the demand curve is assumed to be shifted parallel to the left. Under the proportional rule (or randomized rationing rule) all consumers have the same probability of being served by the low-cost producer.

Since the first contract of importance in the iron ore industry is a price and quantity commitment I am assuming efficient or parallel rationing, because the quantity commitment in the contract reduces the amount of iron ore available to the rest of the market. This is an important assumption. Major research that made significant contributions to the field of industrial organization done by Kreps and Scheinkman (1983) showed, very nicely, that when companies play a two-stage game, first choosing quantity (capacity) and then, in a Bertrand way, competing with prices, the outcome is of the

"Cournot type." In their model two firms first choose capacities, "dump" these capacities on the market and then compete in price, i.e., they install capacity before price and demand are realized. This reduction of the game, from a two-stage game to a Cournot game in capacities, holds only if the rationing rule is the efficient one. It should not be far-fetched to assume this situation in the iron ore industry. Although it is the price negotiations that are observed, the activities prior to these negotiations are most probably setting the capacities. Making use of this assumption, and the result that a Cournot competition in capacities followed by Bertrand competition in prices, leads to the standard Cournot outcome, speaks in favor of using the Cournot model in the analysis of the iron ore industry. Another important assumption in Kreps and Scheinkman's analysis for this "Cournot reduction" is that the investment cost (the investment in new and larger capacities) is relatively high. High cost for installing capacities in one period creates a large discrepancy between cost in this period and cost in the next period, thereby leading to a higher willingness to "dump" existing capacities after the investment in larger capacities has been made. (High investment costs in one period are assumed to be "sunk" in the next period.)

Since one of the players, usually Brazil, is "allowed" to move first, it seems appropriate to include the Stackelberg model of quantity leadership in the analysis. This model is also basically a two-stage game. One firm gets to move first, the other firms observe this choice and choose their own optimal level of output.

If the capacity chosen by the first firm is held secret and the capacities chosen by the other firms also are held secret, the outcome is of the Cournot type, even if the capacities are chosen at different times. If the capacities are held secret we can think of the capacities being chosen simultaneously. Research done by Anderson and Engers (1992), however, shows that even if the first firm earns more under a Cournot game (secret output choice), all firms will reveal their outputs in the subgame,[2] suggesting the Stackelberg model. The idea of holding capacities a secret in the iron ore industry is in addition not very likely, again suggesting the Stackelberg model. The Stackelberg model is further developed later in this chapter.

It should now be obvious that, this thesis, will use the Cournot and Stackelberg model to analyze the iron ore market. Since this oligopoly game will be considered as "one-shot" in nature, a strategic variable is needed that cannot be changed immediately, in this case capacities. In addition, research as outlined above, shows that Bertrand competition in prices after capacity competition leads to the Cournot model. The importance of the Stackelberg model is also shown in important research, outlined above, and is considered in this paper.

I will now further develop the Cournot and Stackelberg models and derive from them the concept of conjectural variation. This conjectural variation parameter will then be used to test different hypotheses to see whether the iron ore industry can be described by the Cournot, Stackelberg, or the Bertrand model.

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[2]This is shown by backwards recursion and the hierarchical Stackelberg model.

The analysis will treat the oligopoly situation as a duopoly situation. The purpose is to simplify the analysis. This simplification, however, does not change the results in any essential way.

The Cournot Model

The Cournot model, developed by Augustin Cournot and first published in 1838, deals with a homogeneous product which is sold by two sellers (duopoly) at zero cost of production. The model can easily be generalized to three or more sellers and a cost of production above zero.

Consider first a duopoly, i.e., an industry with two firms, firm 1 and firm 2. The two firms are assumed to compete in quantities. Consider the decisions made by firm 1. The problem is to choose quantity so as to maximize profit:

$$\text{Max}(x_1) \qquad \pi_1(x_1, x_2) = p(x_1+x_2)x_1 - C_1(x_1) \tag{1}$$

where x_1 and x_2 are the production of firm 1 and 2, $p(\cdot)$ is the (inverse) demand function, and $C_1(x_1)$ is the total production cost for firm 1 producing x_1 units. The first order condition for profit maximization for firm 1 becomes

$$\frac{\partial \pi_1(x_1, x_2)}{\partial x_1} = p(x_1+x_2) + p'(x_1+x_2)x_1 - c_1(x_1) = 0 \tag{2}$$

and the second order condition

$$\frac{\partial^2 \pi_1(x_1, x_2)}{\partial x_1^2} = 2p'(X) + p''(X)x_1 - c_1'(x_1) \leq 0 \tag{3}$$

where $c_1(x_1)$ is the marginal cost and $X = x_1 + x_2$. The first order condition can be defined as firm 1's optimal choice of output as a function of firm 2's choice of output. The first order condition (2) has a simple interpretation. The first and second term are the marginal revenue (MR). The third term represents marginal cost (MC). Profit maiximizing behavior means, as usual, that marginal revenue equals marginal cost, or MR=MC. Equation (2) is similar to the formulas obtained for a competitive firm and a monopoly. For a competitive firm, MR=$p(x_1+x_2)$, i.e., price equals marginal revenue, which equals marginal cost at profit maximizing output. For a monopoly, x_1 is equal to the industry output. Market price in an oligopoly will therefore be lower than the monopoly price, but higher than the competitive price.

Since firm 1's profit depends on the output decisions made by firm 2, we can introduce the reaction function, i.e., the function that shows firm 1's optimal output choice as a function of firm 2's decision. Introducing this reaction function, $x_1 = f_1(x_2)$, the first order condition for firm 1 becomes

$$\frac{\partial \pi_1(f_1(x_2), x_2)}{\partial x_1} = 0 \tag{4}$$

where $f_1(x_2)$ is firm 1's reaction curve showing how firm 1 reacts to firm 2's output choice. One hypothetical reaction function is shown in figure 2.

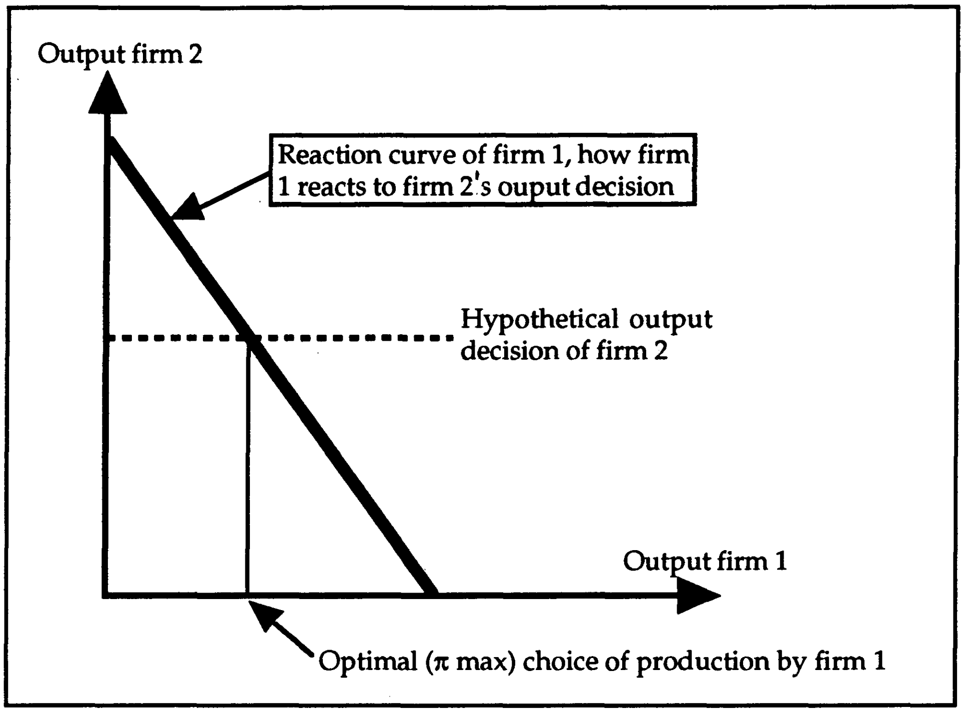

Figure 2. One Reaction Curve and the Optimal Production Decision

For the coming analysis it is however the slope of the reaction curve that is of interest, since the slope reveals the marginal change in output decision made by, in this case, firm 1 as a response to changes made by firm 2. By differentiating Equation (4), using the implicit function theorem[3] we get

$$\frac{\partial x_1}{\partial x_2} = f_1'(x_2) = -\frac{\partial^2 \pi_1 / \partial x_1 \partial x_2}{\partial^2 \pi_1 / \partial x_1^2} \tag{5}$$

[3]See, for example, Chiang 1984, 208.

The denominator in the right hand expression is negative because of the second order condition. This means that the slope of the reaction curve is determined by the sign of the mixed partial, i.e.,

$$\text{sign}\,(f_1'(x_2)) = \text{sign}\,(\partial^2\pi_1/\partial x_1\partial x_2).$$

Following Varian (1992), the mixed partial is negative if the inverse demand function is concave (or at least not too convex). Following Tirole (1993), the actions taken by a firm are considered to be strategic substitutes if $(\partial^2\pi_1/\partial x_1\partial x_2)<0$. Since capacity actions are most often considered to be strategic substitutes, i.e., if one of the firms increases its production, the other firm decreases its production, the expression will be negative indicating reaction curves sloping downwards[4]. Figure 2 shows one possible reaction curve for firm 1 and firm 1's optimal production decision given the output decided by firm 2.

To obtain and show the interdependence between the firms in the Cournot equilibrium, it is easiest to work with a case of linear demand and costs. Assume linear (inverse) demand $p(X) = 1-X$, and the total cost function $C_i(x_i) = c_i x_i$, with $i = 1, 2$. Then firm 1 is maximizing

$$\text{Max}\,(x_1) \qquad \pi_1(x_1, x_2) = x_1(1-X) - c_1 x_1,$$

where $X = x_1 + x_2$. From the first order condition

[4]You can also say that we assume firm 1's marginal profit is decreasing with the other firm's quantity.

$$\frac{\partial \pi_1(x_1, x_2)}{\partial x_1} = 1 - 2x_1 - x_2 - c_1 = 0$$

we get firm 1's reaction curve $f_1(x_2)$:

$$f_1(x_2) = x_1 = \frac{1 - x_2 - c_1}{2} \tag{6}$$

In the same way we can obtain the reaction curve for firm 2, i.e., how firm 2 reacts to firm 1's output decision:

$$f_2(x_1) = x_2 = \frac{1 - x_1 - c_2}{2} \tag{7}$$

The Cournot equilibrium (from firm 1's point of view) can now be obtained by replacing x_2 in Equation (6) by Equation (7):

$$x_1 = \frac{1 - (\frac{1 - x_1 - c_2}{2}) - c_1}{2}$$

which yields the Cournot equilibrium:

$$x_1 = \frac{1 + c_2 - 2c_1}{3} \tag{8}$$

The profit for firm 1 becomes

$$\pi_1 = \frac{(1 + c_2 - 2c_1)^2}{9} \tag{9}$$

The Cournot equilibrium from firm 2's point of view and firm 2's profit function can be obtained in a similar way. It is now obvious that the output from firm 1 decreases with its marginal cost. It can also be seen that firm 1's output increases with firm 2's marginal cost, since a higher c_2 reduces the output from firm 2, leaving a higher "residual" demand for firm 1, thereby encouraging firm 1 to produce more. The Cournot equilibrium and the effects of changing marginal costs can be seen in figure 3.

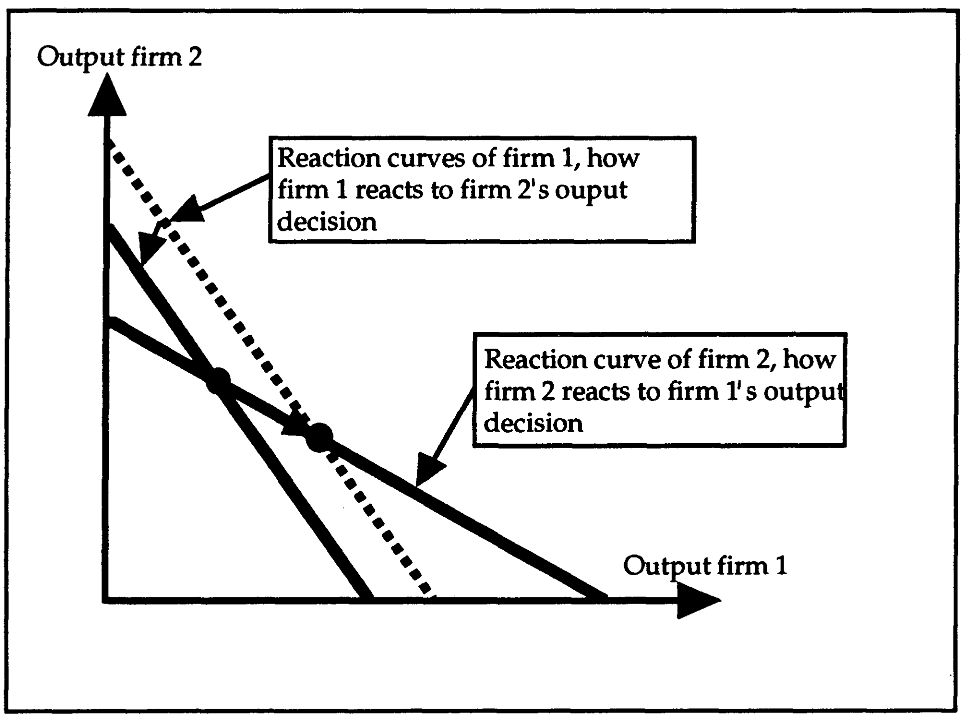

Figure 3. Cournot Equilibrium and the Effect of a Decrease in Firm 1's Marginal Cost

The Cournot equilibrium is where the reaction curves intersect. Figure 3 shows the effects of a decrease in firm 1's marginal cost. Output from firm 1 increases and output from firm 2 decreases.

In the above models, no firm is assumed to have knowledge of the other firm's reaction curve. The output from the other firm is in each period taken to be given and is assumed not to be affected by any output decision. When this "Cournot game" is played over time, the long-run equilibrium is where the reaction curves intersect.

Stackelberg, Quantity Leadership

Now assume instead that one firm, say firm 1, has complete knowledge of how firm 2 will react to firm 1's output decision, but that firm 2 does not know about firm 1's reaction. If, as in this case, firm 1 has knowledge of firm 2's reaction curve, firm 1 is called a Stackelberg leader and firm 2 is called a Stackelberg follower. In this case we let firm 1 choose its output quantity first (knowing the reactions from firm 2), i.e., we have a two-stage game in which firm 1 gets to move first. We begin solving this model from firm 2's point of view, since firm 2's problem is straightforward, maximizing its profit given firm 1's decision. The first order condition for firm 2 is

$$p(x_1 + x_2) + p'(x_1 + x_2)x_2 = c_2(x_2) \tag{10}$$

Firm 1 knows the reaction from firm 2, i.e., knows $f_2(x_1)$. Thus, firm 1 wants to maximize

$$p(x_1 + f_2(x_1))x_1 - C_1(x_1) \tag{11}$$

This leads to the first order condition for firm 1:

$$p(x_1 + f_2(x_1)) + p'(x_1 + f_2(x_1))x_1 + p'(x_1 + f_2(x_1))f_2'(x_1)x_1 - c_1(x_1) = 0,$$

$$p(x_1 + f_2(x_1)) + p'(x_1 + f_2(x_1))[1 + f_2'(x_1)]x_1 = c_1(x_1)$$

or

$$p(X) + p'(X)[1 + f_2'(x_1)]x_1 = c_1(x_1) \tag{12}$$

where $X = x_1 + x_2$ and $x_2 = f_2(x_1)$.

The term $f_2'(x_1)$ in Equation (12) is the slope of firm 2's reaction curve and indicates firm 1's belief of how firm 2 will react if firm 1 changes its optimal output choice. If firm 1 has complete knowledge of this slope, then the two stage game, choosing output according to first Equation (12) and then Equation (10), yields the Stackelberg equilibrium. This equilibrium can be seen graphically in figure 4. Knowing the reactions from firm 2, firm 1 chooses a profit maximizing output level on firm 2's reaction curve.

The isoprofit curve for firm 1 indicates the combination of output levels of the two firms that yield a constant profit for firm 1. Isoprofit curves outside the one in figure 4 indicates lower profit, and isoprofit curves inside indicate higher profits. As can be seen in figure 4, firm 1 wants to operate at the point on firm 2's reaction curve where firm 1 has the highest profit. It can also be seen that the Stackelberg leader has a higher output and the follower lower output compared to the Cournot case.

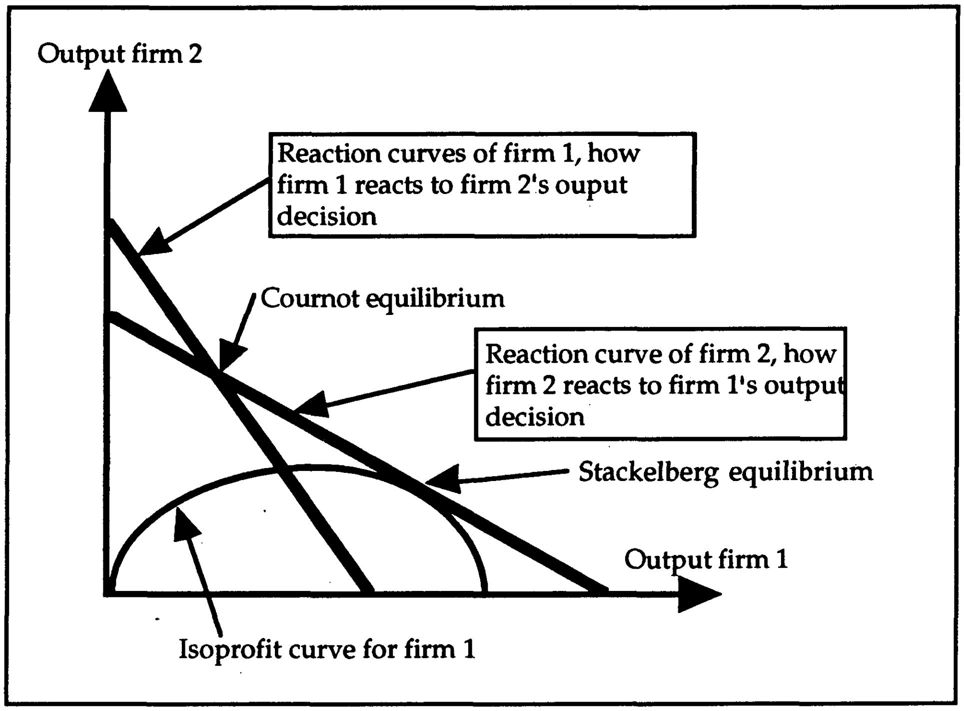

Figure 4. Comparison of Cournot and Stackelberg Equilibria

The profit to the leader is generally higher in the Stackelberg case than in the Cournot case. It can also be shown (Varian 1992: 297) that a firm wants to act as a leader if $\pi_1(x_1, x_2)$ is a decreasing function of x_2, $\pi_2(x_1, x_2)$ is a decreasing function of x_1 and if the reaction curves $f_i(x_j)$ are strictly decreasing functions.

Dominant Firm, Price Leadership

Although this study relies on the Cournot reduction with quantities as the strategic variable, it might be worth mentioning the dominant firm model of price leadership. In this model it is the price that is taken to be the strategic variable and the objective for the dominant firm is to determine the optimal value of p_1 in order to maximize

$$p_1 x_1(p_1, g_2(p_1)) - C_1(p_1, g_2(p_1)) \tag{13}$$

In Equation (13) the price set by the follower, $p_2 = g_2(p_1)$, is to be regarded as the reaction function that gives the optimal choice of p_2 as a function of p_1.

In the case of a homogeneous product, the follower, if it wants to sell a positive amounts of output, must charge the same price as the leader, i.e., $p_2 = p_1$. For each price p_1, the follower will produce the amount of output on its supply curve, $S_2(p_1)$, that maximizes its profit. This becomes then a special case of the Stackelberg model with the reaction function equal to the competitive fringe supply curve. It can further be shown that the slope of the reaction curve involves calculations of the competitive fringe supply elasticity.[5]

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[5]See, for example, Ordover and Saloner 1989.

Chapter 4
CONJECTURAL VARIATIONS

If the term $f_2'(x_1)$ in Equation (12) is not known completely by firm 1, it can be thought of as being an arbitrary "conjecture" of how firm 2 is expected to respond to firm 1's output choice. From now on we call this term the *conjectural variation* of firm 1 about firm 2, and denote it by v_{12}. By definition v_{12} is still the slope of the reaction curve, i.e., $v_{12} = \partial x_2 / \partial x_1$, the "expected" reaction by firm 2 to a change in firm 1's output decision. We thereby rewrite the first order condition (Equation 12) for firm 1

$$p(X) + p'(X)[1 + v_{12}]\, x_1 = c_1(x_1) \tag{14}$$

By this parameterization and by giving this parameter (v_{12}) different values we obtain different models.

a) $v_{12} = 0$, this is the Cournot case (equation 2).
b) $v_{12} = -1$, this is the competitive outcome, price equals marginal cost. An increase in firm 1's output is expected to lead to an equal decrease in firm 2's output.
c) $v_{12} = f_2'(x_1)$, this is obviously the Stackelberg case.
d) $v_{12} = x_2/x_1$, this is the collusive outcome (for a symmetric duopoly $v_{12} = 1$).

In the first case above, the Cournot case, it is important to note that the output decisions made by the competitors are not totally ignored. The level of the competitors' output is taken into account; it is, however, assumed in a "Cournot way" that this level is not going to be changed as a reaction to any decision made by firm 1. This means, among other things, that firm 1 in this case takes into account the marginal effects on the price that follows any decisions from firm 1, but does not include any marginal effects on the price following its competitors' decisions since their decisions are assumed to be fixed.

In the second case, the competitive case, the decisions made by the competitors are totally ignored. In this case, each company is so small on the market that no decision made by it will affect the price or any decisions made by the other companies.

Equation (14) can be extended easily to an arbitrary number of firms (n) and a specific point in time (t)[6]. Consider firm i, ($i = 1,\ldots, n$) in time t. The first order condition for this firm is

$$p_t(X) + p_t'(X)[1 + v_{ijt}]\, x_{it} = c_{it}$$

where $X = \sum_{i=1}^{n} x_{it}$ and $p_t'(X) = dp_t/dX$. For convenience we write $p_t(X) = p_t$ and $p_t'(X) = p_t'$:

$$p_t + x_{it}p_t' - c_{it} = -x_{it}p_t'v_{ijt} \tag{15}$$

Solving Equation (15) for v_{ijt} we get an expression for the conjectural variation for firm i at time t about the other firms:

[6]See, for example, Varian 1993 and Iwata 1974.

$$v_{ijt} = -\frac{1}{x_{it}p_t'}(p_t - c_{it}) - 1 \tag{16}$$

Making use of the inverse rule, $1/p_t' = 1/(dp_t/dX) = dX/dp_t$, and by multiplying each term with $(p_t/X)/(p_t/X)$ we get

$$v_{ijt} = \frac{\varepsilon_t}{s_{it}}\left(\frac{p_t - c_{it}}{p_t}\right) - 1 \tag{17}$$

where ε_t is the (positive) elasticity of market demand, $-(dX/dp_t)(p_t/X)$ and s_{it} is the market share of firm i in time t, x_{it}/X. It is difficult to have an intuitive interpretation of Equation (17), but one extreme is obvious. If it is a perfectly competitive industry, price equals marginal cost, and $v_{ijt} = -1$. It is also obvious that $v_{it} = 1$ in the symmetric collusive duopoly case (two companies with equal market shares). In that case the market share equals 0.5, and by the inverse elasticity rule for monopoly profit maximization $\varepsilon_t\left(\frac{p_t - c_{it}}{p_t}\right) = 1$, we get $v_{ijt} = 1$.

We now have the conjectural variation of firm i in time t about the other firms, v_{ijt}, as a function of the price elasticity, the market share, the price and the marginal cost, all in time t. If we knew the values on the right hand side of Equation (16) and assumed oligopoly, the conjectural variation could be calculated and compared to the outcomes that would be expected under different models. The different values of v_{ijt} over time could perhaps also be used to see if the analyzed market is becoming more or less competitive or is going from a Cournot equilibrium to a Stackelberg equilibrium in quantities or vice versa.

It is important, however, to remember that v_{it} is the conjecture of firm i about the other firms as a group, so in some sense we are still dealing with the duopoly case, i.e., how the firms together are expected to react to firm *i's decision*. The model can be extended to include the expected reactions from the individual firms. The first order condition for firm i then becomes (dropping the subscript t)

$$p + \frac{\partial p}{\partial x_i} x_i + \sum_{j=1}^{n} \frac{\partial p}{\partial x_j} x_i \frac{\partial x_j}{\partial x_i} = c_i$$

where $i \neq j$, n is the number of firms, and $\frac{\partial x_j}{\partial x_i} = v_{ij}$ is firm j's expected reaction to firm i's output decision. This is basically the same model as Equation (15). Assuming $\frac{\partial p}{\partial x_i} = \frac{\partial p}{\partial x_j} = \frac{\partial p}{\partial X} = p'$, we get

$$p + p'x_i \; [1 + \sum_{j=1}^{n} v_{ij} \;] = c_i \tag{18}$$

As before (see Equations 15, 16 and 17), this can be shown to be

$$\sum_{j=1}^{n} v_{ij} = \frac{\varepsilon}{s_i}\left(\frac{p - c_i}{p}\right) - 1 \tag{19}$$

The right hand side of Equation (19) can be expanded using $s_i = x_i/X$, and $X = \sum_{i=1}^{n} x_i$. An expansion like that, however, does not change anything. Unfortunately, we do not have enough information to obtain unique solutions to the conjectural variation terms on the left side. We have information to get an estimate only of the expected overall reactions, $\sum_{j=1}^{n} v_{ij}$. It would, however, be interesting to estimate firm i's conjecture about its individual competitors. Such information would reveal a company's major and minor competitors. A conjecture parameter of -1 for one of the competitors and zero for another would mean that the company is taking into account only the reactions from one of the competitors, assuming the reaction from the other to be zero (Cournot).

It is, however, beyond the scope of this study to obtain the solution to the individual conjectures (if it is possible), and the ensuing analysis will calculate and interpret the conjecture of one firm about all its competitors as a group.

Chapter 5
ESTIMATION AND TEST OF HYPOTHESIS ABOUT v_{it}

Equation (17) will be used to get a point estimate of the conjectural variation in each time period. In order to do this it is necessary to make three assumptions. These assumptions follow Iwata (1974) and mean that the second order conditions will hold as long as $v_{it} > -1$[7].

a) The price elasticity of market demand is assumed to be constant regardless of the level of market demand.

b) The marginal cost for each firm is assumed to be constant with respect to short run variation in output for each period.

c) The conjectural variation is assumed to be constant in each period.

The first assumption is fairly common. To meet this assumption a double-logarithmic demand function will be used. The second assumption is also realistic, at least in mining. Capital intensive industries, as for example mining, often reveal relatively constant marginal and average cost curves up to capacity (Torries 1988). The third assumption means that each oligopolist ex ante has some conjecture about his rivals' reactions, based on past experience, and that this conjecture does not change during a given time period.

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[7] It is complicated to show this. For a brief explanation and proof, see Iwata 1974.

Not only is the price assumed to be a function of exogenous variables only, but so is the market share, s_{it} . Price, marginal cost, and market share are assumed to be directly observable without uncertainty. The only factor in Equation (17) that needs to be estimated is the elasticity of market demand.

Estimation of Demand Elasticity

To get an estimate of the price elasticity for demand a classical double-logarithmic demand function will be used

$$X = \alpha p^{\beta_1} y^{\beta_2} e^{u} \tag{19}$$

where X, the dependent variable, is quantity demanded, p is the price of the commodity, and y can be some other variable that is assumed to explain some of the variation in quantity demanded. α, β_1 and β_2 are parameters to be estimated. u is the error term, and $e \approx 2.718$ is the base of the natural logarithms. Regarding the error term the classic assumptions are assumed to hold.[8]

The explantory variables are the iron ore price (f.o.b. Brazilian ore) and the production of pig iron in Europe. The production of pig iron is used because the demand for iron ore is considered to be a derived demand, derived from the demand for steel. It would perhaps be more appropriate to use the c&f, Rotterdam price in the analysis, but the statistics for f.o.b. prices are more reliable, and it is assumed here that the two prices are following approximately the same pattern. Time series data from 1970 to 1989 is used

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[8]See, for example, Koutsoyiannis 1977.

for European countries that are major importers of iron ore and major producers of pig iron[9] with the following results

The estimated regression equation is
log(import) = - 0.181 - 0.179 log(price) + 1.24 log(pigiron)

Predictor	**Coef**	**Stdev**	**t-ratio**	**p**
Constant	-0.1813	0.5610	-0.32	0.751
log(price)	-0.17946	0.04197	-4.28	0.001
log(pigiron)	1.2367	0.1383	8.94	0.000

s = 0.04282   **R-sq** = 82.7%   **R-sq(adj)** = 80.7%

The two elasticities are highly significant and the R^2 is relatively high (82.7%) suggesting that the price and production of pig iron explain 82.7% of the variation in the import of iron ore in Europe. The point estimate of the price elasticity of demand is (negative) 0.18, showing, as expected, a relatively inelastic demand. A recent study (Chang 1994) of the Japanese iron ore market estimated the demand elasticity for Brazilian ore to Japan to be approximately (negative) 0.15. This study, however, used the Brazilian market share as the independent variable.

The elasticity of demand with respect to pig iron production seems to be fairly adequate. With modern technology used today in Europe, it takes about 1.2 tons of iron ore to produce 1 ton of steel (Priovolos 1987: 11).

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[9]Austria, Belgium, Finland, France, Germany, Italy, the Netherlands, Spain, and United Kingdom.

If the price increases by 1 percent the demand will decrease by 0.18% at average. The variance of this point estimate is $0.04197^2 = 0.0018$. Since the error term is assumed to follow a normal distribution, so does the estimate of the elasticity of demand.

The Durbin-Watson statistics for serial correlation turned out to be 1.57. By using the ordinary Durbin-Watson test for serial correlation (see, for example, Green 1993: 423) I could not reject the null hypothesis of zero serial correlation.[10]

Estimation of Conjectural Variation v_{it}

Assuming that we can observe the prices, marginal costs, and the market share, we now have information to estimate the conjectural variation:

$$\text{Est}(v_{it}) = \frac{\text{Est}(\varepsilon_t)}{s_{it}}\left(\frac{p_t - c_{it}}{p_t}\right) - 1 \tag{20}$$

Since $\text{Est}(\varepsilon_t)$ is an unbiased estimator of ε_t, $\text{Est}(v_{it})$ is an unbiased estimator of v_{it}. For the coming tests of different hypotheses we also need the variance of this estimate:

$$\text{Var}(v_{it}) = \text{Var}\left(\frac{\varepsilon_t}{s_{it}}\left(\frac{p_t - c_{it}}{p_t}\right) - 1\right) = \text{Var}\left(\frac{\varepsilon_t}{s_{it}}\left(\frac{p_t - c_{it}}{p_t}\right)\right)$$

[10]The observed value of 1.57 is entirely to the right of the 5 percent significance bounds, dL=1.1 and dU=1.537 (Green 1993, table 7b).

since the variance of –1 is zero. Setting $a = \frac{1}{s_{it}}\left(\frac{p_t - c_{it}}{p_t}\right)$ we get

$$\mathrm{Var}(v_{it}) = \mathrm{Var}\,(\varepsilon_t\, a) = a^2\mathrm{Var}(\varepsilon_t) \qquad \text{or}$$

$$\mathrm{Var}(v_{it}) = \mathrm{Var}(\varepsilon_t)\left(\frac{1}{s_{it}}\left(\frac{p_t - c_{it}}{p_t}\right)\right)^2 \tag{21}$$

We have now an unbiased estimate of the demand elasticity and its variance. In addition we have an unbiased estimate of the conjectural variation and its variance. It should now be possible, with observations of prices, marginal costs, and market shares, to obtain yearly estimates of the conjectural variations for different firms or group of firms. It should now also be possible to test the hypotheses and to calculate confidence intervals for the conjectural variation term v_{it} for different years.

Chapter 6
RESULTS

The conjectural variations for Brazil, Australia, Scandinavia, Africa and Canada were estimated using Equation (20), and the variance in each estimate was calculated using Equation (21). The conjectural variation for each country (or group of countries) was estimated for the years 1984-1992. The price variable used was the f.o.b. price received in each country or region for each year. The market is defined by the countries in EG-12 (now EU-12), and the market share is defined as each country's or region's trade in EU-12, divided by the total amount of iron ore traded with the EU-12. The estimate of demand elasticity (0.18) was used in the calculations. Quantities are regarded as being output capacities and here we assume low and constant marginal cost up to that capacity. This low marginal cost assumption means that the price-cost margin, $(p_t - c_{it})/p_t$, in the iron ore industry is relatively close to unity, leading to a small effect on the conjectural variation. Any change in the price-cost margin does, however, change the conjectural variation. This will help to explain the eventual changes in the conjectural variations over time. As an estimate of the marginal costs in different countries I have used the cost data presented by the U.S. Bureau of Mines. Data and calculations are presented in appendix A.

The estimated conjectural variation terms are presented in table 3. The values for Brazil are consistently below zero with a slight trend of becoming more and more negative, indicating that Brazil is to a greater and greater extent considering the actions of its competitors in making its own output decisions. The values for the other countries do not consistently fall on either side of zero, and confidence intervals for the yearly values of the conjectural variation do not exclude zero. It is only for Brazil that the null hypothesis of zero conjectural variation (Cournot behavior) can be rejected at 5 percent significant level. The confidence intervals are given in appendix B.

Table 3. Conjectural Variation Estimates

Year	Brazil	Australia	Scandinavia	Africa	Canada
1984	-0.46	0.18	-0.01	-0.35	0.28
1985	-0.47	0.13	0.06	-0.20	0.00
1986	-0.48	0.25	0.10	-0.22	-0.03
1987	-0.52	0.10	0.11	-0.18	-0.01
1988	-0.51	-0.05	0.24	-0.20	0.07
1989	-0.51	0.05	0.36	-0.21	0.15
1990	-0.59	0.13	0.42	0.09	0.33
1991	-0.57	0.01	0.38	0.38	0.14
1992	-0.59	-0.01	0.27	0.45	0.24

Since we can reject the Cournot hypothesis for Brazil, we can say that Brazil does consider the reactions from other countries. For 1992, for example, Brazil conjectured that the other countries would decrease their production by 0.59 for every unit of increase in Brazil. Since we cannot reject the Cournot hypothesis for the other countries or regions — Australia, Scandinavia, Africa and Canada — we cannot exclude the possibility that they do "play" a Cournot game, i.e., they take the production from their competitors as given when making their own output decisions.

It thus appears that the European iron ore market reflects a Stackelberg situation with Brazil acting as the leader. Brazil considers the output decisions from other countries and conjectures a decrease of its competitors' output when increasing its own production. This means that Brazil has an additional factor to consider in its output decision. Brazil "knows" the reaction from the other countries and "picks" a point on their, instead of its own, reaction curve (see figure 4). The other countries do not have this conjecture, they take any output as given in making their decisions; they are acting as followers or are playing a Cournot game.

Market share is the major contributor to the level and changes in the conjectural variations. An increased market share makes the conjectural variation smaller, i.e., more and more negative. A company or country that is increasing its market share seems, therefore, to take more and more account of its competitors' reactions.

It is puzzling that the values for Scandinavia, Africa, and Canada are becoming more and more positive as the values for Brazil are becoming more and more negative. These three countries appear to conjecture that the other countries will increase their production when their own production increases, suggesting collusive behavior or at least an expectation that the other firm will "match" an increase or decrease in output. So although the confidence intervals include zero, the trend for the conjectural variation for these countries is puzzling.

Two possible explanations might be that the countries expand together in an economic upswing and that natural market segmentation exists as a result of transport constraints and buyer diversification. The iron ore market did expand in the middle of the observed period. Since Sweden, the major producer in Scandinavia, is to a greater extent trading on a short-term basis, it expands in an upswing without any expectations of decreasing output from its competitors. In addition, specific requirements from buyers regarding the right mix of input in the blast furnace can mean that the demand for different qualities from different mines increases in an economic upswing. This can help explain the positive values for conjectural variations for different countries. If, for example Scandinavia increases its output, it does expect an increase from other suppliers. Yet another factor that does complicate the analysis for Sweden is the product differentiation that has been the major activity in Sweden during the late 1980s. The major product sold by Sweden today is not iron ore, as this country has, from the mid 1980s, become more and more devoted to the market for pellets.

The average values for the conjectural variations for the observed years are given in table 4. For the mean values, we get almost the same result. For Brazil, the Cournot hypothesis can definitely be rejected. Brazil does consider the reactions of other countries in making its decisions and appears to act as a Stackelberg leader. For the other countries, except Scandinavia, the confidence intervals include zero, i.e., we cannot reject the Cournot possibility. It is not certain that these countries consider the *reactions* from the other countries. It is important, however, to realize that they do consider the *level* of production in other countries, but do not expect the levels to *change*.

Table 4. Mean Conjectural Variations for 1984-1992 and Confidence Intervals

Country	Mean (v)	St. dev (v)	95% confidence interval Lower limit	Upper limit
Brazil	-0.52	0.0038	-0.59	-0.45
Australia	0.09	0.086	-0.08	0.26
Scandinavia	0.21	0.096	0.02	0.40
Africa	-0.05	0.078	-0.20	0.10
Canada	0.13	0.085	-0.04	0.30

For Scandinavia, however, the confidence interval does not include zero. The interval is entirely on the positive side of zero, indicating in theory a "collusive" behavior. Possible explanations for this have been given earlier. The lower confidence limit is "close" to zero, and considering the unstable behavior over time, the value of conjectural variation is uncertain in this case.

As mentioned, it is the market share that contributes most to the different levels of conjectural variation and its changes. How sensitive then is the above result with respect to changing costs, price elasticity of demand, and market shares? The answer is that the conjectural variation factor is not very sensitive to changing costs, and is about equally sensitive to changing demand elasticity and changing market shares.

For a 50 percent reduction in costs in Brazil, for example, the conjectural variation for Brazil will decrease by between 4 percent and 6 percent. A 1 percent increase in demand elasticity will mean a decrease of the conjectural variation by approximately 1 percent. The same is of course valid for a decrease in the demand elasticity. The same holds for the market share. A 1 percent increase in market share will on average yield a 1 percent decrease in the conjectural variation. Similarly, for a 1 percent decrease in market share, the conjectural variation will on the average increase by 1 percent.

Chapter 7
CONCLUSIONS

The Cournot hypothesis was rejected for Brazil, but could not be rejected for the other countries and regions in the study — Australia, Scandinavia, Africa and Canada. This means that Australia, Scandinavia, Africa and Canada could be playing a Cournot game in quantities on the European market. These countries seem not to consider any reaction from the other countries, i.e., they take the production from the other countries as given when they make their output decisions.

This is not the case for Brazil. It does consider the reactions of other countries; it expects that other countries will decrease their production if Brazil increases its production. The trend in the conjectural variation for Brazil also shows that it seems to expect a greater reaction from the other countries over time. This suggest that Brazil is acting as a Stackelberg leader on the European market for iron ore. Knowing the reactions from the other countries, Brazil might "pick" a point on its competitors' reaction curve and thereby achieve a level of output higher than if it were to play a Cournot game. The major explanation for this behavior seems to be the increasing market share that Brazil has experienced during the observed period.

The market share appears to be the major contributing factor in the determination of conjectural variation and its changes over time. As a company or country grows bigger it seems to act more as a leader in that it expects a decrease in the competitors' output as a response to its own output. This also means that it does not expect any major effects on the price since an increasing output is expected to be offset by the competitors. Being in this position, Brazil does have an indirect influence over price in making its output decision.

What are then the implications for the future? Can Brazil take over the European market totally? Probably not. With a continuing trend of shorter contract lengths, there will be opportunities for small mines to make contracts for deliveries before Brazil. Future buyer diversification and product differentiation also speak in favor of the future existence of smaller mines. Although Brazil is the lowest-cost producer in the world, buyers will not totally rely on deliveries from one single seller. In addition, blast furnaces still require a certain mix of different qualities, a mix that a single supplier cannot fulfill.

A more interesting and important question is whether Brazil can become a leader on the world market. Brazil has, during the beginning of the 1990s, experienced an increasing market share on the Japanese market. The cost advantage in Brazil is apparently so significant today that it can supply the Japanese market at a c&f price lower than the c&f price from Australia.

There are signs that Brazil is now concentrating its efforts towards the Japanese market, perhaps in the belief that its part of the European market cannot grow much more. The significant difference in price of Brazilian ore between the European market and the Japanese market, the trend of early price settlements on the Japanese market in December and January, slightly before settlements on the European market, are some of the signs.

Prior to and during the observed period, Brazil strengthened its position on the European market as a "Stackelberg" leader, and there are signs, outlined above, that indicate that Brazil is now trying to do the same on the Japanese market. Whether Brazil can succeed in its efforts will depend on a number of different factors: the difference in costs between Brazil and Australia, the transportation costs, and the buyer strategy on the Japanese market, just to mention some. One thing, however, is certain: the expected continuing efforts of Brazil on the Japanese market, the trend of uncertain timing of price settlements, and the uncertainty about the future contract lengths, makes price forecasting for the rest of the century very uncertain.

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APPENDIX A

Data

	Year	Market Share	Elasticity/ Market Share	Price	Price/Cost margin	Conjectural Variation
Brazil	1984	0.30	0.60	26.15	0.91	-0.46
	1985	0.31	0.59	26.65	0.91	-0.47
	1986	0.31	0.57	26.26	0.91	-0.48
	1987	0.34	0.53	24.50	0.90	-0.52
	1988	0.33	0.55	23.50	0.90	-0.51
	1989	0.34	0.54	26.56	0.91	-0.51
	1990	0.41	0.44	30.80	0.92	-0.59
	1991	0.38	0.47	33.25	0.93	-0.57
	1992	0.41	0.44	31.62	0.92	-0.59

	Year	Market Share	Elasticity/ Market Share	Price	Price/Cost margin	Conjectural Variation
Australia	1984	0.13	1.35	23.60	0.87	0.18
	1985	0.14	1.28	26.65	0.89	0.13
	1986	0.13	1.41	26.20	0.89	0.25
	1987	0.14	1.28	21.55	0.86	0.10
	1988	0.16	1.11	21.10	0.86	-0.05
	1989	0.15	1.18	25.70	0.88	0.05
	1990	0.14	1.24	32.00	0.91	0.13
	1991	0.16	1.11	33.55	0.91	0.01
	1992	0.17	1.09	32.65	0.91	-0.01

	Year	Market Share	Elasticity/ Market Share	Price	Price/Cost margin	Conjectural Variation
Scandinavia	1984	0.13	1.38	27.70	0.71	-0.01
	1985	0.12	1.47	28.50	0.72	0.06
	1986	0.12	1.54	27.90	0.72	0.10
	1987	0.11	1.61	25.25	0.69	0.11
	1988	0.10	1.78	26.00	0.70	0.24
	1989	0.10	1.84	30.00	0.74	0.36
	1990	0.10	1.83	35.70	0.78	0.42
	1991	0.10	1.76	37.10	0.79	0.38
	1992	0.11	1.62	36.50	0.78	0.27

	Year	Market Share	Elasticity/ Market Share	Price	Price/Cost margin	Conjectural Variation
Africa	1984	0.24	0.76	27.75	0.87	-0.35
	1985	0.20	0.91	28.95	0.87	-0.20
	1986	0.20	0.89	28.60	0.87	-0.22
	1987	0.19	0.96	26.00	0.86	-0.18
	1988	0.19	0.93	25.10	0.85	-0.20
	1989	0.20	0.90	28.65	0.87	-0.21
	1990	0.15	1.23	33.65	0.89	0.09
	1991	0.12	1.54	36.20	0.90	0.38
	1992	0.11	1.62	34.15	0.89	0.45

	Year	Market Share	Elasticity/ Market Share	Price	Price/Cost margin	Conjectural Variation
Canada	1984	0.11	1.61	26.80	0.79	0.28
	1985	0.14	1.21	26.80	0.79	0.00
	1986	0.15	1.22	26.50	0.79	-0.03
	1987	0.14	1.25	27.17	0.80	-0.01
	1988	0.13	1.39	23.65	0.77	0.07
	1989	0.12	1.45	27.00	0.80	0.15
	1990	0.11	1.61	31.80	0.83	0.33
	1991	0.13	1.35	34.60	0.84	0.14
	1992	0.12	1.48	33.15	0.83	0.24

APPENDIX B

Confidence intervals

	Year	Conjectural Variation	Standard Deviation	95percent Confidence Lower-Upper Limit	
Brazil	1984	-0.46	0.13	-0.71	-0.20
	1985	-0.47	0.13	-0.71	-0.22
	1986	-0.48	0.12	-0.72	-0.24
	1987	-0.52	0.11	-0.74	-0.30
	1988	-0.51	0.12	-0.74	-0.28
	1989	-0.51	0.11	-0.74	-0.29
	1990	-0.59	0.10	-0.78	-0.41
	1991	-0.57	0.10	-0.77	-0.37
	1992	-0.59	0.10	-0.78	-0.40

	Year	Conjectural Variation	Standard Deviation	95percent Confidence Lower-Upper Limit	
Australia	1984	0.18	0.28	-0.37	0.72
	1985	0.13	0.27	-0.39	0.66
	1986	0.25	0.29	-0.33	0.83
	1987	0.10	0.26	-0.41	0.61
	1988	-0.05	0.22	-0.49	0.39
	1989	0.05	0.25	-0.44	0.53
	1990	0.13	0.27	-0.39	0.65
	1991	0.01	0.24	-0.46	0.47
	1992	-0.01	0.23	-0.47	0.44

	Year	Conjectural Variation	Standard Deviation	95percent Confidence Lower-Upper Limit	
Scandinavia	1984	-0.01	0.23	-0.47	0.44
	1985	0.06	0.25	-0.43	0.56
	1986	0.10	0.26	-0.41	0.61
	1987	0.11	0.26	-0.40	0.62
	1988	0.24	0.29	-0.33	0.81
	1989	0.36	0.32	-0.27	0.98
	1990	0.42	0.34	-0.24	1.08
	1991	0.38	0.33	-0.26	1.02
	1992	0.27	0.30	-0.32	0.86

	Year	Conjectural Variation	Standard Deviation	95percent Confidence Lower-Upper Limit	
Africa	1984	-0.35	0.15	-0.65	-0.04
	1985	-0.20	0.19	-0.57	0.17
	1986	-0.22	0.18	-0.58	0.14
	1987	-0.18	0.19	-0.56	0.20
	1988	-0.20	0.19	-0.57	0.16
	1989	-0.21	0.19	-0.58	0.15
	1990	0.09	0.26	-0.41	0.60
	1991	0.38	0.33	-0.26	1.02
	1992	0.45	0.34	-0.22	1.11

	Year	Conjectural Variation	Standard Deviation	95percent Confidence Lower-Upper Limit	
	1984	0.28	0.30	-0.31	0.87
	1985	0.00	0.24	-0.46	0.47
	1986	-0.03	0.23	-0.48	0.41
	1987	-0.01	0.23	-0.47	0.45
	1988	0.07	0.25	-0.43	0.56
	1989	0.15	0.27	-0.38	0.68
	1990	0.33	0.31	-0.29	0.94
	1991	0.14	0.27	-0.39	0.66
	1992	0.24	0.29	-0.33	0.81