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**Conjectures, reactions and collusive pricing strategies:
Revisiting the U.S. electrical machinery industry, 1956–1962**

Husbands, Humphrey Oliver, Ph.D.

City University of New York, 1991

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**CONJECTURES, REACTIONS AND COLLUSIVE PRICING STRATEGIES
REVISITING THE U.S. ELECTRICAL MACHINERY INDUSTRY
1956 - 1962**

by

Humphrey Oliver Husbands

A dissertation submitted to the Graduate Faculty in Economics
in Partial fulfillment of the requirements for the degree of
Doctor of Philosophy, The City University of New York.

1991

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This manuscript has been read and accepted for the Graduate Faculty in Economics in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract**CONJECTURES, REACTIONS AND COLLUSIVE PRICING STRATEGIES
REVISITING THE U.S. ELECTRICAL MACHINERY INDUSTRY
1956 - 1962**

by

Humphrey Oliver Husbands**Adviser: Professor Ronald W. Anderson**

This paper presents a new empirical industrial organization (NEIO) study of the US. electrical machinery industry over the period 1956-62. It is a NEIO study because it emphasizes empirical results.

The major goal is to determine by regressions in conjunction with summary statistical analysis whether General Electric and Westinghouse as a duopoly engaged in collusive pricing of their products over the period under review for the purpose of achieving oligopoly power. One of the secondary but nonetheless important goals is to determine whether the duopoly price discriminated against its customers on the basis of the size of orders.

This study encompasses one of the most significant discussions of NEIO by using conjectural variations theory empirically to determine market structure and behavior within an industry. What is unique about this author's approach is the partitioning of the industry for the period 1956-62 into two parts, with the dominant duopoly at the top of a pyramidal structure and with some 10,000 firms at the base competing mostly among themselves.

The study is presented in four chapters. Chapter 1 is comprised of an introduction, an overview and a statement of the purpose of the study. Chapter 2 first introduces a basic theoretical framework which mathematically defines the profit-maximizing model, and then presents a price reaction model which serves as the basis for developing an econometric model. In Chapter 3, the basic theory is translated into the econometric model which in turn is developed into the study's final empirical form. The core of the study, Chapter 3 also discusses the data and analyzes the results. Chapter 4 brings the study to its conclusion by

stating the implications of the exercise and by offering ideas for future study.

Given the data, this study has successfully estimated price conjectural variations which are highly significant and which show that, over the period 1956-62, the duopoly had engaged in collusive behavior, at least in the marketing of switchgear, and had price discriminated against small orders. The study achieved its goals.

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To Waple and Kaye
and in memory of my Mother

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1.0 Introduction

1.1 Overview

On May 13, 1959, reporter Julian Granger of the Knoxville News-Sentinel, Tennessee, reads a Tennessee Valley Authority (TVA) release regarding TVA's intention of purchasing a boiler from Babcock and Wilcox Co., Atlanta, Georgia.¹ The release is routine enough to be discarded.

At first paying little attention to the content of the release, Granger's curiosity is later aroused as information relating to identical sealed bids² on TVA contracts for electrical machinery is received by the Knoxville News-Sentinel. This propels Granger to launch an investigation of possible price fixing in the U.S. electrical machinery industry (EMI).³

The alleged technique used for price fixing was allowing a chosen EMI firm to submit the low bid to win a given contract while requiring all other participating firms to submit equal bids substantially higher than the low bid.⁴ For over 20 years, EMI executives had engaged in this activity involving sealed bids. These contracts generated sales of approximately \$1.5 billion a year.

The consequences of Granger's initial curiosity turned out to be more far-reaching than could have been predicted in May 1959. The U.S. Department of Justice (DOJ) eventually prosecuted "the largest antitrust case in the history of the country," Fuller writes, with EMI firms and executives as codefendants.

On another occasion, Fuller recounts, the TVA sealed-bids contracts involved I-T-E Circuit Breaker Company (I-T-E), Allied Chemical and Dye, Westinghouse (Wh), Allis

¹John G. Fuller.(1962). The Gentlemen Conspirators. New York: Grove Press, Inc., p. 8.

²Sealed bids are supposed to be secret so that, for example, firm i should not be privy to firm j 's price quotation, and conversely, $i \neq j$. This being so, the question Granger ponders is: why should the sealed bids quote the same prices?

³Fuller, p. 8.

⁴Ibid., p. 14.

Chalmers (A-C), General Electric (GE) and Pennsylvania Transformer.¹ Wh is awarded this contract for custom-built machinery at a sealed-bid price of \$96,760. But, identical sealed-bid prices of \$112,712 had been submitted to TVA by the other firms.²

However, it is not the equality of bids per se that warrants an economic investigation of collusive price fixing. For the adoption by firms of any oligopoly of standard price-cost margins (PCMs)³ would yield identical price quotations if costs happen to be identical across firms. Furthermore, this of itself would not be considered illegal price fixing in the U.S. Also, the equality of sealed bids does not necessarily signal that price-fixing meetings must have taken place. Adherence to a basing-point policy could also have yielded identical price quotations,⁴ or the use of a target-profit pricing model, as sketched in Figure 1.1.1, could have been used by colluders to arrive at identical prices (GE actually used such a model in 1958).

¹Although occasional references will be made to firms other than GE and Wh, the focus on EMI in this study will be on GE and Wh as a duopoly in the industry.

²The difference of \$15,592 between the winning low bid and the identical higher bids is 16% of the final contract price. This significant difference was doubtless taken into account by TVA when the award was made. Also see Fuller, *op. cit.*, p. 9.

³Note that PCMs may be expressed in different forms. For example, PCMs may be written as: $PCM = f(A/S, C_n, ES, K, 1/e)$ where A/S is the advertising-sales ratio, C_n is concentration, ES is economies of scale, K is capital and $1/e$ is the reciprocal of the price elasticity of demand. In this study, however, PCM refers to the form reflected in the Lerner (1934) index, $(P-MC)/P$.

⁴Under a basing-point system, oligopolists agree that a given price will consist of a fixed price plus a transportation fee for the distance between the buyer and the nearest pre-assigned location or basing-point. If a basing-point is nearer to the buyer than to the seller, then the buyer pays less than the true transportation cost, and conversely. The system results in the same "delivered price" to all buyers while the actual price received by sellers will vary with the transportation costs. The basing-point system is really a type of "spatial price discrimination." See Dictionary of Modern Economics (1981); Machlup (1949), p. 2. Basing point pricing may be structured as follows: (1) the dominant firm publishes new prices and pricing formulas according to the goods' specifications; (2) the calculated prices are multiplied by specific multipliers so that participating firms use the same book prices and multipliers; (3) the dominant firm then announces a commitment to no price discrimination. See Jean Tirole.(1989). The Theory of Industrial Organization. Cambridge, Mass.: MIT Press, pp. 241-42.

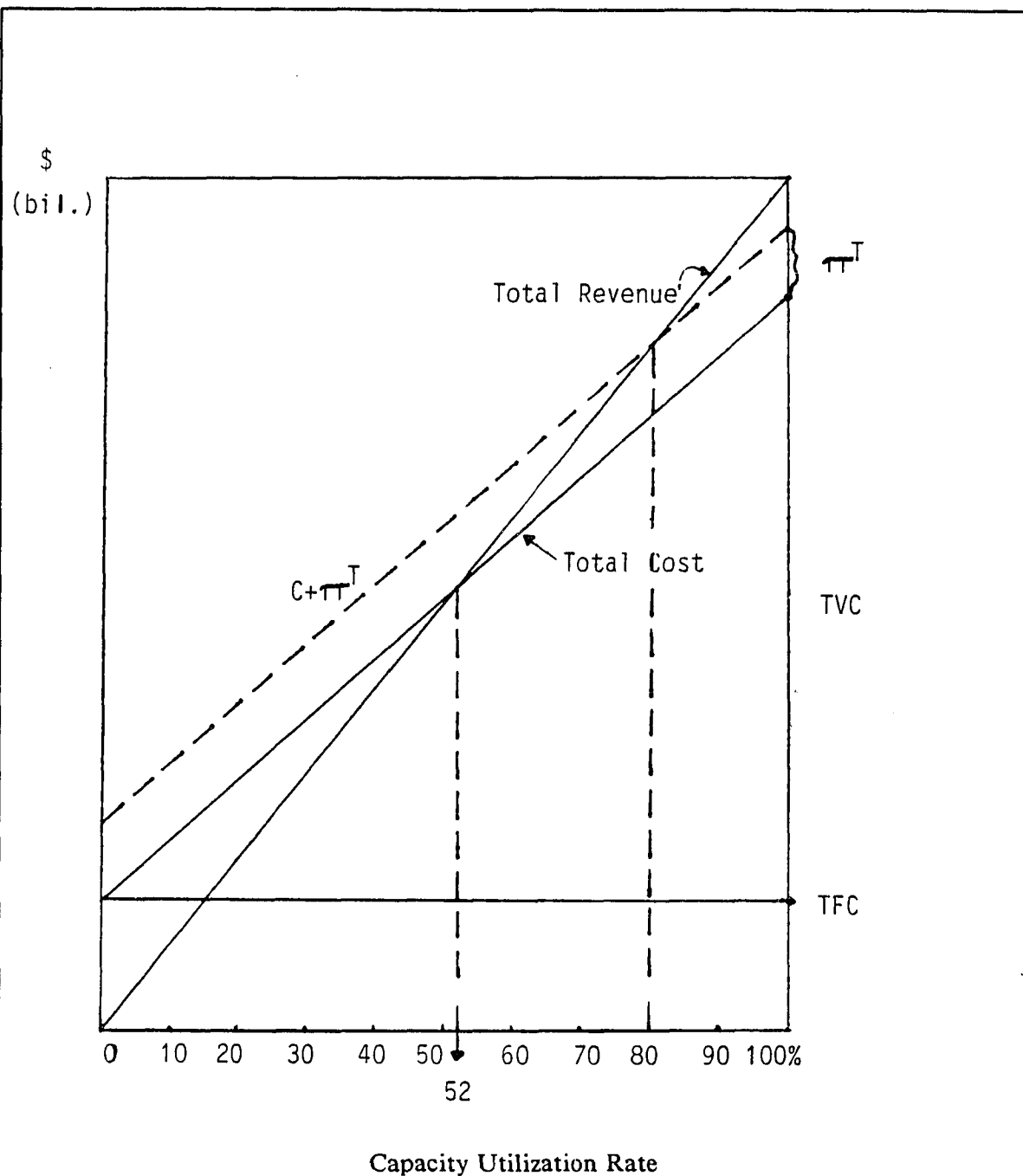


Figure 1.1.1. Target-Profit (π^T) Pricing Model.

Source: Adapted from Douglas F. Greer (1980), Industrial Organization and Public Policy. New York: Macmillan Publishing Co., Inc., Figure 11-b, p. 270.

Note: This sketch is only illustrative of and not specific to EMI. GE used this technique in 1958.

As Greer (1980) explains, target-profit pricing differs from cost-plus pricing only in form. This technique was developed by General Motors executives for the purpose of attaining a desired level of profit through price maintenance in conjunction with output flexibility. It has become a significant approach to pricing in manufacturing. Target profit is an arbitrary percentage of total investment (I). Say π^T is target profit and τ is the chosen percentage. Then $\pi^T = \tau I$ and $(\pi^T + C)$ gives the broken line in Figure 1.1.1, where C means total cost. Under a regime of target-profit pricing, C varies with output while π^T remains constant. But, as can be seen from Figure 1.1.1, this requires price cuts during booms and price increases during recessions--an unwanted countercyclical policy. This problem is surmounted by pricing so that, on average, the target profit is earned while prices are kept "fairly constant" over the business cycle.¹

Support for the foregoing argument comes from Scherer (1980) who stresses that, although the frequent use of sealed bids by EMI firms resulted from an observable collusive strategy to establish administered prices in the markets for electrical transformers and insulators, collusion is not necessary for the attainment of identical bids. (p. 193). GE and Wh (the Big Two) did not exclusively depend on rigged bidding as a collusive device. The method chosen depended upon the characteristics of the market being served. For example, Tirole (1989) cites the Big Two as exemplifying an industry using basing-point pricing for collusive purposes in the turbine generator² market. (p. 241).

A further complication arises from the common practice of firms' choosing the industry leader's catalog prices. This results in identical prices which means that identical bidding could prevail in the absence of criminal collusive behavior. This practice,

¹Douglas F. Greer.(1980). Industrial Organization and Public Policy. New York: Macmillan Publishing Co., Inc., pp. 269-71. Also see Greer for a numerical example, loc. cit.

²A turbine generator (or turbogenerator) is an electric power-generating machine adapted for direct coupling to a steam turbine. Once classified under industry (SIC code) 3614, the generators are now classified under industry 3515 and will thus be excluded from the econometric analysis of this study. See U.S. Bureau of the Census (1954).

euphemistically known as conscious parallelism, precludes consumers from obtaining the benefit of lower prices from free competition.¹ As Scherer (1980) puts it: "For nearly a century, the heavy electrical equipment industry had exhibited the pricing patterns associated with complex, multidimensionally differentiated products." (p. 201).

Although price fixing is supposed to be a limit to heterogeneity since it fosters homogeneity, yet price fixing alone cannot transform significant heterogeneity into homogeneity. For example, significant differences in transportation costs could reduce competition so that the goods, despite physical similarities, would still be perceived by buyers as differentiated.

Forms of collusive pricing practiced by EMI also varied according to the product and to the method used to sell a given product. Examples of the variation in techniques used are as follows: for standard transformers² and industrial controls (meetings to fix prices); for turbine generators (publication of a pricing formula for the components of such generators); for switchgear³ (beginning with book prices, the sealed-bids system is used); for power switchgear equipment (low bids are rotated among the collusive firms by the phases of the moon).⁴ Perhaps, the sealed-bids method was the most interesting of all. It seemed to draw the most attention at the various hearings on EMI's pricing behavior.

What does create reasonable grounds for an economist to look into accusations of collusive price fixing against EMI is the fact that, although costs (not just transportation costs)

¹Fuller, op. cit., p. 212.

²A power transformer is an electrical device for changing the ratio of current to voltage in alternating current systems, while keeping power substantially constant. A transformer often consists of two coils wound on the same iron core. See Funk & Wagnalls Standard College Dictionary, (1968) ed., s.v. "transformer."

³Switchgear is "the aggregate of switching facilities for a power station or [for] a transforming station." See Webster's Third New International Dictionary (1966) ed., s.v. "switchgear."

⁴F. M. Scherer.(1980). Industrial Market Structure and Economic Performance, 2 ed. Chicago: Rand McNally College Publishing Company, pp. 170-71.

differed by location among the firms, the bids other than the low bid were still identical. Moreover, any claim of purely coincidental pricing would not be convincing since the examples earlier cited were not isolated cases.¹ However, it would be a mistake of course for this study to leap from reasonable grounds for levelling accusations of collusive behavior to a premature conclusion that the accusations and subsequent convictions in the courts will hold under econometric scrutiny.

In addressing this issue, Iwata (1974) goes as far as to call for empirical determination of whether "incidental" cooperation exists in a given oligopolistic industry before any attempt is made to determine collusive behavior. Iwata also claims that researchers can never be reasonably sure that a given conjectural variations (CV) value really reflects the degree of collusion reported.

Perhaps, a solution to Iwata's concerns lies in the need for a redefinition of the economic meaning of collusion so that the term covers all significant oligopolistic cooperation, incidental or willful, tacit or overt.² Then leave it to the courts to judge whether the conduct complained of is willful. Until such a convention exists, I.O. economics would be well served, in this author's view, by those who, after careful preparation and analysis, let the results speak for themselves while keeping in mind that more than an econometric measure is required to establish the presence of collusion in an industry.

There is indeed a missing link. In regard to EMI, the missing link is being forged by the presentation in this Section of unbiased theoretical, legal and historical facts affecting this industry's case over the period 1956-62. For example, one such theoretical fact comes from

¹Fuller, op. cit., pp. 9-10.

²Note that The Dictionary of Modern Economics (1981) defines collusion as follows: "Agreement between firms to co-operate [sic] in order to avoid mutually damaging rivalry. The means of achieving such cooperation range from informal or tacit agreement, arising from the pooling of information for instance, to formal arrangements within cartel organizations where sanctions are imposed on defectors." s.v. "Collusion."

Krishna et al. (1989) who argue that the ability of firms in an industry to maintain PCMs is a clue to the likely presence of collusion in that industry.

But even stronger than this clue is the fact that it soon became public knowledge, as Fuller states, that the executives of GE and Wh were among 45 leading executives of EMI who admitted holding surreptitious¹ meetings to allocate awards of contracts at fixed prices. (p. 13). Even so, admission of guilt should be nothing more to an I.O. analyst than part of the missing link. For admission of guilt does not constitute an empirical finding of collusion in EMI. The executives who pleaded guilty could have done so as loyal company men to protect the trade secrets of the firms involved. It is known that some executives as defendants find it more expedient to plead guilty or to enter nolo contendere pleas than to have the affairs of the firms exposed to rivals, and to the public from whom they seek goodwill. When the usual absence of scientific objectivity in a typical courtroom is also taken into account, then it becomes clear why an econometric study of EMI's pricing behavior is both important and needed to complete the authenticity of the record.²

As Fuller's story continues to unfold, one learns that three indictments of firms and executives of EMI were handed down in Philadelphia on February 16, 1960. The indictments involved power switchgear assemblies, oil and air circuit breakers and low voltage power circuit breakers.³ (p. 61). The firms first indicted included GE, Wh, A-C, I-T-E⁴ and Federal Pacific which were accused of price fixing and of restricting the force of competition as from 1956. As Fuller observes, the Big Two were far from being unaccustomed to

¹The GE and Wh executives had even gone to the extent of using code names to identify themselves.

²Incidentally, it is remarkable how often economic conclusions have been at variance with decisions of the Courts.

³Circuit breakers are switches or relays for interrupting "a circuit under specified or abnormal conditions of current flow." See Funk & Wagnalls, op. cit., s.v. "circuit breaker."

⁴A-C, considered No.3 in the industry at that time, was much smaller than GE or Wh. I-T-E specialized in manufacturing circuit breakers.

defending themselves against antitrust actions. For example, over the period 1910-58, Wh had been involved in 17 and GE in "a barrage" of antitrust actions. (pp. 195, 201).

This probably explains why, even during the period of the Philadelphia criminal sessions, EMI firms continued to hold illegal clandestine meetings in the interest of maintaining or perhaps enhancing market power and performance. The questions that still arise are: What is it that could have impelled the firms' executives to persist in holding price-fixing meetings even in the face of possible imprisonment? Why did the executives not abandon group meetings knowing that law enforcement agencies had become aware of the practice?

Perhaps, the answers lie in the theory of channels of communication which may be quantified by:

$$\text{COC} \geq N(N-1)/2 \quad (1.1.1)$$

where COC means channels of communication and N is the number of firm representatives involved in the price-fixing schemes. If the dominant duopoly, GE and Wh, had ignored all other firms in the industry and each had been represented by only one person, then only one channel of communication would have been necessary. There would have been no need for meetings in hotels to bring about a meeting of the minds.

But, 29 firms often met.¹ From (1.1.1), the firms would have needed at least 406 channels of communication² in the absence of hotel-type meetings or of some equally effective scheme. This author therefore concludes that, given the strength of the profit motive in U.S. markets, especially in tight oligopoly, then Fuller's story of the great U.S.

¹Fuller, op. cit., p. 17. The 29 firms involved so dominated production of the goods mentioned in the indictments that these firms could have ignored the fringe with impunity. Indeed, for the heavy machinery and most highly priced goods, GE and Wh probably could have ignored all other firms, but the Big Two chose not to do so.

²Plugging 29 into (1.1.1) yields 406. When, as Scherer (1980) points out, "products are heterogeneously differentiated, [as is the case with EMI goods], the terms of rivalry become multidimensional, and the coordination problem grows in complexity by leaps and bounds." (p. 200).

pricing conspiracy defined a scenario yet in its course. Group meetings had become the way of efficiently charting the course of business performance.

One year after the Philadelphia first indictments, seven executives named in the indictments began serving prison terms in Montgomery County jail, Alabama, while many EMI firms pleaded guilty to the criminal offense of violating the Sherman Antitrust Act, 1890.¹ The undisputed leaders of the industry and of the "Great Electrical Conspiracy", GE and Wh, were, to Fuller, "the two biggest giants in the business--a cartel [which] flatly prevented any competition and saw to it that the public suffered while the cartel profited." (p. 18).

Section 1 of the Sherman Act dealt with price fixing which is of special interest here. The Act also dealt with monopolization.² Regarding price fixing, the Courts applied the rule of reason to cases dealing with economies of scale. Since the Trenton Potteries et al. case (1927), price fixing had been deemed per se illegal provided that there existed a contract or a conspiracy and evidence of content. But some economists are concerned that the Courts have not properly distinguished between conscious parallelism and willful schemes of price fixing. The dictum regarding monopolization was that monopolization and not monopoly was an offense.³

Section 1 also prohibited contracts, combinations, and conspiracies in restraint of trade. Violators were subject to imprisonment or fines or both. Section 2 deemed as illegal "monopolization, attempts to monopolize, and combinations or conspiracies to monopolize" interstate or international commerce.⁴

¹Named for its sponsor, Senator John Sherman of Ohio, the Sherman Antitrust Bill was signed into law by President Benjamin Harrison on July 2, 1890, giving the U.S. its first antitrust law. The Act was however scarcely reflective of the original form of Sherman's bill.

²The Courts had applied the per se rule to assert that mere size was not an offense.

³Scherer (1980), op. cit., p. 528.

⁴Ibid., p. 494.

As Scherer (1980) describes it, EMI's "massive conspiracy" warranted 2,333 or over one-third of the 6,500 triple damage antitrust suits of the 1960s.(p.503). GE failed in 1961 by just 1.38 percentage points to qualify as the dominant producer of circuit breakers and by 1.28, 9.30 and 0.83 in 1959, 1961 and 1962, respectively, in regard to switchgear apparatus, if Scherer's (1980) lower bound of four-firm concentration ratio (C_4) equals 40 is adopted as the individual firm's criterion.¹ But GE was dominant in other goods. When the sentences were handed down in 1961, only three U.S. industrial corporations were larger than GE.² Important merger activity in EMI, which ended as the nineteenth century came to a close, had resulted in GE's leadership of EMI and in the dominance of GE and Wh combined in the industry. No other EMI firm could mount even a token challenge to the size of the Big Two.³ In the major markets of EMI, the Big Two had appeared to have achieved oligopoly power. Scherer (1980) suggests that a fair assumption would be that an industry achieves incipient oligopoly power if that industry's C_4 ratio exceeds 40 percent. Indeed, EMI's C_2 ratio exceeded 40 percent. Scherer further suggests that the Big Two belonged to "something in excess of half of all American manufacturing industry [which] can be categorized as oligopolistic." (p. 67).

¹Scherer (1980), op. cit., p. 117.

²Fuller, op. cit., p. 189.

³Igor M. Tomic.(1985). "Electrical Equipment Purchasing Patterns of Utilities and Commercial Companies as Affected by Collusion Among Equipment Manufacturers: An Aspect of Rate-Base Padding by Electrical Utilities." Dissertation Paper: City University of New York, p. 46.

For example, in 1959, steam turbines¹ generated over 80% of U.S. electricity. The C_4 ratio² of the manufacturers of these turbines was 75, three of the firms being GE, Wh and A-C. With regard to current carrier equipment which involved sealed bids, GE and Wh were the only manufacturers in 1959. In the market for large turbogenerators, GE, Wh and A-C were the only manufacturers, thus having a C_3 ratio of 100%.³ GE emerged as the dominant price leader in book prices for turbogenerators as well as the covert collusive price leader of the Big Two.⁴

I.O. economists sometimes use the rate of return (ROR) to determine firm dominance. This is not necessary here since, by consensus, it is clear that GE was the leading firm of EMI over the period 1956-62 and that the Big Two was a dominant duopoly of EMI.⁵ The expectation is that it will be determined that the collusive posture of GE and Wh, with GE as the dominant firm, led to higher prices in EMI. This is because, in general, prices and thus profits, *ceteris paribus*, are expected to rise in concentration. But, as Scherer (1980) explains, this should not be interpreted as a causal relationship between concentration and profits since both concentration and profits are functions of innovative and managerial efficiency. (p. 288).

¹Steam turbines are "hydraulic motors consisting of one or more rotary units, mounted on a shaft and provided with a series of curved vanes actuated by the impulse of steam...." See Funk and Wagnalls, op. cit., s.v. "turbine."

²Four digit SIC values often undervalue concentration ratios because four-digit industries are usually too broadly defined. Thus, if warranted, some subjective judgment should be used in adjusting for concomitant biases. Fortunately, this problem does not arise in this study since the chosen categories are suitably defined. See Scherer (1980), op. cit., p. 275.

³Fuller, op. cit., pp. 40, 22.

⁴Scherer (1980), op. cit., pp. 176-77.

⁵The rate of return (ROR) may be defined as $ROR = a_0 + a_1 s_1 + a_2 C_4 + a_3 (A/S) + a_4 V$ where s_1 is market share, C_4 the four-firm concentration ratio, A/S the advertising/sales ratio, V the value of assets, a_3 measures the height of entry barriers and a_4 corrects for capital intensity. Simultaneity exists with s_1 and C_4 correlated, but ROR is regarded as a good measure in intraindustry research. It may also be defined as $q^T = 1/(e_s - e_s Le_1)$ where q^T is Tobin's q , $e_s = AC/MC$ is elasticity of the cost function, and Le_1 is firm i 's Lerner index.

In fact, higher prices did follow GE's rise to dominance in EMI. In September 1959, representatives of the Senate Antitrust and Monopoly Subcommittee learned from the Director of the Division of Materials for TVA that TVA had sought foreign quotations on large power transformers because domestic prices had been too high. TVA had concluded that domestic prices had risen more rapidly than had been justified by increases in the cost of labor and materials.¹ In the case of turbine generators, evidence before the Courts stated that the collusive behavior in EMI had led to a 21% increase in prices.²

It should be noted, however, that some I.O. economists are skeptical of any attempt to link higher prices to collusive behavior without the benefit of sound empirical evidence. For example, Greer (1980) contends that the goal of collusion is "frequently" the attainment of "price stabilization" and not the maintenance of excessive administered prices. Furthermore, Greer suggests that the incidence of collusive activity apparently varies indirectly with the business cycle, but admits that this relationship is weak. (p. 283).

The question of higher prices in EMI will be further discussed in Section 2.3. But, as far as pricing power is concerned, both GE and Wh as a duopoly had set the tone for EMI.

To argue that GE and Wh exercised power over price in EMI is tantamount to maintaining that the Big Two had erected significant entry barriers to preclude entry into the market-power sector from the ranks of the competitive fringe. Supporting this view, Scherer (1980) argues that the existence of monopoly or of oligopoly essentially depends upon effective barriers to entry. Otherwise, monopolists or oligopolists would be powerless over the determination of prices. (p. 11).

Some idea of the existence of entry barriers in EMI may be confirmed by observing selected concentration ratios for EMI in Table 1.1.1 which presents statistics for the combined years of 1958 and 1963. Notice, for example, that C_{50} ratios of 80% or more are experienced

¹Fuller, op. cit., p. 43.

²Greer, op. cit., p. 305.

Table 1.1.1. Electrical Machinery Industry
Frequency Distribution of C_4 , C_8 , C_{20} , and C_{50} Ratios
EMI Products: 1958 and 1963 Combined

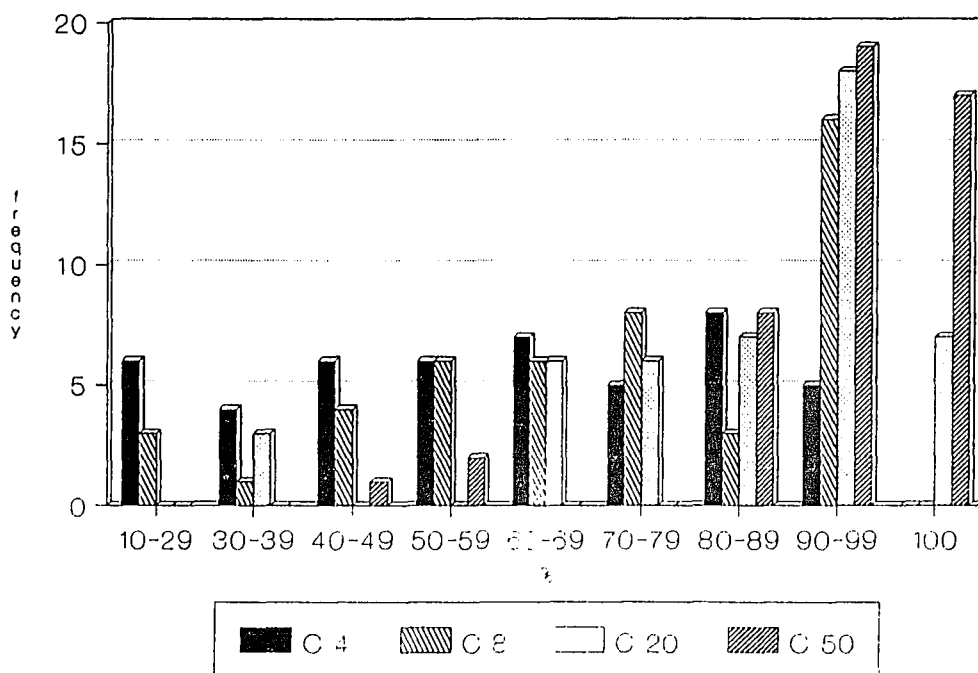
Value of Concentration Ratios (%)	Frequency			
	C_4	C_8	C_{20}	C_{50}
100	0	0	7	17
90 - 99	5	16	18	19
80 - 89	8	3	7	8
70 - 79	5	8	6	0
60 - 69	7	6	6	0
50 - 59	6	6	0	2
40 - 49	6	4	0	1
30 - 39	4	1	3	0
10 - 29	6	3	0	0
Total	47	47	47	47

SIC Categories: 3612 - 13; 3621 - 24; 3629; 3631 - 36; 3639; 3641 - 44; 3651 - 52;
3661 - 62; 3671 - 74; 3679; 3691 - 94; 3699.

Source: Adapted from U.S. Bureau of the Census (1963), Table 2.

Note: Table 1.1.1 is reflected in Chart 1.1.1 below.

Chart 1.1.1. EMI
Frequency Distribution



EMI products: 1958 and 1963 combined

in EMI for 94% of the 47 occurrences. Also, 100% concentration values occur as many as 17 times at the C_{50} level and seven times at the C_{20} level. For concentration values of 40% or more,¹ the C_4 frequency is 37 which is 79% of the 47 occurrences. But, as Scherer (1980) points out, it should be kept in minds that concentration ratios may overestimate or underestimate the actual level of monopoly power. On the one hand, overestimates occur when nonsubstitutes are included in market definitions, when markets are not national, when product heterogeneity plays an important role, or when a firm's unique characteristics are important ingredients of that firm's success. On the other hand, underestimates occur when industry definitions exclude substitutes or when competition from imports is important.

EMI, as represented by GE and Wh, falls into none of Scherer's categories. There is no concern by this author that the concentration ratios convey a distorted picture of EMI. In any case, only "some idea" of or a clue to the existence of entry barriers in EMI is being presented at this point. Also, the high concentration ratios alone do not constitute evidence of collusive behavior in EMI.² But these ratios certainly sound the alarm.

Regarding market power, Porter's (1980) conditions for a "supplier group" to be powerful in an industry include the following: (1) A few firms are dominant and more concentrated than the buyers; (2) the group's products do not face substitutes from outside the industry; (3) the group's products are important inputs to the industry's buyers; (4) the group's products are differentiated. These conditions apply to EMI products listed in Table 1.1.2. The products include expensive machinery such as turbine generators, industrial controls, power transformers, power switchgear assemblies and switching equipment, and distribution transformers. It is from this short list in Table 1.1.3 that representative goods for econometric

¹Scherer (1980), op. cit., p. 117. Scherer's definition of a national oligopoly as an industry having $C_4 > 40$ is adopted here. In terms of EMI, a list of goods requiring such structures is given in Table 1.1.2 which follows.

²A. K. Dasgupta and J. E. Stiglitz.(1980). "Industrial Structure and the Nature of Innovative Activity." The Economic Journal 90: 266-93.

**Table 1.1.2. Electrical Machinery Industry
Goods Requiring Oligopolistic National
Industry Structures: 1958, 1963
($C_4 > 40$)**

<u>SIC</u> <u>Code</u>	<u>Goods</u>	<u>C₄ Ratios (%)</u>	
		<u>1958</u>	<u>1963</u>
3612*	Transformers	71	68
3613*	Switchgear & switchboards	a	51
3621*	Motor generators	47	50
3622*	Industrial controls	a	56
3624*	Carbon and graphite products	87	83
3623	Electric welding apparatus	b	41
3631	Household cooking equipment	a	51
3632	Household refrigerators	a	74
3633	Household laundry equipment	71	78
3634	Electrical housewares & fans	a	41
3635	Household vacuum cleaners	a	81
3639	Household appliances	a	41
3641	Electric lamps	92	92
3651	Radio & TV receiving sets	a	41
3652	Phonograph records	76	69
3661	Telephone; telegraph apparatus	92	92
3671	Electron tubes, receiving type	a	87
3672	Cathode ray picture tubes	a	91
3673	Electron tubes, transmitting	a	52
3674	Semiconductors	a	46
3691	Storage batteries	64	59
3692	Primary batteries, dry and wet	84	89
3693	X-ray apparatus and tubes	63	67
3694	Engine electrical equipment	66	69

Source: Adapted from U.S. Bureau of the Census (1963) data, Table 2.

Note: a = value not given; b = given value < 40%; * means goods prominent in the conspiracy cases. Also, see Scherer (1980), op. cit., pp. 117, 170-76.

Table 1.1.3. Annual Sales and Market Share (%) for Selected Products of (a) Indicted Firms and (b) Conspirators of EMI

Product	(1) SIC (1963) Code	(2) Annual Sales (\$m)	(3) Number of Firms Indicted	(4) Number of Conspirators	(5) Mkt. Share of (a)	(6) Mkt. Share of (b)
Turbine generators	3621	\$400	3	6	95	100
Industrial controls	3622	262	9	9	75	75
Power transformers	3612	210	6	6	100	100
Power switchgear assemblies	3613	125	5	8	100	100
Power switching equipment	3613	35	8	15	90	95
Distribution transformers	3612	220	8	8	96	96

 Source: Adapted from Douglas F. Greer.(1980). Industrial Organization and Public Policy. New York: Macmillan Publishing Col, Inc., Table 12-3, p. 303.

analysis will be chosen for this study.

In late 1958, the apparent market power of the Big Two was reflected in the agreement reached by these firms with A-C and I-T-E to share EMI's \$125 million-a-year power switchgear assembly market. The C_4 and C_2 ratios of 100% and 80%, respectively, were as follows:

<u>Firm</u>	<u>C_4 (%)</u>	<u>C_2 (%)</u>
GE	42.0	
Wh	38.0	80.0
A-C	11.0	
I-T-E	<u>9.0</u>	<u>—</u>
	<u>100.0</u>	<u>80.0</u>

The Big Two's market share for this good is four times that of A-C and I-T-E combined--an effective duopoly at least in power switchgear assemblies.¹ This was not an isolated case.

Discussions involving market power usually raise questions about price discrimination. This is because classical theory limits the ability to price discriminate to the presence of a significant degree of monopoly power. The greater the degree of monopoly power, the greater will be the ability to price discriminate,² given the other necessary conditions for effective price discrimination. Oligopoly is generally excluded, however, because market segmentation is an essential element of successful price discrimination and oligopolists generally find it inappropriate to segment the markets into groups of customers.³

However, some modern theorists and empiricists question this exclusion of oligopoly. For example, Slade (1986) identifies product differences as the basis of market segmentation in the Vancouver, British Columbia retail-gasoline market, a differentiated oligopoly. In this study, an attempt will be made to determine whether GE and Wh as a duopoly had a tendency

¹Fuller, op. cit., pp. 34, 64.

²Timothy Bresnahan.(1989). "Empirical Studies of Industries with market Power." Forthcoming in Handbook of Industrial Organization by R. Schmalensee and R. Willig, eds.

³Michael Waterson.(1984). Economic Theory of the Industry. Cambridge: Cambridge University Press, p. 47.

over the period under review to price discriminate between large-order and small-order customers.

So, given the assumption here that differentiated oligopolies can and do price discriminate, then collusive behavior, which confers market power on cartels, becomes essential to the price discriminator. But this does not mean that a desire to price discriminate necessarily plays a major role in the formation of collusive behavior among oligopolists. The converse is far more plausible. In fact, oligopolists, taking a long-term view of industry, usually become concerned that noncooperative behavior and entry might reduce market price to the level of marginal costs and even to lower levels during periods of price wars. Stigler (1964) argues that such long-term views are ingredients of the glue that keeps collusive agreements from falling apart.

Nevertheless, problems of collusion stability do arise. The expectation for the Big Two is that, with GE the price leader, the price conjectural variations (PCVs) to be estimated in Section 3.2 will reflect periods of successful collusion and of significant competitive behavior over the period under review.

Over time, GE's relative size significantly varied. For example, GE was the sixteenth largest of all U.S. corporations in 1909, the fourth largest in 1961 and the tenth largest in 1977. No other EMI firm qualified for the short lists of large relative size.¹ Although GE's leadership of EMI over the years remains undisputed, yet opinions of the type of leadership GE exerted are not unanimous. For example, Greer (1980) argues that GE was a barometric² rather than a dominant leader in transactions prices. Figure 1.1.2 shows GE's transaction prices (panel (a)) relative to average industry transaction prices (panel (b)). GE's prices slightly exceed rival prices during recessions and periods of falling prices, and conversely

¹Scherer (1980), *op. cit.*, p. 55; Fuller, *op. cit.*, p. 189.

²A barometric leader is defined by Greer as nothing more than "the first firm to announce formal price revisions in list or book prices to reflect prevailing, realized or transactions prices." p. 275.

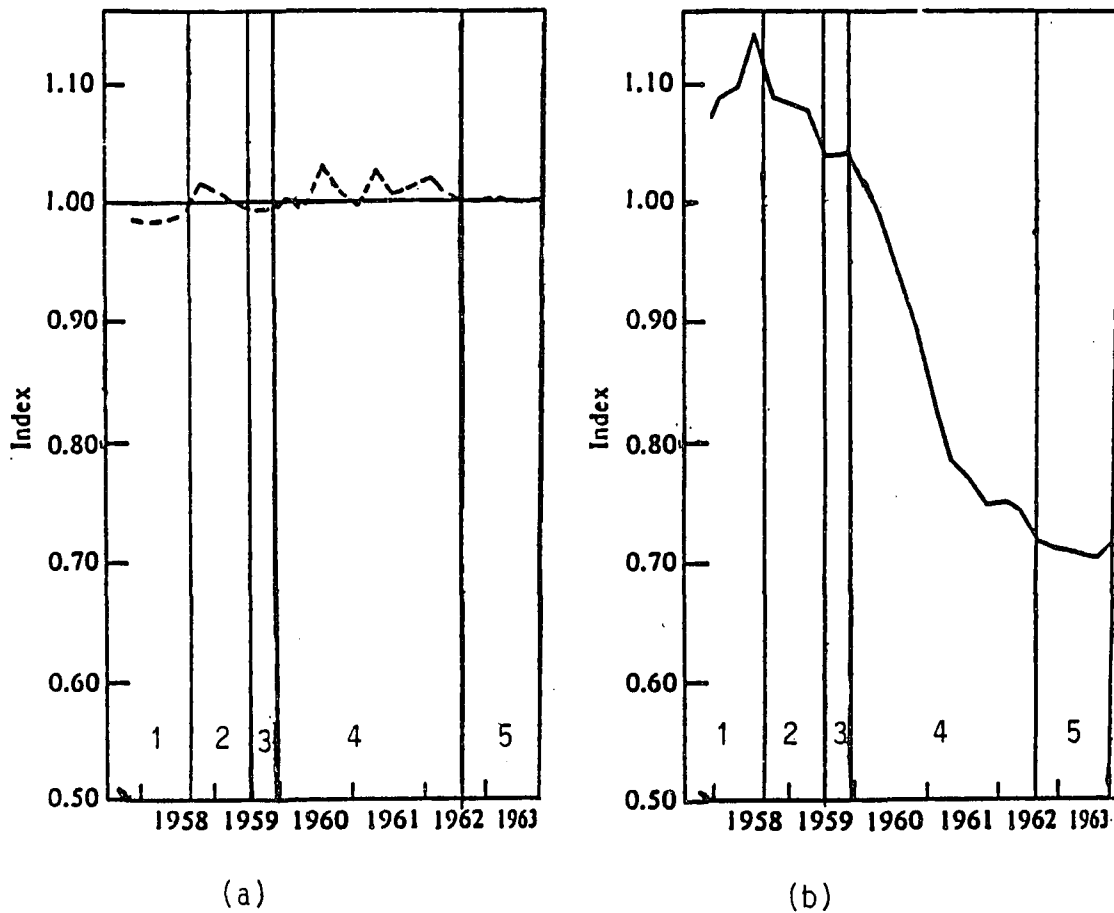


Figure 1.1.2. Transaction prices of turbine generators.

(a) GE's price as a ratio of Average EMI price, 1958-63.

(b) Index of Average EMI price, 1958-63.

Trends: (1) GEP < EMIP, 1958; (2) GEP > EMIP, 1958-59;

(3) GEP < EMIP, 1959; (4) GEP > EMIP, 1959-62;

(5) GEP = EMIP, 1962-63; where P means price.

Source: Adapted from Ralph G. M. Sultan.(1974). Pricing in the Electrical Oligopoly. Vol.1. Cambridge, Mass.: Harvard University Press, p. 282.

during booms and periods of rising prices in EMI. Greer's interpretation of this pricing behavior¹ is that GE was merely intent on maintaining a 60% market share and not on exercising dominant price leadership. (p. 275).

Overall, GE was in one sense a leader of Markham's stripe--dominating a tight oligopoly, selling close substitutes of relatively low demand elasticity, having cost curves similar to those of rival Wh's, and insulated with entry barriers from the competitive fringe.² Because of GE's established position as the price leader of EMI's duopoly over the period 1956-62, the kink disappeared from the duopoly's demand curve! For it is a matter of record that GE expected Wh to follow all of its price changes, up or down, in all markets.³

Yet, in another sense, GE's price leadership was not Markham. This is so since electrical machinery is a heterogeneous good. Markham (December 1951) saw price leadership as a meaningful concept only for homogeneous goods. But Scherer (1980) disputes this by pointing out that, beginning from the 1950s, the leaders of the U.S. automobile industry have clearly demonstrated a price leader-follower behavior, (p. 180), the inference being that automobiles are heterogeneous goods.

It is therefore important to note that a clear understanding of an industry's conduct critically depends upon a clear understanding of that industry's structure and of the social and economic climate in which the industry exists. GE was created in 1892 by the Thomson-Houston and Edison General Electric merger which formed "a virtual duopoly (with

¹Greer's definitions of two other types of leadership roles are: (1) dominant firm leadership (e.g., IBM) where the dominant firm controls "50 - 95% of the market" while other firms "will simply, if sheepishly" follow; (2) collusive price leadership (e.g., C₄ in aluminum) where the leader controls "20 -30% of the market." (pp. 272-73). Notice that Greer's lower bound of 50% for dominant price leadership is 10 percentage points higher than Scherer's (1980) lower bound.

²Jesse W. Markham.(December 1951). "The Nature and Significance of Price Leadership." American Economic Review 41: 891-905.

³Scherer (1980), op. cit., p. 184.

Westinghouse) in many lines of electrical equipment manufacturing."¹ The creators of GE were really pursuing monopoly power, but were forced to share oligopoly power with Wh.²

GE and Wh are here treated as classical firms, each engaged in joint input production.³ The major inputs are labor (L), capital (K) and raw materials (M). It is reasonable to assume that the two EMI firms faced the same market boundaries, using similar technology in producing electrical machinery.⁴

In terms of the 1963 international composite rankings of "average market concentration in manufacturing," EMI ranked seventh among the 17 leading industries of 12 major countries. For the U.S. alone, EMI ranked fifth, a net gain of three places since 1929.⁵

Notwithstanding the Amish, EMI is vital to the U.S. economy. It is not only a significant sector of all U.S. manufacturing, but also the producer of the lifeblood of all industrial and utility activity in the economy. The machinery EMI produces is a combination of shopping and specialty goods which are durable, heterogeneous and mostly high-priced. This perhaps explains why buyers requested EMI firms to submit sealed bids for supply contracts. A sealed-bid system is tantamount to shopping before making a purchase.⁶

¹Scherer (1980), op. cit., p. 121.

²Ibid., p. 129.

³Armen A. Alchian and Harold Demsetz.(1972). "Production, Information Costs, and Economic Organization." American Economic Review: 777-95. By "joint inputs" these authors mean "Team productive activity [where]...a union, or joint use, of inputs yields a larger output than the sum of the products of the separately used inputs." (p. 794).

⁴Compare: Richard Schmalensee.(April 1987). "Inter-Industry Studies of Structure and Performance." rev. version, forthcoming Handbook, p. 23 of draft.

⁵Greer, op. cit., p. 131. The 11 foreign countries are: France, West Germany and Italy (with lower weighted concentration ratios than those for the U.S.); Japan, the Netherlands and the United Kingdom (with slightly higher ratios than those for the U.S.); Belgium, Canada, Sweden, Switzerland and Yugoslavia (with ratios about 5% higher than those for the U.S.).

⁶Scherer (1980), op. cit., p. 5.

Dominance in the industry naturally raises questions about collusion which is an effective way of exercising market control, at least in the short run. In this study, the focus is on price fixing as the vehicle of collusive behavior. Recall that the Sherman Act considers any price-fixing agreements among competing firms per se illegal. The Act also deems as per se illegal any firm behavior observed as having the effect of a direct limit on competitive forces.¹

To I.O. economists, collusive behavior includes any price-fixing schemes that impedes the forces of competition. Thus, this study of collusion in EMI should econometrically determine whether EMI can be shown to have engaged in collusive pricing behavior over the period 1956-62. Moreover, the Courts' records of identical sealed bids in EMI, however intriguing, are treated here only as one of the clues to and not as proof of the existence of collusion in the industry. The determination of collusive pricing in EMI is assigned to Sections 3.2 and 3.3 where econometric estimation and testing will be done.

Put differently, this author points with Krishna et al. (1989) to the importance of developing a "flexible" framework which will not "dictate the direction of the results." This is essential "since the optimal policy resulting from one model can differ dramatically from that of another model." This important caveat, however, does not proscribe the formation of reasonable a priori notions about market structure and conduct in EMI. In fact, EMI is here assumed to be a duopoly, consisting of GE and Wh, which practiced collusive pricing behavior over the period 1956-62.² These assumptions have already been shown to be reasonable.

The choice of price as the strategic variable presupposes the existence of market power so that the duopoly's PCMs are expected to be greater than zero. If market power here

¹Scherer (1980), op. cit., p. 497.

²For example, see: Elie Appelbaum.(1982). "The Estimation of the Degree of Oligopoly Power." Journal of Econometrics 19: 283-94; and Fuller, op. cit.

amounts to collusive behavior, then the associated problems of collusive pricing and market cheating arise.

Collusive pricing and market cheating are difficult to detect. As Fuller observes: "Only a major break brought the details of the electrical conspiracies to the front." (p. 218). The assumption that the two firms were symmetric¹ implies that price coordination was facilitated and that monopoly price could have been chosen for price collusion.

Nevertheless, oligopolists and monopolists do not have the same options. For example, a profit-maximizing monopolist simultaneously determines output and price, given costs and demands. But oligopolists attempting joint profit maximization find it almost impossible to exercise that option in the absence of overt or covert collusion. Even then, oligopolists still find it difficult to achieve joint determination of output and price. The popular alternative, according to Scherer (1980), is where oligopolistic colluders use price as the main collusive strategy while relegating output determination to the level of demand evoked by the chosen pricing policy. Meanwhile, the colluders agree to refrain from any output decisions for fear that such decisions would destabilize equilibrium price. The chosen policy might be in the form of overt collusion, price leadership, rough but practical price estimates, or "focal points."² Output policies are abandoned if PCMs are greater than zero, and are not reactivated unless price falls to the level of marginal cost. This is because output policies, given PCMs greater than zero, would destabilize the jointly-fixed price.³

¹The concept of symmetry here means that GE and Wh expand along parallel marginal-cost paths. See Appelbaum (1982), *op. cit.*

²Introduced by Schelling (1960), a focal-points theory of pricing is where established industry-wide round numbers or simple rules are used for price reductions by firms. The idea behind this system is that the use of focal points by a given firm signals that that firm is not engaging in the undesirable practice of price shaving. A focal point is such that there is no tendency for change once it has been reached. The concept is similar to that of a unique equilibrium since it would be natural for firms to resist any further attempt to change price. See Scherer (1980), *op. cit.*, pp. 190-93.

³Scherer (1980), *op. cit.*, p. 193.

Thus, the expectation here is that measures of collusion theoretically developed in Sections 2.2 and 2.3, and estimated in Section 3.2, will not reflect perfect price collusion since there is no basis for assuming that GE and Wh could have attained the market posture of a pure monopolist. Three reasons for this immediately come to mind, and will be discussed in turn. As Tirole (1989) points out, one reason is that violations of collusive agreements are possible and violators always have an opportunity to renegotiate. This weakens threats of punishment, increases the incentive to undercut the collusive price and increases collusive instability. (p. 253).

A second reason is that, at monopoly price, firms would have strong incentives secretly to shade prices in an attempt to increase individual profits. Thus, the nearer to monopoly price the collusive price is, the greater is the expectation that collusive price agreements will collapse. So collusive groups often face problems of: (1) attaining the equilibrium that would yield monopoly profits; (2) sharing the gains from collusion; (3) anticipating and detecting violations; and (4) maintaining or increasing the group's market share.¹

Stigler (1964) finds that price cutting within a collusive group becomes more likely as: (1) the number of new buyers and the number of new sellers increase; (2) the probability of repeat purchasing falls; and (3) the pool of all buyers in the market becomes smaller. These conditions make it more probable for a cheater to gain at the expense of other firms. One such episode for EMI was the "white sale" or the EMI price war of 1955 when the industry's prices for heavy electrical equipment fell as much as 60% off book value.²

Tirole (1989) believes that, in oligopoly markets, price wars are inevitable once other firms know that at least one firm has previously cut prices. What Tirole refers to as a

¹D. K. Osborne.(1976). "Cartel Problems." American Economic Review 66: 835-44.

²Fuller, op. cit., p. 52. Incidentally, GE performed well despite the sharp decline in prices.

'bootstrap' effect occurs in the market and gathers momentum as time passes. This most likely explains A-C's initiative in cutting prices in the steam turbine generators market during EMI's recession of 1960-61. A-C's price-cutting initiative followed a substantial drop in capacity use of steam turbine generators. Prices plunged to almost ruinous lows. Strangely enough, this plunge was led, not by GE or by Wh, but by A-C, a relatively small firm being followed by the two "giants."¹

It is also reasonable to conclude that, in the absence of price cooperation, sellers have an incentive to cheat if demand elasticities are significantly greater than one. Thus demand elasticities at the firm level along with PCM changes should be scrutinized for evidence of cheating. Demand elasticities sufficiently greater than one accompanied by rising profits would indicate that cheating may have occurred.

Stigler (1964) provides a model for detecting cheating, but some critics find it open to Type II errors.² However, Waterson (1984) believes that "the basic factors Stigler found relevant retain their importance...." But merely detecting cheating will not do. It is important that the gains from cheating be wiped out if cheating is to be discouraged. With quantity as the strategic variable, a reversion from collusive to Cournot behavior is one means of wiping out gains from cheating. The parallel with price as the strategic variable (the case here) is a reversion from collusive to Bertrand behavior.³

The third reason why perfect collusion seems unattainable in EMI is that, at a collusive monopoly price, individual producers will also have an incentive to increase output.

¹Sultan, op. cit., pp. 151, 211. Also return to Figure 1.1.1 and notice what occurs when there is a large enough drop in the level of capacity.

²That is, open to the acceptance of false hypotheses that cheating actually occurred.

³Robert H. Porter.(1983). "A Study of Cartel Stability: The Joint Executive Committee, 1880-1886." The Bell Journal of Economics 14, 2: 301-14; G. J. Stigler.(1964). "A Theory of Oligopoly." Journal of Political Economy 72: 44-61.

This could result in output levels beyond the level at which the fixed price could be sustained.¹

Overall, the expectation is that collusive behavior between GE and Wh will be empirically supported. But, these expectations are tempered with caution. In the words of Scherer (1980):

...it would be misleading to conclude that we cannot develop theories predicting oligopolistic conduct and performance with tolerable precision....We must not expect too much, however. The most that can be hoped for is a kind of soft determination: predictions correct on average, but subject to occasionally substantial errors. (p. 152).

Since the machinery involved in EMI changed slowly over time and generally faced stable market demand, then, as Scherer (1980) suggests, the firms are expected to opt for maximization of joint profits--the most likely but of course not the only course open to the firms. This is shown in the collusive model of Section 2.1. The firms will pursue the basic goal of achieving market power.

Market power may be defined as the ability to increase and to maintain profitable PCMs. The key to success is stable collusive behavior, ceteris paribus, given the characteristics of the good sold and of economic conditions. For example, homogeneous goods are more promotive of collusion than heterogeneous goods, and recessions are more conducive to collusive behavior than booms.² Oligopolists are aware of these things as the firms strive to maximize joint profits. Even so, joint-profit maximization is not a matter of course. For oligopolists encounter serious difficulties in trying to maintain high price-cost margins. Disagreements over the choice of industry price, the degree of acceptable product differentiation, cheating, entry and threats of entry, unmet fixed costs or just the idiosyncracies of human nature limit the oligopolists' freedom to maintain high PCMs.³

¹Scherer (1980), op. cit., pp. 171-72.

²Ibid, p. 176.

³Ibid., p. 266.

Led by Bain (1951), scores of papers, some supportive and some not, have been devoted to the idea that tight oligopoly is expected to have positive PCMs. It would be interesting to find out whether the Big Two were able to maintain profitable PCMs over the entire period under review.

In terms of welfare effects, the criteria in this study should and will be the expected levels of price and production in the absence of collusive behavior. It should be noted that the criteria should not be based on a competitive model because EMI goods are assumed to be heterogeneous. Producer surplus of GE and Wh as a duopoly should be high relative to the surplus that the firms would earn as monopolistic competitors. But this would depend on whether GE and Wh were able to adhere to interdependence in pricing and group-profit policies, and on whether government policy exerted a negative influence on the duopoly's performance. Agreeing with Chamberlin (1948) and Scherer (1980), this author sees the welfare question as the quantitative problem: "how much purity [a reference to pure competition] to sacrifice in order to maximize social welfare?"¹

Clearly, the appropriate welfare criteria cannot be the greatest possible quantities of EMI goods, as would be the case under a perfectly competitive structure. The criterion should be the satisfaction of the buyers' wants in EMI's technologically maturing markets. More and more, buyers perceive increments in the elements of product differentiation as increments to social welfare and are willing to trade off some quantity for more variety. The trick is to find the optimal level of variety if the social welfare increments are to be measured with reasonable accuracy. Furthermore, as Gisser (1986), Worcester (1975) and Harberger (1974) strongly suggest, it would be more appropriate within oligopoly theory to derive the deadweight loss at the firm level by using the more elastic demand curve facing GE and Wh as individual firms instead of the less elastic duopoly demand curve. This is a challenging goal for future research, a goal which is not within the purview of this study.

¹Scherer (1980), op. cit., p. 24.

1.2 Purpose and Summary

This paper properly belongs to the category of the new empirical industrial organization (NEIO) since it is essentially an econometric study of the electrical machinery industry. The I.O. approach to studying such an industry traditionally calls for an exposition rich in "quantitative and institutional detail." Indeed, the I.O. analyst generally moves in the opposite direction to that of the pure microeconomic theorist by trading off "elegance" for "explanatory power."¹ But the NEIO economist goes a step further by emphasizing empirical results.

So the major goal here is empirically to determine whether, at any time over the period under review, EMI resorted to collusive pricing behavior in order to achieve oligopoly market power. This goal is important. For, as Friedman (1983) points out, successful collusion provides an opportunity for the firms concerned to attain a point on the profits possibilities frontier and thus to earn more than Cournot noncooperative profits. Furthermore, as Slade (1986) argues, price discrimination can be expected to accompany collusion as colluders try to use product differences to transform consumer surplus into producer surplus.

Consequently, this author has chosen prices as the strategic variable of this study with no expectation that a Bertrand story of price competition among the leading firms of the industry will naturally emerge. On the contrary, the expected story is one about administered prices in collusive markets, a story of dominance by the few as social welfare diminishes in a vital industry.

The public record has already established that EMI's behavior was collusive in the eyes of the law. Moreover, EMI has been found by some analysts using quantity as the strategic variable to have practiced collusion. It is expected that the price approach taken here will also find collusive behavior in the industry.

¹Scherer (1980), op. cit., p. 2.

In a general sense, this study deals with one of the most significant discussions of NEIO as it discusses the empirical determination of market structure and of collusive behavior within a given industry. In Section 2.1, it will be maintained that the duopoly (GE and Wh) of EMI produced heterogeneous goods while almost 10,000 small firms formed a competitive fringe of the industry. The basic model to be presented in Section 2.2 will establish the basic conditions facing EMI as well as the market structure, conduct and performance (S-C-P) of that industry over the period 1956-62. Section 2.3 will offer an alternative analytical method in the form of a reaction function model. Chapter 3 will be devoted to all the elements which will make this a NEIO study. After an overview in Section 3.1, Section 3.2 will present the empirical models while it will be left to Section 3.3 to discuss the data and the results. The conclusion will be presented in Chapter 4, with Section 4.1 being devoted to the summary and implications of the study and with Section 4.2 making suggestions for future study.

It is ironic that, although analysts have found that certain oligopoly solution techniques generate more accurate predictions than those achieved under competitive and monopolistic paradigms, yet matching those techniques to actual markets is often beset by failure. Nevertheless, I.O. economists are not without striking successes.

2.0 Oligopoly Theory

2.1 Overview

Oligopoly theory is the Achilles heel of structural economic theory. The consensus is that, despite the proliferation of oligopolistic paradigms in modern economic literature, a complete oligopoly theory is yet to be captured in a unified model as has been accomplished with the theories of perfect competition, monopolistic competition and monopoly.

Perhaps the incompleteness of oligopoly theory lies in Schmalensee's (1987) explanation of the relationship between market structure (S) and conduct (C). Schmalensee believes that a market cannot be complete unless the relationship $C = f(S)$ holds.¹ Oligopoly is the only market structure in which this relationship does not hold. But this is unimportant to Fisher (1987) who finds that no "precise useful" outcomes are achieved by assuming that $C = f(S)$ or that $P = f(S)$, where P means market performance. The reason is that although "conscious parallelism" is logically more likely the fewer the number of firms, yet economists do not know at what level of concentration the "danger point" is reached.

Anyhow, holding oligopolistic principles somewhat together is the notion of reciprocal dependence among firms. This principle has its foundation in the key concept of strategic conjectures about firm behavior which finds ultimate confirmation in the distribution of profits and of market share.²

The literature abounds with a wide and often complex array of econometric applications to these concepts. Subtle and useful perceptions have emerged over time bringing enrichment and a clearer understanding of the nature of oligopoly to I.O. economics. But this

¹Schmalensee is referring to the structure-conduct-performance (S-C-P) theory of industrial organization (I.O.) economics.

²Gyoichi Iwata.(September 1974). "Measurement of Conjectural Variations in Oligopoly." *Econometrica* Vol.42, No.5: 947-66; Frank M. Gollop and Mark J. Roberts.(1979). "Firm Interdependence in Oligopolistic Markets." *Journal of Econometrics* 10: 313-31.

field seems to be more singularly served by those analysts who either assume the presence of oligopoly in most U.S. markets, or attempt to determine the degree of monopoly power in a given industry instead of assuming a structure of perfect competition. This is largely because the benefits from methodological ease enjoyed under an assumption of perfect competition in U.S. industry studies are often offset by the costs of obtaining insufficiently accurate results.¹

Thus, the level of accuracy attained in depicting oligopolistic behavior more so than any other market behavior crucially depends upon the aptness of the assumptions made. For example, Cournot (1927) and Bertrand (1883) make the same assumptions about costs and demand curves, but Cournot chooses quantity while Bertrand chooses price as the strategic variable. The resulting equilibria are not even close.²

Against this background, the theoretical frameworks developed in Sections 2.2 and 2.3 will mainly attempt to establish that the two major firms of the U.S. electrical machinery industry (EMI) functioned as a duopoly over the period 1956-62, and engaged in collusive pricing behavior during those years. The two firms, General Electric (GE) and Westinghouse (Wh), together held a highly dominant position in EMI.

Now collusion emerges in U.S. industry either as a result of semi-Procrustean methods or of conscious parallelism. Whatever the source, this study concerns itself mostly with reporting its own empirical findings for the period under review. During those years EMI was a tight oligopoly.³ For example, after 1958, the "Big Two", GE and Wh, held a joint

¹Appelbaum (1982), op. cit.

²Timothy Bresnahan.(December 1981). "Duopoly Models with Consistent Conjectures." American Economic Review Vol.71, No.5: 934-45.

³William G. Shepherd.(1979). The Economics of Industrial Organization. Englewood Cliffs, New Jersey: Prentice Hall, Inc. Shepherd defines tight oligopoly as a "shared monopoly" having a four-firm concentration ratio of at least fifty percent ($C_4 \geq .5$). Shepherd writes: "The distinctive feature is that the high concentration enables the leading firms to coordinate well, much as if they were really just parts of one dominant firm." (p. 63).

market share of sealed-bid orders for circuit breakers and switchgear of 69.9% and 74%, respectively. Meanwhile, EMI's C_4 ratios were correspondingly 95.8% and 93%. In each case, the C_4 ratio far exceeds Shepherd's definition of a tight oligopoly. Notice in Table 2.1.1 that

**Table 2.1.1. Market Share, Sealed-Bids Orders After 1958
Electrical Machinery Industry (EMI)**

<u>Firm</u>	<u>%</u>		<u>%</u>	
	<u>Circuit Breakers</u>		<u>Switchgear</u>	
General Electric	38.8		39.0	
Westinghouse	<u>31.1</u>	69.9	<u>35.0</u>	74.0
Allis-Chalmers	10.0		8.0	
Federal Pacific	15.9		7.0	
I-T-E	<u>4.0</u>	<u>29.9</u>	<u>11.0</u>	<u>26.0</u>
Total		<u>99.8</u>		<u>100.0</u>

Source: Adapted from Ralph G. M. Sultan.(1974). Pricing in the Electrical Oligopoly. Vol.1. Cambridge, Mass.: MIT Press.

adding the next two largest suppliers to GE and Wh combined results in an increase of only 25.9 and 19 percentage points, respectively. This and other strong evidence confirm that GE and Wh were indeed the Big Two of EMI.¹

But the road to collusion is usually far from smooth. For example, Chamberlin (1962) mentions possible impediments to collusion and Tirole (1989) identifies two such factors as firm asymmetries and detection lags (pp. 240-41). The problem of asymmetries is not important here since the Big Two are assumed to be symmetric. But detection lags did pose problems for EMI since GE and Wh specialized in filling big orders. For example, Tirole predicts that big orders are likely to have deleterious effects on collusive stability since the short-term benefits from undercutting collusive price greatly outweigh the long-term costs of waging a price war. Indeed, as Tomic (1985) observes, EMI experienced a price war called

¹Sultan, op. cit., and Tomic, op cit.

the "white sale of 1954-55" which was precipitated by cheating as demand unexpectedly weakened. However, no price war has been recorded for the period under review.¹

To Tirole's two factors, Porter (1983) adds entry as an impediment to collusive behavior. Porter shows that entry (and thus barriers to entry) is important with price as the strategic variable since firms know that the likelihood of industry price wars occurring rises with entry.

But entry, actual or potential, is important also because it introduces the question of whether innovation has been successful as a barrier. Interestingly enough, innovation might have had a positive effect on any collusive behavior in EMI during 1956-62 when GE and Wh experienced a reduction in dominance as the small firms increased their market share.² Rose and Joskow (1988) have found that, while the speed of adoption of technological advancement rises with firm size, it so happens that for "the very largest firms in the industry..., increasing size reduces the probability of quickly trying the industry's innovations." But the Big Two were at the time experiencing decrements rather than increments in size. Any effects from innovation should be captured in the econometric model, Section 3.

As EMI coped with cheating during the "white sale", the Big Two probably could not even depend upon Chamberlinian threats of retaliation.³ For, traditionally, price-cutting has been difficult to detect in industries like EMI that handle big orders. Nevertheless, remedies such as the formation of a trade association, resale price maintenance, uniform margin

¹In April 1959, there were rumors of a price war between GE and Wh in the market for turbine units. However, a Philadelphia grand jury was at that time looking into collusive pricing in EMI. It could well be that the price cuts which seemed to signal a price war were in fact generated by consideration of the legal ramifications. This author believes that 1959 price-cutting episode was more likely a legal strategy than a price war.

²Ralph L. Nelson.(1959). Merger Movements in American Industry, 1895-1956. Princeton University Press.

³E. H. Chamberlin.(1962). The Theory of Monopolistic Competition 8 ed. Cambridge, Mass.: Harvard University Press.

pricing, and basing-point pricing were available to the two firms as means of diminishing or removing threats to their dominant collusive positions.

Overall, modern theories support earlier predictions of collusive conduct varying with time.¹ The implications for this study are that a determination should be made as to (1) whether EMI, represented by GE and Wh, alternated between collusive and noncooperative episodes during 1956-62; (2) given no specific information to the contrary, whether innovation was indeed an influence in any significant collusive behavior found. These questions relate to changes in EMI's structure, conduct and performance (S-C-P) over 1956-62.

Standard measures and techniques for identifying S-C-P include conjectural variations (CVs), concentration ratios (C_4), the height of entry barriers (BE), reaction functions, various elasticities, and other indexes of market power and performance, especially the Lerner (1934) and Herfindahl (1950) indexes for measuring oligopoly power. Like Bresnahan (1981), this study distinguishes between CVs and reaction functions. CVs are defined as the firms' conjectures about other firms' behavior while reaction functions are defined as the "actual behavior" of the firms. As Bresnahan points out, Nash equilibria equate CVs and reaction functions. These measures can be estimated and used for identifying collusive or other behavior.

■ Conjectural Variations. The concept of CVs, a term coined 37 years ago by Frisch (1933), really owes its origin to Bowley (1924).² But the prevalence of and the sophistication attached to its use are modern phenomena.

¹Porter (1983), op. cit.; L. F. Lee and R. H. Porter.(1984). "Switching Regression Models with Imperfect Sample Separation Information--with an Application on Cartel Stability." Econometrica 52, 2: 391-418.

²Also see Iwata, op. cit., and J. W. Friedman.(1983). Oligopoly Theory. New York: Cambridge University Press.

CVs are generally regarded by I.O. economists as mirrors of producer behavioral strategies. CV theory will play a crucial role here as determinants of and in the development of other determinants of collusive behavior. The theory applies uniquely to oligopoly and thus to EMI. The polar structures of monopoly and perfect competition are so complete that the question of conjectures does not arise. In regard to monopolistic competition (also a complete structure), the accent is on non-price competition and on physical uniqueness of the product, and conjectures about prices or quantities become meaningless if product differentiation is complete.¹

So CV theory matters only where the possible reactions of firms to quantity or price changes are likely to be considered by the firm which initiates the change. The conjectures range from values for perfect competition (the lower bound) to values for monopoly (the upper bound). These values are benchmarks of CV theory. High values depict periods of successful collusion while low values reflect periods of either price wars or of other noncollusive behavior.²

But the theory is not without its detractors. For example, Dixit's (1988) criticism is that the CV model has "shortcomings", a CV being "a simple and intuitive summary measure of market conduct." Dixit further asserts that CVs do not provide a proper foundation on which to build oligopoly theory, but admits that a "workable alternative" does not yet exist. Meanwhile, Eaton (1988) refers to the CV approach as "unfashionable", finding it unsuitable for analysis of trade policy. But, like Dixit, Eaton still finds some good in the CV approach, defending its role as an "easy comparison of the special (more acceptable) cases of Cournot-Nash, Bertrand-Nash and perfect collusion." (p. 166).

¹Keep in mind that it is the consumer who determines whether or not any two goods are economically differentiated, whatever the physical characteristics of the goods happen to be.

²Bresnahan (1989), *op. cit.*

These criticisms came five years after Friedman (1983) almost dismissed the theory as meaningless. Rejecting the use of CVs in static models, Friedman argues that: (1) the models should be explicitly dynamic; (2) discounted rather than current-profits maximization should be the firm's problem in a dynamic framework, and this would widen the spectrum of collusive outcomes; (3) single-period frameworks cannot accommodate new information that require adjustments to firm behavior over time.(p. 110). Friedman further maintains that firms have to make simultaneous decisions and, therefore, one price cannot rationally be considered as a function of another if prices are simultaneously made in one period.

Nevertheless, this study accepts Dixit's (1988) opinion that CV theory is the state of the art and adopts CV theory as an instrument for detecting collusion in EMI. To this end, the convention is that firm i's conjecture about the effect of own-price changes on rival firm j's behavior is stylized as PCV_i , where PCV means price conjectural variation, and firm j's opposite conjecture is stylized as PCV_j . When notions of constancy and consistency simultaneously arise, the term for firm i becomes "constant $CPCV_i$ ", and similarly for firm j.

Interestingly, the earlier assumption that the Big Two are symmetric firms provides a precise correspondence between quantity conjectural variations (QCVs) and PCVs which involves equal equilibria. Kamien and Schwartz (1983) show this by manipulating the first order conditions of quantity and price approaches for symmetric firms. Table 2.1.2 presents a summary of this correspondence from the individual work of Gollop and Roberts (1979), Bresnahan (1981), Appelbaum (1982), Kamien and Schwartz (1983) and Liang (1988).

But this correspondence is also present in a Kamien and Schwartz equation for perceived product differentiation. For a duopoly, firm 1's equation would be:

$$1-PCV_1 = (1-QCV_1)(1-\tilde{p})/(1+QCV_1\cdot\tilde{p}) \quad (2.1.1)$$

where $0 < \tilde{p} = (\partial p_1/\partial q_2)/(\partial p_1/\partial q_1) < 1$. Also, for the heterogeneous case, Figure 2.1.1 is an adaptation of a Kamien and Schwartz (1983) sketch of the correspondence. The relation is concave and increasing so that PCV_1 rises in QCV_1 for differentiated products. Importantly,

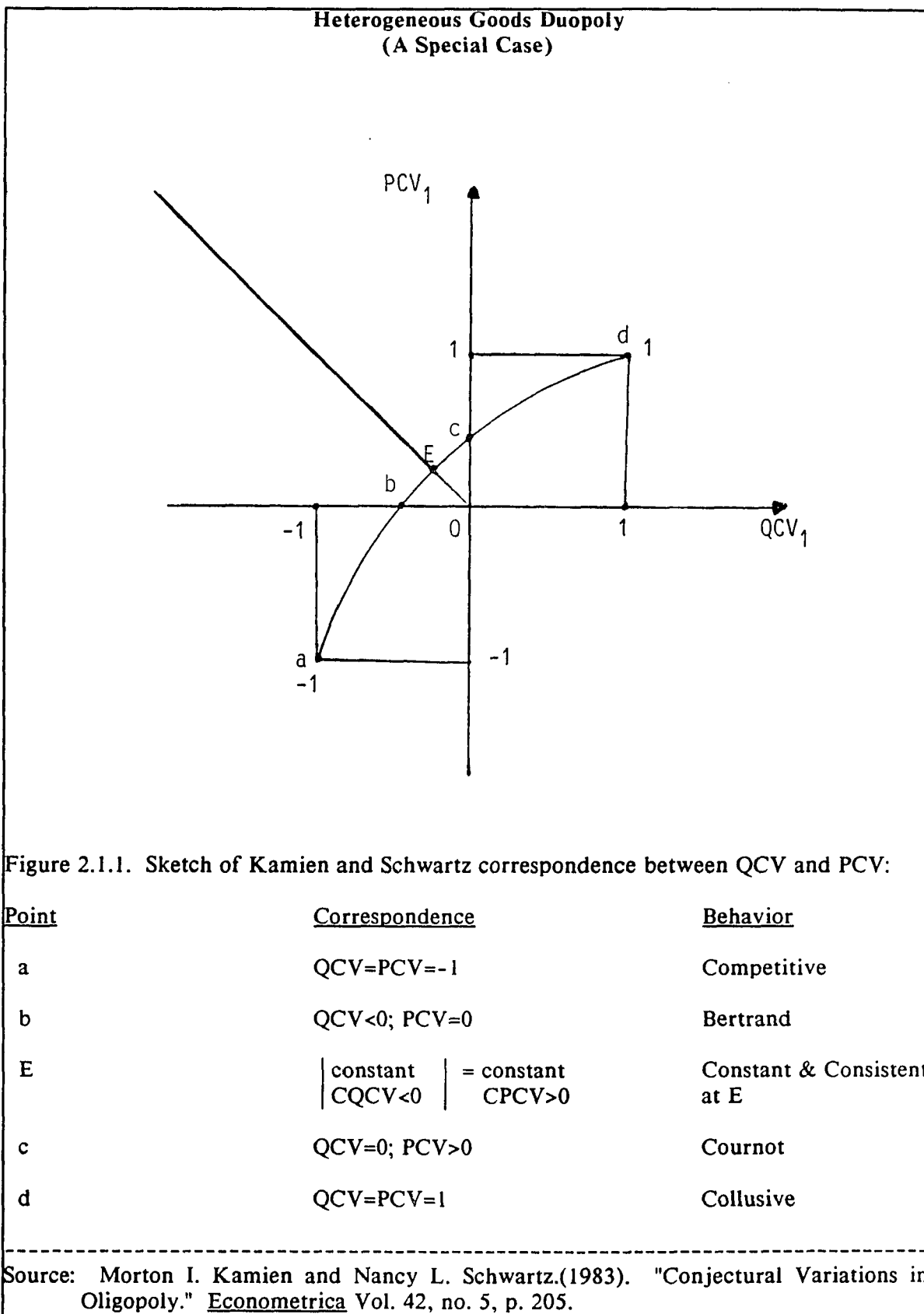
Table 2.1.2. Critical Conjectural Variation Values

Behavior	Bench Marks				
	Gollop & Roberts (1979)	Bresnahan (1981)	Appelbaum (1982)	Kamien & Schwartz (1983)	Liang (1988)
Competitive	QCV=0 ^a	----	----	PCV=-1 ^b or PCV<0 (s.l.t.) ^c	PCV= $\frac{-\beta_i+\delta_i}{-\beta_i+\delta_i}$ PCV \leq 0 QCV=-1 PCV=-1 \Rightarrow symmetry PCV=0 \Rightarrow p. comp.
Bertrand	----	QCV=-1 Q*,P* ^e	QCV=-1	PCV=0 or PCV=0 (n.s.d.f.) ^d ; QCV<0	----
Cournot	QCV=0	QCV=0	QCV=1	QCV=0	----
Collusive	QCV \geq 0	QCV=1	QCV=1	PCV>0 PCV>0 (s.g.t.) ^f ; QCV=1	PCV= $\frac{\beta_i+\delta_i}{\beta_i+\delta_i}$ PCV \geq 1 QCV=1 PCV=1 \Rightarrow symmetry

Source: Adapted from papers of authors (see Bibliography).

Notes: (a) QCV means quantity conjectural variation; (b) PCV means price conjectural variation; (c) s.l.t. means significantly less than; (d) n.s.d.f. means not significantly different from; (e) * here means equilibrium; (f) s.g.t. means significantly greater than.

Liang's Definitions: (1) competitive pricing: QCV=-1; PCV \leq 0 | $(-\beta_i+\delta_i)/(-\beta_i+\delta_i)$ of ambiguous sign (but see Appendix I.1); (2) collusive pricing \Rightarrow QCV=1; PCV $=(\beta_i+\delta_i)/(\beta_i+\delta_i)\leq$ 1 but > 0 (see Appendix I.2 and Figure 2.1.1).



the sketch indicates that the two CVs need not have the same sign but may be equal in absolute value. Attainment of the point $PCV_1=QCV_1=1$ would mean that there is perfect collusion in EMI. Also notice that perfectly competitive PCV_1 matches perfectly competitive QCV_1 in the limit. The relevance to EMI of this Kamien and Schwartz special case is deferred to Section 2.2 where it will be more conveniently discussed when equation (2.2.12') is introduced.

■ **Concentration Ratios.** These are also used by I.O. economists as measures of inequality and of the likelihood of effective cooperation among firms. For example, Stigler (1964) recommends the use of the Herfindahl (1950) concentration index, $H = \sum s_i^2$, as the proper measure of effective cooperation. Furthermore, a Stigler (1963) finding implies that a direct relationship exists between concentration and the share of industry assets owned by large firms.

Concentration ratios have also been linked to price-cost margins (PCMs) and thus to market power. Empirical results relating to firm conduct have often been interpreted as predicting that PCMs and, by inference, market power rise in concentration because increasing concentration changes conduct.¹ But, for U.S. manufacturing industries in the long term, large increases or large decreases in concentration are generally associated with price (productivity) increases which are below (above) average.²

Regarding the use of concentration as a measure of market power in U.S. industries, the Big Two's record is already well documented in previous studies thus precluding the need for full repetition here. But, as a means of sharpening the focus on the period 1956-62, a few of the facts should be presented. For example, of the 202 transactions involving sales of electrical machinery to industrial firms over the period 1957-63, manufacturers GE and Wh

¹See Bresnahan (1989), *op. cit.*, who withholds final judgment until he sees a "careful defense of this interpretation." (p. 55).

²Schmalensee (April 1987), *op. cit.*

accounted for 165 or 82% of those transactions. In regard to the 1950 official lists of four leading firms as producers of 47 different kinds of electrical equipment, GE appeared on the list 36 times and Wh 25 times while RCA was next with only 8 appearances.¹

On the whole, EMI's four-firm concentration ratio (C_4) was, on average, 68% for the two years 1958 and 1963 if only transformers, motor generators, and carbon and graphite products are considered. Together, GE and Wh manufactured 75% of these orders over the period 1957-63.²

During the period under review, there was no doubt that GE and Wh dominated EMI. This domination is reflected in the concentration ratios shown in Table 2.1.3. For example, in 1958, EMI's C_4 , C_8 and coverage ratios³ for carbon and graphite products were 87%, 92% and 95%, respectively. It is remarkable that EMI's C_4 ratios could be so high in an industry consisting of almost 10,000 firms at the time. This pyramidal effect is strongly suggestive of an atomistic fringe.⁴

It is apparent from these preliminary facts that the Big Two were, not only dominant in EMI, but also structured as a duopoly. Nonetheless, this is a question for testing and the econometric models in Section 3 have all the requirements for rejecting or accepting the duopoly assumption.

■ **Barriers to Entry.** As previously discussed, entry may constitute an impediment to collusion. So it is important to observe entry patterns in EMI over the period 1956-62. It

¹For example, see Tomic, op. cit.

²U.S. Department of Commerce, Bureau of the Census (1958; 1963).

³As defined by the U.S. Bureau of the Census (1963), coverage ratios measure "the extent to which all shipments of primary products of an industry are made by plants classified in the industry, as distinguished from secondary producers elsewhere; that is, value of shipments of the primary products made by plants classified in the industry expressed as a ratio of the total shipments of primary products made by all producers, both in and out of the specified industry."

⁴For confirmation, see Jules Backman.(1962). The Economics of Electrical Machinery Industry. New York: New York University Press.

**Table 2.1.3. C_4 , C_8 and Coverage Ratios
Electrical Machinery Industry (1947-63)**

Year	SIC (percent)						Coverage		
	C_4	C_8		C_4	C_8				
1947	73	59	87	84	66	93	91	92	95
1954	78	50	86	89	59	93	94	84	94
1958	71	47	87	84	51	92	93	88	95
1963	68	50	83	79	59	92	94	84	96

Source: Adapted from U.S. Bureau of the Census.(1963). Table 2.

Notes: 3612 = power and distribution transformers; 3621 = motors and generators; 3624 = carbon and graphite products; coverage ratio = the percentage of all shipments of primary products of an industry manufactured by that industry.

turns out that, by the second half of the 1940s, GE and Wh had reached the peak of dominance in EMI. Despite later entry and growth of the small firms of the industry, this dominance, although diminished, was never seriously threatened. The Big Two effectively remained a dominant duopoly.¹

In this author's view, it would be a mistake, however, to conclude a priori, on the basis that the industry consisted of almost 10,000 firms, that GE and Wh did not erect barriers. For it is apparent that EMI was a two-tier market structure with an oligopoly at the top and with thousands of firms at the base competing among themselves in the manufacture of goods essentially not produced by the oligopoly which was dominated by the Big Two.

¹Nelson, op. cit. Incidentally, any mention in I.O. economics of the assets of firms invariably sets the stage for a discussion on barriers to entry in the context of the Averch-Johnson (1962) hypothesis. But, as Bresnahan (1981) points out, overcapitalization, under an assumption of constant returns to scale [which relates well to the U.S. economy], becomes meaningless as a barrier to entry. Consequently, the A-J hypothesis receives no further attention in this study.

Barriers might have been erected between tiers. This is a question for further discussion and analysis.

Linking entry barriers to both the price and quantity approaches, Friedman (1983) finds that, for duopoly, entry barriers are associated with preentry prices (outputs) which are lower (higher) than they would be if no threat of entry were posed. Friedman also finds that prices do not generally fall to the level of marginal cost to wipe out pure profit, and calls for dynamic analysis of these effects.

■ **The Lerner Index.** A detailed discussion of this measure is deferred to Sections 2.2 and 2.3 where the basic and the price reaction theoretical models, respectively, are presented. Suffice it at this point to state that the Lerner index is an important measure in this study.

However, before completing the discussion on measures, it is important to realize that any reference here to the Lerner index, an important measure of oligopoly power, leads to consideration of econometric methods and testing. Economists such as Iwata (1974), Gollop and Roberts (1979) and Appelbaum (1979, 1982) have set great store on the relevance of methods used and on establishing robustness of measures. Unlike Bain (1956) and Scherer (1970), these economists apply econometric procedures to test theoretical measures of oligopoly power. For example, Gollop and Roberts, using inverse demands, make a distinction between the formulation of conjectures for the purpose of analyzing both the presence and the form of interdependence. Regarding the presence of interdependence, Iwata's technique of aggregating output will suffice. But in terms of the form of interdependence, however, disaggregation is required, as Gollop and Roberts demonstrate, because "the rival's size" is then regarded as the discriminating feature. This has implications for the availability of data. For the unavailability of data at the firm level restricts analysis to determining the presence of interdependence. Fortunately, data at the firm level have been acquired by this author.

Of the studies just mentioned, this author finds Appelbaum's (1982) application of production theory to the study of oligopoly appealing and germane to the purpose of this study. Covering the period 1947-1971, Appelbaum empirically tests for the degree of competitive behavior and for the degree of firm and industry oligopoly power. The analysis is performed for four U.S. industries, including EMI. The Lerner index, as a measure of oligopoly power, is first theoretically developed at the firm level and then used in defining a similar measure at the industry level where testing had to be conducted because of data unavailability at the firm level. So Appelbaum's theoretical framework provides models for empirical research at both the firm and industry levels.

What makes Appelbaum's method enterprising is its permitting the researcher to overcome the usually insurmountable problems associated with obtaining firm data. The industry framework requires nothing more than data on inputs, on market prices and on quantities in order to estimate the degree of collusion. Such data are easily obtainable from published accredited sources.

Appelbaum defines inverse market demand functions for the four industries. The EMI firms buy capital, labor and raw materials as inputs and supply electrical machinery to industrial and utility buyers. Appelbaum treats the supplies as homogeneous goods.

Using the properties of Shepherd's (1970) lemma,¹ Appelbaum (1) obtains the firm's input demand function by differentiating its cost function while assuming that the vector of input prices is common to all firms in the non-competitive industry; (2) formulates the firm's profit maximization problem with respect to quantity, subject to the inverse market demand function facing the industry. The first order conditions provide the means of obtaining the firm's conjectural variations, the conjectural elasticity of total industry output with respect

¹Also see Hal R. Varian.(1984). Microeconomic Analysis 2 ed. New York: W. W. Norton & Company, p. 54.

to the typical firm's output and a measure of oligopoly power which is easily converted to the well known Lerner and Herfindahl indexes.

It is in the formulation of the firm's maximization problem that Appelbaum's approach to analyzing EMI (among other firms) differs from that of this study. Appelbaum uses the quantity approach¹ while this study uses the price approach.

Appelbaum's rationale for choosing the quantity approach is that the goal is mainly to create a framework for studying collusion in and the "underlying market structure of an industry." Appelbaum has chosen the popular method.²

But this study has a more specific goal. It intends empirically to establish whether or not there was a "great conspiracy" in pricing behavior,³ and thus the pricing approach is preferred. This is a significant departure from Appelbaum's (1982) model. It is conceptually more appropriate if tests of hypotheses about the existence of price collusion in EMI are conducted in a model with price as the strategic variable.

Now, Labini (1979) seems to think that, although price is the appropriate strategic variable in studying oligopoly behavior, yet price changes are orderly in oligopolistic markets.

¹Throughout the remainder of this study, the term price (quantity) approach means a theoretical model, as developed in Section 2.2, having a direct (an inverse) demand curve and using price (quantity) as the strategic variable of firm or industry behavior. This convention leads to the use of the expression PCV (QCV) for price (quantity) conjectural variation. Note that, for homogeneous goods under the quantity approach, market price is a function of: the conjectural variation, marginal cost, and the elasticity of demand.

²Judging from the extensive amount of reading done for this study, this author finds the quantity approach more popular than the price approach. The most likely reason for this is that data are by far more readily available for the quantity approach than for the price approach.

³Incidentally, the term price-taking behavior at times seems to be defined as identical to perfectly competitive behavior. The truth is, all perfectly competitive behavior is price-taking behavior but all price-taking behavior is not perfectly competitive behavior. For some cases of collusion and of price leadership involve price-taking by weaker firms in noncompetitive situations. So although profit maximization behavior in EMI as a differentiated goods market rules out any meaningful discussion of marginal cost pricing, this does not imply that price-taking behavior cannot exist in EMI. See Margaret E. Slade.(1986). "Conjectures, Firm Characteristics, and Market Structure: An Empirical Assessment." International Journal of Industrial Organization 4: 347-69. North Holland.

Labini contends that oligopolies are expected to use changes in prime costs as excuses for effecting systematic simultaneous price changes. Meanwhile, Dixon (1983) reminds analysts that, almost two decades earlier, Stigler (1964) had found evidence of such orderly pricing. However, the Labini and Stigler conclusions are rejected in Dixon's model.

Waterson (1984) and Slade (1986) also recommend the price approach for heterogeneous goods. For example, following Cubbin (1974) in developing a model for symmetrical heterogeneous oligopoly, Waterson refers to the price approach as "more convenient for price setting."

- Another significant departure from Appelbaum's (1982) model must be made for a different reason. In specifying conjectural elasticity of total industry output with respect to the typical firm's output share, Appelbaum linearly pegs the conjectural elasticity (CE here) to input prices while admitting that this procedure is neither "necessary" nor "very appealing," but restrictive of "firm behavioral modes." (p. 294). This author considers the pegging of CE to input prices as riskily exclusive and agrees with the Husbands (1990) technique used in a somewhat parallel case. Conjectural elasticity is there treated as a parameter for its determination within the econometric model while suitable dummy variables are included to account for important economic conditions not captured by that parameter.

Indeed, Gollop and Roberts (1979) allude to this kind of procedural problem, noting that a model of "producer behavior" should not treat CE as constant since CE can be controlled by the firms and should therefore be allowed to vary as time passes. An earlier attempt by Iwata (1974) assumed the QCV to be a constant parameter for each firm. It is clear that the assumptions of Iwata and Appelbaum cannot simultaneously be considered rational for EMI within the framework of the quantity approach.¹ For CE is the product of QCV and s_j . For example, holding both CE and QCV constant in Appelbaum's study would suggest the

¹There is no suggestion made here that any such application exists. This author knows of none.

unsupported scenario that market share s_i remained constant in EMI over the period 1947-71. Assumptions of CE and PCV being simultaneously constant would be even more inappropriate since CE now becomes the product of PCV_{ij} and p_i/p_j .

As previously indicated, a third question arises as to whether electrical machinery should be treated as a heterogeneous good, or as a homogeneous good as Appelbaum has done. The assumption of heterogeneity is more suitable than that of homogeneity where price is the strategic variable so long as the requisite data are available. The reasoning is as follows: Homogeneity is an important element of perfect competition. Increases in homogeneity lead to decreases in individual firm output while market output increases and thus facilitate the creation of atomistic markets. But homogeneity alone cannot create such markets since it is a necessary but not a sufficient condition for perfect competition. So if goods that would normally be thought of as belonging to competitive markets are being sold in noncompetitive markets, it must be that factors other than the physical elements of the goods have caused buyers to perceive them as heterogeneous.

For example, convenience, cost cutting opportunities, speed of delivery, brand loyalty, distance between supplier and buyer, length of warranties, conditions in service contracts, and the proneness of some goods more than others to be used by sellers as instruments for practicing collusion will differentiate such good in the minds of buyers. Support for regarding EMI products as heterogeneous comes from Friedman (1986) who writes: "In my view, homogeneous product markets are virtually nonexistent; therefore, introducing differentiated product markets is an important step forward."

It is therefore reasonable to assume that the Big Two faced downward sloping direct demand curves as they supplied heterogeneous electrical machinery, which are reasonably close substitutes, mainly to industrial and utility customers. The Bulow, Geanakoplos and Klemperer (1985) study of strategic substitutes and strategic complements in oligopoly markets bases the distinction between quantity and price competition on whether goods are

homogeneous or heterogeneous, respectively. To sum up, the assumption of product differentiation conforms to Porter's (1980) definition:

Product differentiation means that established firms have brand identification and customer loyalties, which stem from past advertising, customer service, product differences, or simply being first in the industry.¹

Ironically, the homogeneous physical nature of EMI goods provides an analytical advantage where firm price data are unavailable. That is, it permits unambiguous summing of firms' output to obtain industry output if estimation must be done at the industry level.²

A fourth departure from Appelbaum's (1982) study stems from this author's agreement with Bresnahan's (1989) view that it is incorrect to treat the conjectural elasticities in equilibrium as equal across firms. Bresnahan asserts that "there is nothing in the logic of oligopoly theory to force all firms to have the same conduct."

Using the quantity approach, Appelbaum found that EMI wielded "significant oligopolistic power" over the period 1947-71. The primary purpose here is to attempt to detect collusion in EMI by using the price approach over the 1956-62 segment of that period. But an effort will also be made to determine whether: (1) outbreaks of cheating occurred; (2) Slade's (1986) notion of price discrimination in oligopoly can be supported by available EMI data; (3) PCVs were constant and consistent in EMI.

■ Reaction functions. Returning to the discussion of measures and techniques, this study now looks at reaction functions. For purposes of econometric estimation, some economists embed CVs in single-period reaction function models, notwithstanding the chagrin of Dixit (1988) and, perhaps, the disappointment of Waterson (1984). But Friedman (1983) even more strongly opposes the use of reaction functions in static single-period models. Friedman argues

¹Michael Porter.(1980). Competitive Strategy--Techniques for Analyzing Industries and Competitors. New York: The Free Press, 3-33.

²Waterson, op. cit., argues that, given the price approach, then "it is no longer possible to sum outputs unambiguously to obtain industry output." (p. 27). But this author is convinced that the argument adduced above should satisfy Waterson that EMI products could have been unambiguously summed.

that reaction function models should be used only to distinguish between action in the preceding period and reaction in the current period. Furthermore, where price reaction functions (PR_i) alone are strategies, "only an approximation to noncooperative equilibrium is assured." But if strategies are defined as (p_i, PR_i) --this paper's notation--with p_i being initial price in dynamic models, then collusive "equilibrium is assured." Friedman adds:

Although the decision process of Marschak and Selten rationalizes reactions within a single period model, it is much more reasonable to suppose simultaneous actions within each period and use a multiperiod (dynamic) model.¹

Friedman was not the first economist to criticize the typical use of reaction functions in I.O. economics. For example, Fellner (1949) observes that neither the intersection of reaction functions for outputs nor the stability of achieved equilibria is assured.(p. 73). Dixit (1988) again calls for dynamic modelling.

■ **Elasticities.** Reference has already been made to conjectural elasticities (CEs). Now, QCV_1 may be written as dq_2/dq_1 and PCV_1 as dp_2/dp_1 . Both the quantity approach and the price approach, as represented by these expressions, define bilateral CVs. For example, if there were three firms, then the bilateral PCVs would be: (1) firm 1-- $dp_2/dp_1, dp_3/dp_1$; (2) firm 2-- $dp_1/dp_2, dp_3/dp_2$; (3) firm 3-- $dp_1/dp_3, dp_2/dp_3$. So, as collusive measures are developed for EMI, bilateral PCVs and, by extension, CEs, will simultaneously be involved since CE is the product of the PCVs and the price ratio, p_1/p_2 .

Demand elasticities (e's) will reflect buyer tendencies and the order of buyer preferences in the EMI market. Thus, the procedure used here will provide, not only estimates of own- and cross-price elasticities of demand along with conjectural elasticities, but also the scope for devising tests to determine whether conjectures are both constant and consistent. Elasticities will play a role in this determination.

¹James W. Friedman, op. cit., p. 134; Thomas Marschak and Reinhard Selten.(1977). "Oligopolistic Economies as Games of Limited Information." Zeitschrift fur die Gesamte Staatswissenschaft 133: 385-410.

Although unobserved, elasticity parameters have been estimated in the literature with acceptable degrees of success. Also, Iwata (1974), Friedman (1977), Gollop and Roberts (1979), Bresnahan (1981), Appelbaum (1982), Waterson (1984) and Liang (1988), among others, have made significant contributions both in popularizing and in advancing the usefulness of elasticities in the determination of firm oligopolistic performance.

There has been and will be some arbitrariness introduced. This is because a priori notions about influences of factors such as firm size, output levels, firm assets, sales volume, and the size of the firm labor force will play a selective role in the models for estimating CV parameters. This is precisely the reason why conjectures should be tested for constancy and consistency. For constant and consistent conjectures will imply that arbitrariness has been removed. Nevertheless, even if the hypothesis of constancy and consistency is rejected, the estimates of reaction function parameters in this study should still prove to be useful insights into firm policy since these functions represent a firm's choice of price in a given period after making informed surmises about rival price reactions, and since arbitrariness of conjectures about pricing behavior can be adjusted by econometric methods.

This argument does not address the concerns of Dixit, Eaton and Friedman, in particular, who strongly advise the use of dynamic modelling. But the position taken by this author is partly based on an empirical finding of Fudenberg and Tirole (1987) that, contrary to contestable market theory,¹ incumbents' price adjustments are instantaneous and faster than quantity adjustments.²

Finally, it seems to this author that a theory of oligopoly, however specialized, should make at least passing reference to the controversy surrounding the kinked demand curve. The

¹William J. Baumol.(June 1983). "Contestable Markets: An Uprising in the Theory of Industry Structure." American Economic Review 73: 491-96.

²Incidentally, Metzler's estimate of a typical quantity adjustment period is five months, including the period of planning. See Lloyd Metzler.(February 1947). "Factors Governing the Length of Inventory Cycles." Review of Economics and Statistics 29: 7.

truncation of two demand curves at the point of intersection, which forms the kink, simply provides the means for a firm to accommodate, within demand theory, its asymmetric conjectures of price responses of other firms to changes in its own price.

This author shares Waterson's (1984) view that this is "merely a special case of the general conjectural variations model." In the case of GE and Wh, the asymmetry in conjectures may be defined as:

$$PCV_1 = dp_2/dp_1 = 0 \text{ for } dp_1 > 0; \leq 1 \text{ for } dp_1 < 0, \quad (2.1.2)$$

where the subscripts relate to firms 1 and 2. Now the kink and the variation in conjectures are directly based on perceived firm behavior. Also, behavior between two firms as rivals is measured by CVs while behavior between a firm and its consumers is measured by price elasticity of demand. The link between inter-firm behavior and firm-consumer behavior is firm market prices. This can be shown by deriving mc_1 and mc_2 for the Big Two and then simultaneously solving them to show that, at equilibrium, p_1 and p_2 will depend upon both firms' demand elasticities and CVs.

This analysis seems to suggest that the position of the kink can be restricted by simulation techniques to a small neighborhood. Unfortunately, this would only be an advancement of the theory since the equilibrium would still not be precise.

But another approach is probably more promising. It has to do with the notion of constant consistent conjectures theory. The criticisms levelled at the kinked-demand-curve hypothesis may be significantly muted by this theory which should rid the reaction-theory framework of arbitrariness. So, as I.O. economists succeed more and more in fine-tuning the theory of constant and consistent QCVs and PCVs, more and more should the controversy surrounding the kink fade away.

2.2 The Basic Model

As discussed in Section 2.1, EMI is represented in this study by GE and Wh. The basic model reflects a duopolistic market with the firms buying inputs of labor (L), capital (K) and raw materials (M) to manufacture electrical machinery. The machinery is perceived as heterogeneous goods which are fairly close substitutes, and would be perceived as perfect substitutes only if $\bar{p} = (\partial p_1 / \partial q_2) / (\partial p_1 / \partial q_1) = 1$.¹

The goods sold by firms 1 and 2 may also be described as strategic substitutes in the sense that if, say, firm 1 significantly lowers its price in a given market (an aggressive strategy), this would cause the marginal profit of firm 2 to fall.² The almost 10,000 fringe firms sell products that are mostly imperfect substitutes for the duopoly's products. Compared to GE and Wh (the Big Two), the fringe is so small in terms of market share that, without loss of generality, it suffices to study EMI as a duopoly.

The Big Two are symmetric firms which means that they have parallel cost structures.³ The problem of these firms is to maximize profits (π_i) with price (p_i) as the strategic variable. The expectation is that finite symmetric equilibrium prices greater than zero will emerge in satisfaction of the first order conditions.

With price as the strategic variable, the duopoly will face direct demand curves. The aptness of the assumptions made about demand will play an important role in determining the degree of success achieved in removing arbitrariness from the model now being developed. This is because any misspecification of the nature of the demand functions will make

¹Kamien and Schwartz, op. cit, p. 205.

²Jeremy I. Bulow, John D. Geanakoplos and Paul D. Klemperer, (1985). "Multimarket Oligopoly: Strategic Substitutes and Complements." Journal of Political Economy Vol.93, no.3: 488-511.

³Appelbaum (1982), op. cit.

consistent price conjectural variation (CPCV) results meaningless, as Kamien and Schwartz (1983) show.

So demand is assumed to be linear. This assumption permits testing for the existence of a constant consistent price conjectural equilibrium. This is desirable since a failure to reject such existence would free the constant CPCV results from bias.¹

But, as Kamien and Schwartz point out:

...even in symmetric equilibrium firms' constant conjectural variations are unlikely to be correct since there is only a very narrow class of demand and associated interior conjectural variations for which this is possible....It was...shown that the limiting conjectural variation that leads to competitive output can be consistent for any demand function.²

Notice that Kamien and Schwartz (1983) are distinguishing between constancy and consistency of CVs. These authors stress that: (1) constancy may not be achieved; (2) the absence of constancy can lead to a far broader range of demand functions.

With the Kamien and Schwartz reasoning taken into account, the demand conditions facing EMI are as follows: (1) the demand curve is linear and negatively sloped; (2) demand is finite and positive; (3) given firm i and firm j , q_i increases in p_j and decreases in p_i ; (4) if $dp_i = dp_j$, this will have a simultaneous influence on both q_i and q_j , ceteris paribus, as long as the price change does not define new prices higher than the upper bound of prices for that market.

Formally, firm i faces the direct demand function:

$$q_i = q_i(p, v), \quad i = 1, \dots, N, \quad (2.2.1)$$

where q_i is firm i 's output, p is a vector of demand prices and v is a vector of exogenous determinants of demand, such as the prices and quantities of other goods. Vector v is

¹This is a bonus which is not available if demand is assumed to be loglinear. Constant CPCVs do not exist in the loglinear demand case. See Kamien and Schwartz, op. cit.

²Kamien and Schwartz, op. cit., p. 209.

therefore a demand shift variable. Aggregate demand $Q = \sum_i^N q_i$,¹ and $\partial Q/\partial P < 0$ for the market demand curve. Demand for q_i falls in own price so that $\partial q_i/\partial p_i < 0$, and rises in rival price so that $\partial q_i/\partial p_j > 0$. In absolute value, the response of q_i to changes in p_i is assumed to be greater than the response of q_i to changes in p_j , $i \neq j$.

Firm i 's vector x of n inputs is:

$$x = x^j = (x^1, \dots, x^n), \quad j = 1, \dots, n, \quad (2.2.2)$$

while the vector of input prices r is assumed to be the same for all i and is defined as:

$$r = (r_K, r_L, r_M) \quad (2.2.3)$$

where subscripts K, L and M are capital, labor and raw materials, respectively.

This study adopts Appelbaum's (1982) assumption of constant equal marginal costs² for the Big Two since, as Cowling and Waterson (1976) point out, this precludes "variation in price-cost margins" of the two firms. Thus, firm i 's total cost function,

$$C_i = C_i(q_i, r), \quad i = 1, \dots, N, \quad (2.2.4)$$

is differentiable at (q, r) , $r \gg 0$.³ By Shepherd's Lemma,⁴ firm i 's input demand curve can therefore be derived from the cost function, given the assumption that, for EMI as a noncompetitive duopoly, the two firms face the same input prices.

Firm i 's input demand function therefore becomes:

$$x_i^j = \partial C_i(q_i, r) / \partial r^j, \quad i=1, \dots, N; j=1, \dots, n; \quad (2.2.5)$$

¹Detailed specifications of the entire model are deferred to Section 3 where the econometric model will be presented.

²By the assumption of constant marginal costs, Appelbaum (1982) means that "firms have linear and parallel expansion paths so that marginal costs are equal across firms." The same use of the term is applied here.

³By definition, " \gg " means always greater than any given value for all i . See Varian, op. cit., p. 308.

⁴R. Shepherd.(1970). Cost and Production Function. Princeton, N.J.: Princeton University Press; Varian, op. cit.

where x_i^j is the input demand vector of firm i and $\partial C_i/\partial r$ is a column vector of partial derivatives of C_i with respect to r . Each firm is assumed to be risk averse so that its problem is to maximize profits with respect to p_i . Firm i 's objective function is therefore:

$$\pi_i = (p_i - mc_i)q_i(p_i), \quad i = 1, \dots, N \quad (2.2.6)$$

where mc_i and π_i are firm i 's marginal cost and total profit, respectively.¹

Rewriting (2.2.6) to express the profit maximization problem for the duopoly yields:

$$\text{Max}_{p_i} \pi_i = \sum_i (p_i - mc_i)q_i(p_i), \quad i = 1, 2 \quad (2.2.7)$$

subject to:

$$Q = Q(P, v) \quad (2.2.8)$$

where constraint (2.2.8) is expressed in industry variables, with $Q = \sum_i q_i$ for industry supply.

But, more to the purpose here, joint profit maximization may be used by the two firms as a collusive device. For example, it is reasonable to assume that, in the absence of price cooperation, buyer power would erode the duopoly's market power by bidding price down to the level of marginal cost. Thus, sellers anticipating this could be motivated to collude for the purpose of offsetting price erosion. The result would be joint profit maximization yielding $\pi > 0$ instead of perfectly competitive $\pi = 0$. Thus, (2.2.7) would become:

$$\text{Max}_{p_1, p_2} \pi = (p_1 - mc_1)q_1(p) + (p_2 - mc_2)q_2(p) \quad (2.2.7')$$

subject to

$$Q = Q(P, v), \quad (2.2.8)$$

where subscripts 1 and 2 refer to GE and Wh,² respectively, $Q = (q_1 + q_2)$, P is market price and p is a vector of output prices.

¹Discussion of suitable techniques for estimating mc_i is deferred to Section 3.1.

²As in Section 2.1, GE and Wh will also be referred to as firm i or firm 1, and firm j or firm 2, respectively.

Notice that (2.2.7') contains the price-cost margins (PCMs) of both firms as determinants of the level of duopoly profits. Like the concentration ratio (C_n) and the Lerner index (Le), PCMs are estimable measures of market power and therefore of performance.¹ PCM values, which are directly linked to Le , are expected to rise during booms and to fall during recessions. The more concentrated the industry, the more strongly are PCMs expected to react to changes in the business cycle. Of special interest here is Kwoka's (1979, 1981) finding that the market shares of the two leading firms of an industry [such as GE and Wh of EMI] have a closer relationship with an industry's PCM than broader concentration ratios have with the PCM.²

However, given that the firms jointly attempt to maximize profits, then the duopoly's optimality condition from (2.2.7') with respect to p_1 is the first order condition:

$$\frac{\partial \pi}{\partial p_1} = q_1 + (p_1 - mc_1) \frac{\partial q_1}{\partial p_1} + (p_2 - mc_2) \frac{\partial q_2}{\partial p_1} = 0 \quad (2.2.9)$$

which is a collusive result in terms of firm 1's price. It should be noted that, although large PCMs are generally consistent with profitability, these margins alone should not be interpreted as an invitation to profitable entry. A potential entrant should always consider the existing elasticities of demand in order to make a rational decision about entry.

Assuming now that profits are not jointly maximized, then firm 1's own optimal condition from (2.2.6) with respect to its own price is the first order condition:

$$\frac{\partial \pi_1}{\partial p_1} = q_1 + (p_1 - mc_1) \left[\frac{\partial q_1}{\partial p_1} + \frac{\partial q_1}{\partial p_2} \frac{dp_2}{dp_1} \right] = 0 \quad (2.2.10)$$

which is not the same thing as the result in (2.2.9) and therefore not a collusive result. It is the solution to firm 1's decision to act independently of firm 2 in maximizing own profits.

¹PCM is not to be confused with price-fixing which reflects conduct rather than performance.

²Also see Schmalensee (April 1987), op. cit.

The first order condition given by (2.2.10) may be rewritten for firm 1 (see Appendix I.3) as the equilibrium condition:

$$cmr_1 = p_1 + [q_1/(-\beta_1 + \delta_1 PCV_1)] \quad (2.2.11)$$

where $-\beta_1 = \partial q_1/\partial p_1$; $\delta_1 = \partial q_1/\partial p_2$; $PCV_1 = dp_2/dp_1$; cmr_1 is the conjectured marginal revenue of firm 1; and PCV_1 is the price conjectural variation of firm 1. Notice that $-\beta_1$ measures inverse quantity responses along the demand curve to changes in p_1 . Thus β_1 must be positive. But the demand curve also responds to changes in p_2 since p is a vector of prices. These responses are positive and are measured here by $\delta_1 > 0$. Since the demand curve for firm 1 is assumed to be downward sloping, then $0 < \delta_1 < \beta_1$ must be true since demand is assumed to respond more to own price than it does to rival price for a close substitute.

The PCVs in this study are expected to conform to the Kamien and Schwartz (1983) predictions for heterogeneous goods. These predictions are: PCV_1 significantly less than zero for perfectly competitive behavior; not significantly different from zero for Bertrand behavior; significantly greater than zero for collusive behavior.¹

In general form, (2.2.11) becomes:

$$\{cmr_1 = p_1 + [q_1/(-\beta_1 + \delta_1 PCV_1)]\} = mc_1 \quad (2.2.11')$$

This equation indicates that, at equilibrium, the firms have maximized profits by setting marginal cost equal to conjectured marginal revenue. This is the classical principle of the firm profit maximization problem. Notice that $PCV_1 = dp_2/dp_1$ appears in (2.2.11'). As expected, the PCVs turn out to be key parameters of firm behavior. But, at this point, only the theoretical importance of these parameters is being observed.

If the first order conditions of the quantity and price approaches are equated and then QCV_1 is set equal to one, this would yield collusive PCV_1 given as:

¹Incidentally, Slade's (1986) price-discrimination result for the gasoline industry that she studied requires $PCV_1 = 1$ for a monopoly result. See Table 2.1.2 for interesting comparisons.

$$PCV_i = (\beta_i + \delta_j) / (\beta_j + \delta_i) > 0, \quad i \neq j; \quad (2.2.12)^1$$

But, for the perfectly competitive case, the Kamien and Schwartz PCV_i now requires that QCV_i be set equal to negative one. This yields:

$$PCV_i = (\beta_i - \delta_j) / (-\beta_j + \delta_i), \quad i \neq j, \quad (2.2.12')$$

(see Appendix I.1). Mathematically, this result, in the absence of specific assumptions, is of ambiguous sign. But the Kamien and Schwartz assumption of symmetry, which is defined as all firms having the same CVs, the same quantities and the same prices, assures that $\beta_i = \beta_j$ and that $\delta_i = \delta_j$. This along with the assumption that $\beta > \delta$ means that the Kamien and Schwartz PCV_i result is equal to -1 for the perfectly competitive case as shown in Figure 2.1.1 of Section 2.1, a point not observed by Liang (1988).

However, the Kamien and Schwartz characterization of symmetry defines a special case and does not correspond in this study to the use of that term which, as defined by Appelbaum (1982), means nothing more than the firms concerned having parallel cost curves. Thus, the lower bound of the price approach cannot be defined here for perfect competition. For example, with the price approach, the perfect competitor's problem may be written as $\pi = pq - mcq$. The first order condition yields $q = 0$ which is absurd. Thus, for the competitive result, the lower bound under the price approach is undefined. If this paper finds that $0 < \delta < \beta$, then the perfectly competitive result here would be strictly negative. Notice that this reasoning does not hold under the quantity approach. For example, the problem becomes $\pi = pq - mcq$ so that $p - mc = 0$ as required.

Now if the optimal conditions given by (2.2.9) and (2.2.10), the first order conditions of joint- and own-profit maximization, respectively, are set equal to each other, then the result, after manipulation, becomes:

¹For the derivation, see Appendix I.2. Also, see Kamien and Schwartz, *op. cit.*, and Nellie J. Liang.(1988). "Price Reaction Functions and Conjectural Variations: An Application to the Breakfast Cereal Industry." Federal Trade Commission--* Stop 149, Board of Governors of the Federal Reserve System.

$$PCV_1 = \frac{dp_2}{dp_1} = \frac{(p_2 - mc_2)(\partial q_2)}{(p_1 - mc_1) \partial p_1 \partial p_2} \quad (2.2.13)$$

as shown in Appendixes I.4 and I.5. The useful features that can be deduced by writing PCV_1 in this form are: (1) the dependence of the PCVs on the PCMs showing an obvious link of PCVs to the Lerner index which is still popular as a measure of oligopoly power;¹ (2) the potential for linking the PCVs and the Lerner index to elasticities as shown in Appendix I.6; (3) the opportunity to dissect the conjectural elasticity term which appears in the derivation given in Appendix I.7.

The question arises as to whether the PCVs are consistent, as explained in Section 2.1. But what is also important to observe is whether the conjectures realized bear reasonable relationships to the real world. Some analysts point to the fact that the standard Bertrand (1883), Cournot (1927) and Stackelberg (1952) models, based on assumptions untouched by evolving market realities, arrive at significantly different results.²

However, some important contributions to CV theory maintain that requiring consistency of conjectures is sufficient to free the theory from significant arbitrariness,³ and to generate industry output levels greater than Cournot's and at times matching Bertrand's.⁴ Indeed, Bresnahan (1981) regards consistency of conjectures as the "selection criterion."

For the price-oriented PCVs, references here to consistent conjectures will be in the form "consistent price conjectural variations (CPCV)" as opposed to CQCV for the quantity approach. An attempt will be made to determine whether the PCVs of this study are CPCVs in equilibrium.

¹See Appendix I.6.

²Waterson, op. cit.

³For example, see Bresnahan (1981), op. cit., and M. K. Perry.(1982). "Oligopoly and Consistent Conjectures Variations." Bell Journal of Economics 13: 197-205.

⁴Waterson, op. cit.

But, what is it in oligopoly theory, imperfect as it is, that would lead to consistency of the conjectures? Bresnahan's (1981) answer is:

If [firms] have consistent conjectures, nothing in the comparative statics of equilibrium will reveal those conjectures to be wrong. By what process the conjectures will come to be consistent is an elusive problem, as is the possibility of an informationally consistent stable dynamic for oligopoly prices and quantities.¹

Bresnahan further maintains that comparative statics is the only tool economists need to justify the notion of consistent conjectures equilibrium. Bresnahan has strong support in Kamien and Schwartz (1983) and in Liang (1988), among others.

Regarding the reference to linkages of the PCVs to the Lerner Index (Le) and to elasticities, economic theory teaches that elasticities are always important where interdependence is involved. An assumption of price collusion in EMI presupposes the existence of a reciprocal pricing dependence between firm 1 and firm 2, given the price approach. Such behavior can confer market power on the two firms. Apart from the PCVs, own- and cross-price elasticities along with values of Le can determine the degree of oligopoly power (see Appendix I.6). For example, measures of the inverse relationships between own-price elasticity and Le will shed light on buyer perceptions and reactions to market forces and phenomena.

So price elasticity of demand at the industry level is defined here as:

$$e = \frac{\partial Q}{\partial P} \frac{P}{Q} \quad (2.2.14)$$

But, at the firm level, e_1 may be defined for firm 1 as:

$$e_1 = \left(\frac{\partial q_1}{\partial p_1} + \frac{\partial q_1}{\partial p_2} \cdot \frac{dp_2}{dp_1} \right) \left(\frac{p_1}{q_1} \right) < 0. \quad (2.2.15)$$

This is the elasticity of demand that firm 1 faces as a seller of q_1 . In terms of the parameters of (2.2.11), (2.2.15) in general form becomes:

$$e_1 = (p_1/q_1)(-\beta_1 + \delta_1 PCV_1)$$

¹Timothy Bresnahan (December, 1981), op. cit., pp. 934-45.

or

$$e_i = (-\beta_i p_i + \delta_i PCV_i p_i) / q_i < 0. \quad (2.2.15')$$

The partial derivative of e_i with respect to PCV_i should be positive. Formally, the first derivative of (2.2.15') with respect to PCV_i is:

$$\partial e_i / \partial PCV_i = \delta_i p_i / q_i > 0 \quad (2.2.16)$$

as required. This means that e_i rises in PCV_i . Thus, price elasticity of demand of firm i becomes more inelastic as firm i perceives more and more collusive behavior in conjunction with firm j .¹

Intuitively, the demand curve of firm 1 becomes more inelastic as firm 1's price conjectural variation with respect to firm 2's price increases. As demand becomes more and more inelastic, the more it pays firm 1 to raise rather than lower p_1 . So collusion is expected to be accompanied by higher prices, ceteris paribus. This result is insightful but not surprising.²

A combination of the definition given in (2.2.11) and the form of (2.2.14), but at the firm level, may be written as:

$$e_{ii} = -\beta_i p_i / q_i < 0, \quad i = 1, \quad (2.2.17)$$

for firm i 's partial own-price elasticity of demand showing the demand for firm i 's products falling in p_i ;

$$e_{ij} = \delta_i p_j / q_i > 0, \quad i = 1, j = 2 \quad (2.2.18)$$

which is the partial cross-price elasticity of demand showing the demand for firm i 's products rising with rival price p_j ; and

$$e_{ji} = \delta_j p_i / q_j > 0, \quad i = 1, j = 2 \quad (2.2.19)$$

¹Liang, op. cit.

²This effect is also confirmed in the price reaction approach of Section 2.3 where a graphical analysis is also presented.

the converse of (2.2.18). This analysis can be extended to determine the effect on conjectures of changes in product differentiation. For example, as the firms' products become less and less differentiated, firm 1's profits will become less and less independent of firm 2's policies, and conversely. This can be verified by analysis of partial own- and partial cross-price elasticities.

Elasticities are important also because high PCMs often accompany low elasticities of demand. Low elasticities of demand imply that significant additions to capacity and to production would lead to large price cuts and thus to a worsening of profitability.¹

A discussion of elasticities here naturally leads to a discussion of the Lerner index (Le). This is because Le can be derived in terms of e_{11} , e_{12} and of CE_1 . For example, for firm 1, the lerner index may be written as:²

$$Le_1 = \frac{-1}{e_{11}} + \frac{-1}{(e_{12})(CE_1)} \quad (2.2.20)$$

where $e_{11} = -\beta_1(p_1/q_1) < 0$; $e_{12} = \delta_1(p_2/q_1) > 0$; and $CE_1 = (dp_2/dp_1)(p_1/p_2) = PCV_1(p_1/p_2) > 0$. Price cost margins are positive, as shown in (2.2.13). Further substitutions involving β_1 , δ_1 and PCV_1 will yield:³

$$Le_1 = \frac{-1}{(p_1/q_1)(-\beta_1 + \delta_1 PCV_1)} \quad (2.2.21)$$

or

$$Le_1 = \frac{-1}{(e_{11} + \delta_1 PCV_1(p_1/q_1))} \quad (2.2.21')$$

However, (2.2.20) shows that, in the price approach, Le, the measure of the firms' oligopoly power, depends upon: (1) firm 1's own-partial price elasticity of demand, $e_{11} < 0$; (2) firm 1's partial cross-price elasticity of demand, $e_{12} > 0$; and (3) firm 1's conjectural

¹Michael A. Spence.(1979). "Entry, Capacity, Investment and Oligopolistic Pricing." The Bell Journal of Economics: 534-44.

²See the derivation, Appendix I.6.

³See Appendix I.6.

elasticity, CE_1 . Interestingly enough, these results differ from those of the quantity approach where, for example, Appelbaum (1982) shows that the Lerner index (Le) depends only upon "the inverse demand elasticity and the conjectural elasticity." (p. 290).

Now that the Lerner index has been discussed, it would be useful, as suggested earlier, to analyze the conjectural price elasticity of demand of firm 1 which is defined as:

$$CE_1 = (dp_2/dp_1)(p_1/p_2) = PCV_1(p_1/p_2) \quad (2.2.22)$$

A similar measure exists for firm 2. Parameter CE_1 (See Appendix I.7) may also be written as:

$$CE_1 = (R_1/R_2) (Le_1/Le_2) (e_{12}/e_{21}), \quad (2.2.23)$$

where R means total revenue, Le is the lerner index, and e_{12}/e_{21} is a ratio of partial cross-price elasticities of demand.

Notice that the conjectural elasticity consists of the product of three ratios: (1) the ratio of total revenues of firm 1 and firm 2; (2) the ratio of the Lerner indexes of the two firms; and (3) the ratio of the partial cross-price elasticities which may be rewritten as $(\delta_1 \cdot p_2/q_1)/(\delta_2 \cdot p_1/q_2)$. All three ratios are in the order firm 1 to firm 2. The treatment of conjectural elasticity (CE) as a parameter will be further discussed in Section 3.1.

Following Kamien and Schwartz (1983), it is with interest that this author returns to (2.1.1) of Section 2.1 which gives perceived product differentiation. For convenience, the equation is repeated below:

$$1 - PCV_1 = (1 - QCV_1)(1 - \bar{p})/[1 + (N - 1)QCV_1 \cdot \bar{p}] \quad (2.1.1)$$

where $PCV_1 = dp_2/dp_1$; $QCV_1 = dq_2/dq_1$; $0 < \bar{p} = (\partial p_1/\partial q_2)/(\partial p_1/\partial q_1) < 1$; N = the number of firms. Equation (2.1.1) relates PCV to QCV , a relationship influenced by the number of firms N in the industry and by the ratio, \bar{p} . For a Kamien and Schwartz duopoly, the denominator of (2.1.1) reduces to $(1 + QCV_1 \cdot \bar{p})$, resulting in PCV and QCV having the same upper and lower bounds of 1 and -1, respectively. This means that, in the limit, firms will be expected to engage in matching behavior in both p and q if the Kamien and Schwartz special definition

of symmetry is applied. But, here, a more general definition is used, yielding 1 as the upper bound with the lower bound undefined as previously shown.

Finally, since demand elasticities play an important role in entry decisions, this has implications for welfare analysis. For it is demand elasticity which determines the direction of change in prices, in output and thus in the allocation of resources. However, as Spence (1979) observes, the sign of the effect might be negative or positive.

In Section 2.3 which follows, a price reaction approach will be introduced. This will be followed by a summary in Section 2.4 to complete the theory of oligopoly for this study.

2.3 A Price Reaction Approach

The price reaction function model includes: (1) firm i 's profit maximization problem; (2) the first order conditions from (1) above; (3) equilibrium where constant mc_i equals cmr_i ; (4) price reaction functions from (2) and (3) above; (5) ϕ_{1i} , the coefficient of p_2 and a direct measure of collusion; (6) collusive $PCV_i \leq 1$, depending upon elasticities of demand. For Kamien and Schwartz symmetric firms with identical costs and demands, perfectly collusive $PCV_i \equiv 1$;¹ (7) perfectly competitive $PCV_i = [(\beta_i - \delta_i)/(-\beta_i + \delta_i)] < 0$ for $QCV_i = -1$ and $\beta > \delta$ as assumed, $i \neq j$; (8) independent pricing if $PCV_i = 0$; and (9) unbiased conjectures of independent pricing if conjectures are consistent. However, for symmetric firms as defined in this study, the lower bound of the perfectly competitive PCV_i is undefined, as previously explained in Section 2.2.

With $PCV_i = dp_2/dp_1$ for GE and Wh as a duopoly, observe that, although firm 1 is making conjectures about p_2 , actual p_2 should be and is included in reaction function (2.3.10) and in the general form of the first order conditions (2.3.7) below. It follows that these conjectures are not Stackelberg (1952) in prices. This is because reactions do depend on conjectures.²

Conjectures are necessary since firms do not usually know the slopes of rivals' reaction functions. But this should not be interpreted to mean that firms make wild guesses about rivals' behavior. On the contrary, the notion of consistent conjectures implies a rivalry based on informed, hardheaded surmise.

Perhaps, it would be as well to clarify the meaning of the term consistency in this context. Suppose for a moment that firm 1's conjecture were written as $PCV_i = \Omega_1'(p_1)$, where $\Omega_1(p_1) = p_2$. This sums up how firm 2 will react to changes in p_1 . Then consistency or rational

¹See Appendix I.2 and Table 2.1.2.

²See Bresnahan (1981), *op. cit.*, for a parallel argument with quantity as the strategic variable. Note, however, that Stackelberg models are often presented in a reaction-function framework to explain oligopoly behavior.

or rational behavior would require that $\Omega_1'(p_1)$ be equal to dp_2/dp_1 , the total derivative of p_2 in terms of p_1 , and, similarly, that $\Omega_2'(p_2)$ be equal to dp_1/dp_2 .¹

Put differently, since firms do not know the actual slopes of their rivals, they devise strategies to attain the next best alternative, conjectural slopes, referred to in the literature as conjectural variations which may be constant slopes of linear functions or variable slopes of non-linear functions. Consistency is of singular importance among oligopolistic behavioral assumptions. When conjectures are consistent, they are necessarily in a state of equilibrium.²

But Kamien and Schwartz (1983) show that imposing consistency on CVs does not necessarily translate into a significant restriction on the equilibrium results. What it does translate into, these authors point out, is a restriction on the form of the demand curve.

So for GE and Wh, a consistent price conjectural variation equilibrium (CPCVE) is here defined for equilibrium prices p^* and price conjectures ($PCV_1(p_1)$, $PCV_2(p_2)$) for firm 1 and for firm 2, respectively, such that both firms accurately determine each other's price reaction levels. Firm 1's actual behavior is given by price reaction function PR_1 , and Firm 2's by PR_2 . This definition holds for all prices p_i in the neighborhoods of p_1 and p_2 . More formally:

$$p_1^* = PR_1(p_2^*); p_2^* = PR_2(p_1^*) \quad (2.3.1)$$

$$PCV_1(p_1) = \partial PR_2(p_1)/\partial p_1 \quad (2.3.2)$$

$$PCV_2(p_2) = \partial PR_1(p_2)/\partial p_2 \quad (2.3.3)$$

where the conditions given in the last two equations apply to all p_i in the neighborhoods of p_1^* and p_2^* , respectively. Equations (2.3.1) to (2.3.3) together imply a Nash equilibrium.³

¹Friedman, *op. cit.*

²Bresnahan (1981), *op. cit.*, shows that Bertrand but not Cournot equilibria are consistent. Also, Friedman (1983) is of the view that the price approach cannot define Cournot equilibria for oligopolies with PCMs > 0 . (Notice that, in Table 2.1.2, only QCVs appear for Cournot equilibria).

³Bresnahan (1981), *op. cit.*

In the quantity approach, the slope of a profit maximizing firm's reaction function measures the rate of change in that firm's equilibrium output, in response to a change in a rival firm's output. But Kamien and Schwartz (1983) show that the constant slopes of the linear reaction functions for heterogeneous goods suggest the existence of a constant CPCV. As these authors point out, the assumption of linear demands for EMI requires that:

$$PCV_1^2 [q_2 + (p - c)(q_{21})] + PCV_1 [2q_1 + (p - c)(q_{11} + q_{22})] + q_2 + (p - c)q_{12} = 0 \quad (2.3.4)$$

must be satisfied in order for a constant CPCV to exist. This equation defines a symmetric equilibrium which may or may not exist. If it does exist, then economic sense requires, according to Kamien and Schwartz, that equilibrium price be greater than zero and that a constant CPCVE in the interval $(-1, 1)$, where E refers to the state of equilibrium, is determined by the joint solution of the first order conditions given in (2.3.4).

Although PCVs and not QCVs are of particular interest in this study, some further comparisons with QCVs will prove to be enlightening. For example, given a similar approach in regard to CQCVE, the requirement would be for $q > 0$ and for a constant CQCVE such that $-1 < CQCVE < 1$. Both approaches demonstrate, as Kamien and Schwartz point out, that firms normally expect only partial responses from rivals to both price and output changes. But, more importantly, equilibrium market price and quantity, p^* and q^* , respectively, are the same for both approaches if conjectures are consistent.

In terms of the price approach, the expected result is $PCV \in (-1, 1)$ and, for the quantity approach, $-1 \leq QCV \leq 1$ if conjectures are consistent. However, with linear demand, constant CPCVE equals constant CQCVE in absolute value, a result not assured for nonlinear demand. Thus, a price increase evokes only a partial positive response from the rival firm while a quantity increase draws a partial response of cuts in production.¹

The degree of heterogeneity is important to the determination of the level of rivals' responses. These responses decrease in heterogeneity and increase in homogeneity. This

¹Kamien and Schwartz, *op. cit.* Also see Table 2.1.2.

means that, as goods become more and more differentiated, the less will a price change be followed and the less will a quantity change be offset. But keep in mind, as indicated in Section 2.1, that perceptions of differentiation rest with the consumer.

Also important in applying the notion of consistency to market equilibria in price conjectures is the question of uniqueness of the equilibria. This is assured in linear demand models if marginal costs and PCVs are constant. Indeed, the attainment of a constant consistent conjectural variations equilibrium is the attainment of a unique equilibrium. But, the weakness in the theory lies in the possibility that such an equilibrium may not indeed exist and that, even if it existed, then there is no assurance that a given study would be able to match the oligopoly solutions to world conditions.¹

The questions just raised about rivals' responses and conjectures may be captured in reaction functions which map the paths of any two firms of an industry (as is the case with GE and Wh) moving towards a common equilibrium where the choice variable (p or q) should be positive. But, as Waterson (1984) observes, these paths do not define all possible equilibria, and some economists have begun to pay attention to equilibria which are not associated with reaction function paths.

Proceeding with the reaction function model, this study mostly follows Liang's (1988) technique (this author's notation). Firm i's profit maximizing problem is:

$$\text{Max}_{p_i} \pi_i = p_i q_i - C_i(q_i) - F_i, \quad i = 1 \quad (2.3.5)$$

subject to

$$q_i = \alpha_i - \beta_i p_i + \theta v_i + \delta_i p_j, \quad i \neq j, \quad (2.3.6)$$

where C means production costs, F means fixed costs, and α , β and δ are parameters. Rearranging the first order conditions for firm 1 gives:

¹For example, see Timothy Bresnahan.(1982). "The Oligopoly Solution Concept Is Identified." *Economic Letters* 10: North Holland Publishing Company, 87-92. Regarding the comment about constant marginal cost and constant PCVs, this study of EMI assumes that mc_i are constant across firms but places no such restrictions on the PCVs.

$$q_1 + (p_1 - mc_1)[- \beta_1 + \delta_1 PCV_1] = 0 \quad (2.3.7)$$

with marginal costs mc_1 assumed to be constant, and with $-\beta_1 + \delta_1 PCV_1 = \partial q_1 / \partial p_1$ from (2.3.6).

Thus (2.3.7) becomes:

$$q_1 + (p_1 - mc_1)(\partial q_1 / \partial p_1) = 0 \quad (2.3.8)$$

From (2.3.7), mc_1 can be written as:

$$mc_1 = p_1 + [q_1 / (-\beta_1 + \delta_1 PCV_1)] \quad (2.3.9)$$

Now enters the price reaction function which, formally, can be written as:

$$PR_i(p_j) = PR_i(p_j, mc_i, v), \quad i \neq j, \quad (2.3.10)$$

In terms of firm 1 (GE), (2.3.10) in econometric form becomes:

$$PR_1(p_2): p_1 = \phi_{10} + \phi_{11}p_2 + \phi_{12}mc_1 + \phi_{13}v_1 \quad (2.3.11)$$

where ϕ_{10} to ϕ_{13} are functions of the coefficients of the direct demand curve as given in (2.3.6). Generally, the ϕ 's have Lerner-index properties and are direct measures of price interdependence, measuring the response of p_i to changes in rival price p_j . The ϕ 's are defined as:

$$\phi_{11} \equiv -\delta_i / (-2\beta_i + \delta_i PCV_i) \quad (2.3.12)$$

Since the ϕ 's have Lerner-index properties, it would be interesting, therefore, to compare the Lerner index written in the form:

$$Le_i = (p_i - mc_i) / p_i = -1 / (-\beta_i + \delta_i PCV_i) (p_i / q_i) \quad (2.3.13)$$

(see derivation in Appendix I.6) with the coefficients of the reaction function given above in (2.3.12).

The denominators in (2.3.12) and (2.3.13) provide the links between Le_i and ϕ_{11} . For example, changes in PCV_i , and in β_i as well as in δ_i have implications for the behavior of the measure of oligopoly power (Le_i) and for the direct measure of price interdependence or collusive price-setting (ϕ_{11}).

Analysis of these relationships is precisely the major goal of this study. Immediately, the partial derivatives of (2.3.12) and (2.3.13) are enlightening. Specifically, given mc_i is constant, then:

- (1) $\partial\phi_{i1}/\partial PCV_i$ and $\partial Le_i/\partial PCV_i$ show that ϕ_{i1} and Le_i are increasing in PCV_i ;
 - (2) $\partial\phi_{i1}/\partial\beta_i$ and $\partial Le_i/\partial\beta_i$ show that ϕ_{i1} and Le_i are decreasing in β_i ;
 - (3) $\partial\phi_{i1}/\partial\delta_i$ and $\partial Le_i/\partial\delta_i$ show that changes in ϕ_{i1} and in Le_i are \geq or $<$ 0 as PCV_i are \geq or $<$ 0.
- Also notice that $(-1 < PCV_i < 1)$ implies that both ϕ_{i1} and Le_i are $>$ 0.

It is also theoretically revealing to derive $\partial p_i/\partial PCV_i$, in parametric form, holding mc_i constant. Thus, from:

$$mc_i = p_i + [q_i/(-\beta_i + \delta_i PCV_i)] \quad (2.3.9)$$

the result obtained is:

$$\partial p_i/\partial PCV_i = \delta_i(\alpha_i - \beta_i p_i + \theta_i v_i + \delta_i p_i)/(-p_i \delta_i PCV_i)^2 \quad (2.3.14)$$

(See Appendix I.8). It can be shown that, in order for own price to increase in the price conjectural variations of firm i (that is, for firm i 's reaction function to shift to the right), the condition $mc_i < [(\alpha_i + \theta_i v_i + \delta_i p_i)/\beta_i]$ must be met (See Figure 2.3.1 and Appendix I.9).

One of two remaining theoretical questions of this study relates to determining what hypotheses will be tested and to setting for those tests parametric benchmarks that are widely accepted or that are defensible, given the state of the art and given the goal of establishing whether EMI practiced collusion in prices over the period 1956–62. Two of the many studies surveyed for this paper satisfy all the elements of this question. First, Kamien and Schwartz (1983) have suggested that, for a heterogeneous price approach, tests for rivalrous, Bertrand and collusive behaviors are feasible. These authors have also suggested benchmarks which are given in detail in Table 2.1.2 in Section 2.1 above. Second, Liang (1988), also using a heterogeneous price approach, has proposed feasible tests for rivalrous and for collusive

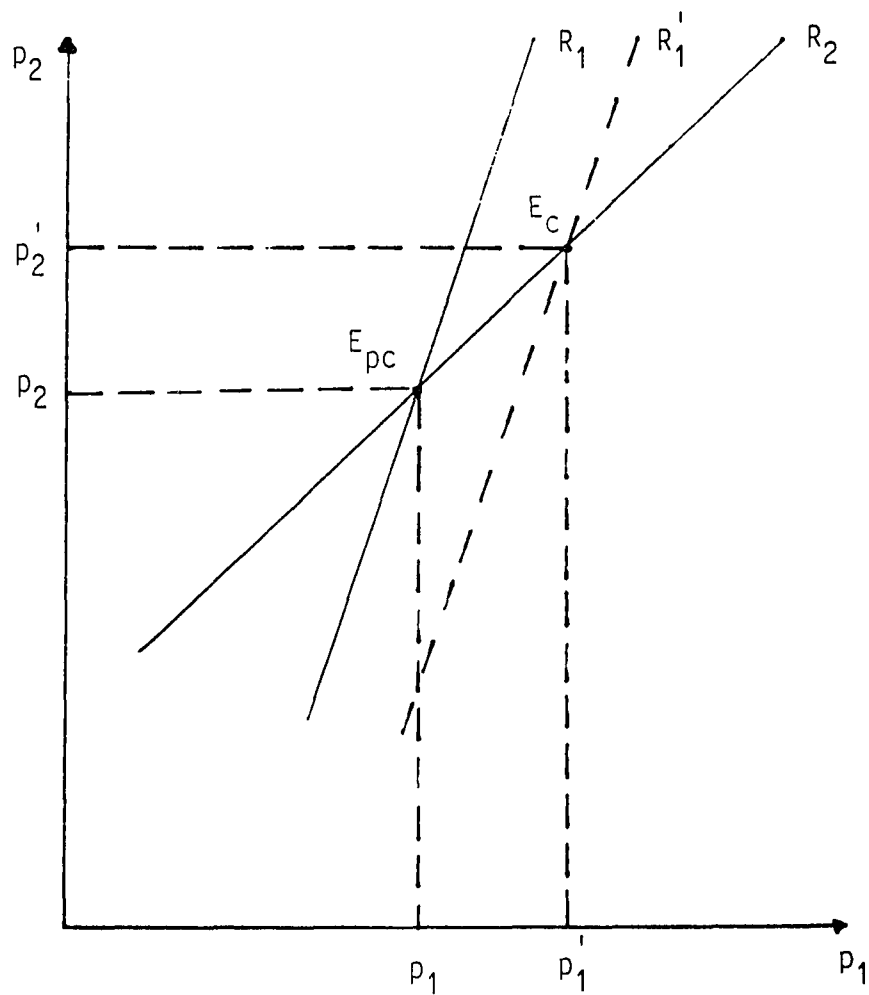


Figure 2.3.1. Collusion Tends to Raise Equilibrium Prices

Note: Collusive price equilibrium (E_c) > competitive price equilibrium (E_{pc}), given reaction curves R_1 , R_2 and R_1' .

behaviors. These details are also given in Table 2.1.2.¹ This question will again be taken up when the econometric model is presented in Section 3.

The other remaining theoretical question relates to determining whether the price conjectural variations, the crucible of studies of this sort, are rational. Kamien and Schwartz (1983) as well as Liang (1988) have dealt with constant consistent price conjectural variations (constant CPCVs). Kamien and Schwartz write:

For differentiated goods, we shall show that constant conjectural variations can be consistent in different circumstances. Consistent constant conjectural variations in quantities may, but need not correspond to consistent constant conjectural variations in prices. To support this suggestion, we show that in an oligopoly facing linear demand, consistency in price conjectures corresponds exactly to consistency in quantity conjectures....in a duopoly facing loglinear demand, there may be consistent constant conjectural variations in quantities but none in prices. In this case, consistent conjectural variations may not be constant.²

Liang (1988) defines consistent conjectural variations [this author's and not Liang's notation] as:

$$CPCV_i = -\beta_i\beta_j + [(\beta_i\beta_j)(\beta_i\beta_j - \delta_i\delta_j)]^{1/2}/(-\beta_j\delta_i) \quad (2.3.15)$$

This result is achieved by first rewriting (2.3.10) in the form:

$$PR_j(p_i) = PR_j(p_i, mc_j, v) \quad (2.3.16)$$

so that PCV_i may be defined as:

$$PCV_i = \partial PR_j / \partial p_i, \quad i \neq j, \quad (2.3.17)$$

The partial derivative yields:

$$PCV_i = -\delta_j / (-2\beta_j + \delta_j\phi_{11}) \quad (2.3.18)$$

or

$$PCV_i = -\delta_j / [-2\beta_j + \delta_j(-\delta_i / (-2\beta_i + \delta_i PCV_i))] \quad (2.3.18')$$

The solution for firm 1 by means of the quadratic formula is:

¹Incidentally, Table 2.1.2 also reports quantity-approach results given by Gollop and Roberts (1979), Bresnahan (1981), and Appelbaum (1982).

²Kamien and Schwartz, *op. cit.*, p. 206.

$$CPCV_1 = -\beta_1\beta_2 + [(\beta_1\beta_2)(\beta_1\beta_2 - \delta_1\delta_2)]^{1/2} / -\beta_2\delta_1 \quad (2.3.19)^1$$

This price reaction function model in the Liang (1988) mode is complete.

¹See Liang, *op. cit.*, and Appendix I.10.

2.4 Summary

In terms of empirical studies, a basic theoretical model may be said to be complete if it provides a suitable framework for building an econometric model in which to estimate parameters pertinent to the purpose of those studies. The basic model in Section 2.2 does just that for this study.

The econometric model may essentially be built within the framework provided by equations (2.2.1), (2.2.2) and (2.2.9). These equations, in the order above, are: (1) the firm's direct linear demand function; (2) the firm's input demand function; and (3) the firm's first order conditions from the joint-profit-maximization problem given in (2.2.7'). A joint-profit-maximization problem is chosen because an attempt is being made to detect collusion in EMI between GE and Wh.

Just as Section 2.2 grew out of Section 2.1, so will Sections 3.1 and 3.2 grow out of Sections 2.2 and 2.3. But, Section 2.3, which presents an alternative procedure in the form of a price reaction function model, is not a fifth wheel. For it can be used either for confirmation of the results emanating from the original structure of the three equations just cited, or it can be used as the model for detecting collusion in the industry.

Both theoretical frameworks are translatable into econometric models to test for structure, conduct and performance (S-C-P). Both have supporters and detractors. But both represent state-of-the-art I.O. economics and are providing useful insights which should promote future theoretical advancement.

In regard to the price reaction function approach, the core of the theory is captured in (2.3.6), (2.3.9) and (2.3.10). In that order, those equations give firm *i*'s direct linear demand curves, the first order conditions and the price reaction functions. Overall, Sections 2.1 through 2.3 have provided an oligopoly theory for econometric testing in Sections 3.

3.0 Econometric Model

3.1 Overview

In the preceding two chapters, the theoretical foundations were laid for the development of the econometric model of this chapter. This relationship, however, is one of synthesis since theoretical formulations depend upon empirical structure for the seal of approval. For, as Gujarati points out, "...it is econometrics that gives content to most economic theory."¹

To this end, two frameworks were presented in Section 2.4 as suitable oligopoly theories for empirically testing, most of all, whether EMI engaged in collusion over the period 1956-62. The first option, given by equations (2.2.1), (2.2.2) and (2.2.9), would have been pursued by this author if firm-sensitive disaggregated cost data were available for this study. But they were not.

So the second option in the form of a price-reaction model will be presented here since this option does not require the formulation of a total cost function and the subsequent estimation of marginal cost. It is an alternative that is desirable and efficient, given the state of the art. It uses equations (2.3.6), (2.3.9) and (2.3.10) as the basis for specifying an econometric model to capture the market behavior of EMI over the chosen period. It therefore attempts to fulfill the major purpose of this paper.

The price reaction model will take the form of a simultaneous equation system for estimation. A potential estimation problem in this study might seem to stem from the fact that an arbitrary choice had to be made of a sample period and of the firms to be analyzed. Rose and Joskow (1988) recommend Tobit estimators as a means of removing any bias introduced by arbitrary selection or by censoring.² However, data availability and the timing

¹Gujarati, Damodar N.(1988). Basic Econometrics 2ed. New York: McGraw-Hill Book Company.

²Rose, Nancy L. and Paul L. Joskow.(August 1988). "The Diffusion of New Technologies: Evidence from the Electric Industry." NBER Working Paper no. 2676: 1-49.

of the indictments of EMI dictated the period chosen, and the only two firms of EMI that would have qualified as having the market power of a duopoly were GE and Wh, the firms under study in this paper. This author therefore regards the Rose and Joskow concerns as generally valid but inapplicable to this study.

As is the case with a large body of economic research, the regressions of this paper will be formulated as analysis-of-covariance models which means that both quantitative and qualitative variables will appear in the equations. The capturing of qualitative effects is assigned to dummy (binary) variables which will be shown to be almost "every bit as important as the quantitative variables."¹

It is expected that each of the eight different dummy variables distributed among the equations to be reported will perform significantly in one or more situations. Indeed, they are designed to tell an important story about the qualitative influences which apparently affected the behavior of EMI during 1956-62. These influences include: innovation in the form of the diffusion in 1956 of 2400 PSI technology which is discussed by Rose and Joskow (1988);² the 1960-61 U.S. economic recession; the 1956-57 residual effects of the EMI white sale of 1955;³ the EMI recession-cum-indictments of 1961; and seasonal effects. Regarding innovation, it is expected that the "process" innovation referred to immediately above, which reduces production costs,⁴ will significantly affect the prices and quantities demanded of GE's goods (GE being the dominant firm of the duopoly), but will have a lesser effect on Wh's prices and quantities demanded. As Scherer (1980) explains:

¹Gujarati, op. cit., pp.434, 21.

²Rose and Joskow, op. cit. These authors studied the effects of the diffusion of steam electric generators involving 2400 PSI (pounds per square inch) technology for conventional units as compared to generators yielding more than 3206 PSI for supercritical units.

³Tomic, op. cit.

⁴Tirole, op., cit., p.389.

...large producers have an advantage in making process innovations. A new process that reduces costs by a given percentage margin yields larger total savings to the company producing a large volume of output than to the firm whose output is small. As a result the large firm presumably has stronger incentives to develop such improvements.¹

Scherer concludes that, although tight oligopoly is less likely than pure monopoly to innovate, a rise in intra-industry rivalry might lead to the acceptance of new initiatives.² So this study's confidence in the inclusion of innovation in demand³ and/or price equations of the model is further sustained by Denison's (1974) finding for the U.S. economy that, between 1929 and 1948, innovation explained 48 percent of the rise in labor productivity as compared to 12 percent of the rise being explained by capital intensity.⁴

Regarding the use of other dummy variables, this paper further expects that: (1) the U.S. 1960-61 economic recession and the 1961 EMI recession will show significant demand effects for the goods of both GE and Wh; (2) the residual effect in 1956-57 of the white sale of 1955 might be significant for Wh alone since, in the firms' documents researched for this paper, only Wh refers to any such residual effect; (3) seasonal effects should be similar for the two firms.

Seasonal dummy variables are popular with I.O. economists who attach them to time-series variables to remove seasonal influences exerted on the intercepts of linear models of industries and of firms.⁵ Indeed, a visual examination of the data for GE and for Wh suggests the presence of seasonal influences on the duopoly's behavior. Thus, seasonal dummy

¹Scherer (1980), op. cit., p.414.

²Ibid., pp.428-29.

³The positive response of innovations to increasing demand is "demand-pull innovations." See Scherer (1980), pp.429-30.

⁴Denison, Edward F.(1974). "Accounting for United States Economic Growth, 1929-1969." Washington, D.C.: Brookings Institution: 131-37.

⁵Kennedy, Peter.(1986). A Guide to Econometrics 2ed. The M.I.T. Press, Cambridge, Massachusetts: p.185.

variables are introduced here to capture any such periodic behavior.¹ A detailed discussion of the significant dummy variables will be given in Section 3.3 when the data are discussed. Table 3.2.1 of Section 3.2 provides a description of the eight dummy variables.

The use of a combination of quantitative and qualitative variables requires extra caution in the specification of the equations of the econometric model if the problem of multicollinearity is to be taken seriously and is to be avoided. For example, correlation tests in the preliminary stages of specifying the demand equations and the price-reaction functions of this study reveal that the dummy variable assigned to capture residual white sale effects is perhaps too highly correlated with, not only the 2400 PSI technology dummy variable ($r=0.64$), but also with two of the better proxies for marginal cost developed by this study: $wwpbq$ (-0.72) in regard to panelboards and $wxcbq$ (-0.66) in regard to circuit breakers. Yet, strangely enough, $wwsq$, the corresponding switchgear marginal-cost proxy, does not have this problem.

But the formulation of marginal cost in itself is a perennial problem to many economists using disaggregated instead of annual industry data. A number of theoretically feasible techniques have been suggested over the years by various economists. Of those tried here on the basis of the likelihood of their being successful candidates to serve as proxies specific to EMI, only two, as shown by preliminary tests, are expected to return what this author considers to be an acceptable level of performance. One is this author's adaptation of Bresnahan's (1989) verbal interpretation² of Hall's (1986) proxy for marginal cost.³ The other is quarterly wages of workers in the industry. The first proxy, as Bresnahan points out, is really average incremental cost (AIC) defined for an industry experiencing long run

¹Pindyck, Robert S. and Daniel L. Rubinfeld.(1976). Econometric Models and Economic Forecasts. New York: McGraw-Hill Book Company, pp.83-84.

²Bresnahan (1989), op. cit.

³Hall, R.(1986). "The Relationship between Price and Cost in U.S. Industry." Mimeo.

constant returns to scale as "the wage rate times the change in labor demand divided by labor's share in cost...." Bresnahan further indicates that this approach "has been largely implemented on aggregate data," and will represent marginal cost quite well if and only if marginal cost is flat.¹ Thus, using this paper's notation, marginal cost is defined for, say, panelboards as:

$$mcpbq = [(hwpwq*cmhwpb)*(clpbq+ckpbq+cmpbq)]/(clpbq*1000) \quad (3.1.1)$$

where the good is denoted by pb, q means quarterly, cmhwpb gives the change in man-hours worked, hwpwq gives hourly wages per worker, and the sum of clpbq, ckpbq and cmpbq is the total cost of labor, capital and materials in the production of the good. Similar formulations apply to this notion of marginal cost for circuit breakers (using cb in place of pb) and for switchgear (using sg in place of pb). Multiplying by 1000 in the denominator is the same thing as dividing marginal cost data by 1000 to match similar manipulations of the data base for purposes of tractability.

The second proxy for marginal cost is defined as:

$$mcpbq = wwpbq/1000 \quad (3.1.2)$$

or simply quarterly wages of workers producing panelboards, and similarly for circuit breakers and for switchgear. The previous explanation of the reason for dividing by 1000 also holds for this formulation which was intuitively tried by this author.

It is expected that both formulations will perform reasonably well for this industry when the full model is estimated. Indeed, making a choice between (3.1.1) and (3.1.2) on the basis of trial results was not at all clear-cut. But, in terms of the major goals of this study, equation (3.1.2) is regarded as the better proxy for marginal cost. Nevertheless, as will be explained at a later stage, both approaches will play separate roles in this study.

Another technique for econometrically estimating marginal cost when specific marginal cost data are unavailable for a given industry (as is usually the case) is referred to

¹Bresnahan (1989), op. cit., p.50.

by Bresnahan (1989) as "cost and factor demand function estimation using flexible functional forms." Here, marginal cost data are generated from total costs or from factor demand data.

The rationale for using this technique is that economic theory treats costs as a dual of production. The two steps involved are: (1) using factor demand equations which are the derivations of total costs with respect to factor prices [$x_t = C_w(\cdot)$], where $C(\cdot)$ is homogeneous of degree 1 in w ; (2) observing marginal cost derived from rates of change in output and in labor input.¹

Now since GE and Wh were large firms over the period under review, their data may be regarded as covering aggregate multi-market activity. Thus, some degree of arbitrariness would have been involved in the allocation of costs² to the goods produced by these firms if both firms were not active in the same markets. However, the indictments brought against these firms in 1961 have confirmed that the two firms were active in the same market for the goods under review in this study.

Equally important as the elements of the econometric system to be estimated is the soundness of the approach chosen to estimate the model. In previous chapters, this paper has unequivocally expressed its rationale for defining price as the control variable. It recognizes that the occurrence of price reactions in an oligopoly market depends upon the conditions and upon the degree of competitiveness in the market. For example, oligopolists are expected to adjust prices downward during recessions to maintain market share, but are reluctant, in the absence of collusion, to increase prices during booms since rising prices might lead to a loss of market share.

¹Bresnahan (1989), *op. cit.*, pp.48 et seq. Also see Gollop and Roberts (1979) as well as Appelbaum (1972, 1982) re step (1), and Hall (1986) re step (2).

²Incidentally, it should be noted that the choice of any proxy for marginal cost has implications for the evaluations of price-cost margins and, by extension, for the specification of the Lerner index (Le). For example, using Bresnahan's (1989) AIC would yield $Le = (P - AIC)/P$.

Given that EMI's goods are assumed to be differentiated, then in the absence of collusion, significant price differences should prevail in that industry as firms choose prices.¹ It is in the spirit of this argument that both price and quantity approaches are justified.² Thus, the job at hand now is for this study to select a suitable econometric model and procedure for estimating market structure in EMI, using the price approach.

The full model will be specified in Section 3.2 which follows. In regard to the choice of procedure, it should be noted with interest that Iwata (1974) argues that the ordinary least squares (OLS) procedure is inappropriate for estimation of oligopoly models with price as the dependent variable unless the model is in reduced form.³ But also to be noted with interest is Fisher's (1961) observation that it is all right to use price as the dependent variable for tight oligopoly since price would normally be constant for at least a year.⁴ These conflicting views are only anecdotal to this study since estimation of a price-reaction model will be accomplished, not by the OLS procedures, but by using two different procedures: (1) three stage least squares (3SLS) which accounts for cross-equation correlation of the error terms; (2) AR1, a regression technique which also corrects for autocorrelated errors.⁵

In Section 3.2, the 3SLS procedure will be applied to the estimation of the simultaneous econometric system developed there. 3SLS is often used by researchers where endogenous variables appear on the right hand side, and where it is likely that serial

¹Friedman (1983), op. cit., p.11.

²See the Kamien and Schwartz (1983), op. cit., reference to Bertrand's "classic criticism" of Cournot's choice of quantity instead of price as the strategic variable, pointing out that choice itself influences the expected outcome. (p.194).

³Iwata (1974), op. cit.

⁴Fisher, F.M.(1961). A Priori Information and Time Series Analysis. Amsterdam: North-Holland Publishing Company.

⁵Beach, Charles M. and James MacKinnon.(1978). "A Maximum Likelihood Procedure for Regression with Autocorrelated Errors." Econometrica 46: 51-58. Note that, as a rule of thumb, time series data are more subject to autocorrelation than cross-sectional data.

correlation exists since 3SLS accounts for "the covariances across equation disturbances." A facilitating feature of 3SLS is that it precludes the need for complete specification of the simultaneous model in order to obtain consistent estimates from regressions. In addition, the 3SLS estimator is "asymptotically efficient" if the simultaneous system is linear in the variables and in the coefficients¹, as is the case in this paper's model.

More efficient than single-equation estimators, 3SLS directly obtains price conjectural variation estimates (PCVs) by imposing cross-equation restrictions (CERs)² on the price reaction functions. It is important to note that, while conjectural variations in quantities (QCVs) exist only in homogeneous cases, PCVs exist both in homogeneous and in heterogeneous cases.

Unlike the 3SLS-cum-CERs approach, AR1, which in TSP is a maximum likelihood (ML) estimator, cannot directly yield PCV estimates. This is because the AR1 estimator using instrumental variables is a two-stage least squares (2SLS) estimator without CERs which are essential to the process of directly estimating PCVs. But since AR1 directly provides other efficient estimates where first-order serial correlation exists in simultaneous systems, it will be used here in conjunction with conjectural elasticities (CE_i) to make inferences about market structure if and where the 3SLS procedure fails to yield significant PCV estimates for panelboards, circuit breakers or switchgear.

In addition to this surrogate role for the AR1 estimator, AR1 results will be presented for purposes of comparison with the reported 3SLS-cum-CERs results. Both procedures will use the same data base. Indeed, an important feature of this study is that the attempt econometrically to define the market structure of EMI over the period 1956-62 will not exclusively depend upon the estimates of PCVs. Apart from the regression results to which

¹Hall, Bronwyn H., Rebecca Schnake and Clint Cummins.(1986). TSP Version 4.1 Reference Manual. TSP International: Stanford, California.

²CERs are also referred to in the literature as cross-equation constraints (CECs).

precedence will be given, descriptive statistics, charts and graphs will be presented in support of both theoretical and econometric findings.

So Section 3.2 is now being introduced. Its purpose is to translate the theoretical price reaction model given by the equations (2.3.6), (2.3.9) and (2.3.10) into an econometric model for testing hypotheses related to structure, conduct and performance in EMI. The econometric model will be subject to all pertinent propositions and caveats outlined in this section.

3.2 The Empirical Model

The econometric model to be presented in this section is predicated on the notion that, over the period 1956-62, a duopoly within EMI comprised of GE and Wh as Firm 1 and Firm 2, respectively, were serving the same markets and dominated the industry in the production and sale of certain goods. Three of these goods, panelboards, circuit breakers and switchgear, have been selected for testing, among other things, the hypothesis of duopolistic collusion. The choices of goods to be modeled and of the period of study are based only on data availability.

So given two firms and a decision to use quarterly data, two demand and two price-reaction models will be econometrically estimated for each of the three goods. Very importantly, as Slade (1986) observes,¹ reaction functions must be carefully formulated before being estimated if they are to yield accurate profit-maximizing results. In particular, Slade calls for accurate identification of slopes and of intercepts in the econometric models, and for researchers to be sure that industry PCVs are not equal to zero before this approach is tried.

The import of Slade's observation is that profit maximization is a given and that economists who use reaction functions to study firms must account for this given in their modeling. Although following Slade's recommendation can only be beneficial to researchers, it should be pointed out that many modern economists have shifted away from the ideal of profit maximization.

Anyway, the model specified in (3.2.1) and (3.2.2) is such that all demand and price-reaction functions are linear both in the parameters and in the explanatory variables. This means that all the parameters, including the PCVs, and explanatory variables are raised to the first power.²

¹Slade (1986), *op. cit.*

²Gujarati (1988), *op. cit.*, p.31.

With a change of notational form, this paper now presents the general demand and price-reaction models for any one of the three goods as:

$$q_i = a_{0i} + b_i p_i + d_i p_j + t_i v_i + e_i \quad (3.2.1)$$

$$p_i = f_{i0} + f_{i1} p_j + f_{i2} mc_i + f_{i3} R + f_{i4} v_i + u_i \quad (3.2.2)$$

where: $i = 1, 2$ ($i \neq j$) represents GE and Wh, respectively; the dependent variables q_i are quantities demanded; the variables p_i are transaction prices; the v_i are real gross national product (RGNP) used as demand-shift variables; mc_i are marginal costs which differ by goods and not by firms; R is the real interest rate (the market yield on three-month treasury bills); e_i and u_i are disturbance terms in the demand and price-reaction equations, respectively.

As explained in Section 3.1, the two procedures being used to estimate the models are three-stage least squares (3SLS) and AR1. The 3SLS approach corrects for cross-equation correlation.¹ Furthermore, for systems like this which are linear in both the parameters and the variables, the 3SLS procedure yields asymptotic efficiency.¹

3SLS results are not only efficient but they are often reassuring. For once 3SLS convergence is achieved, this implies that all equations are identified.² The procedure requires that cross-equation restraints (CERs) be imposed here on (3.2.2), the price reaction functions. The CERs to be imposed are:

$$f_{i0} = -a_{0i}/(-2b_i + d_i PCV_i) \quad (3.2.3)$$

$$f_{i1} = -d_i/(-2b_i + d_i PCV_i) \quad (3.2.4)$$

$$f_{i2} = (-b_i + d_i PCV_i)/(-2b_i + d_i PCV_i) \quad (3.2.5)$$

$$f_{i3} = -m_i/(-2b_i + d_i PCV_i) \quad (3.2.6)$$

¹Pindyck and Rubinfeld (1976), op. cit., p.282.

¹Kennedy, Peter.(1986). A Guide to Econometrics 2ed. The MIT Press: Cambridge, Massachusetts.

²This is so since 3SLS estimates are automatically generated from two-stage least squares (2SLS) estimates and 2SLS cannot yield estimates for equations which are not identified. See Pindyck and Rubinfeld, p.283.

$$f_{i4} = -t_i/(-2b_i + d_iPCV_i) \quad (3.2.7)$$

Put differently, (3.2.3) imposes CERs on the intercepts of the price-reaction functions, (3.2.4) imposes CERs on the slopes which measure price interdependence of the firms, and (3.2.5) imposes CERs on the parameters of marginal costs, while the last two equations above impose CERs on the parameters of the real interest rate and on the demand shift variables, R and v_i , respectively. In this study, the CERs f_{i0} to f_{i2} will always be imposed on the parameters of the same types of variables; but the CERs f_{i3} and f_{i4} will be subject to substitutions for and to retention or complete removal of R or v_i or both from a given price equation. Also, any increase in the number of variables in a price equation by adding, say, quarterly seasonal dummy variables, as done here, will introduce new parameters which will be automatically assigned appropriate CERs because of the form in which the CER substitutions will enter the price reaction functions.

Regarding substitutions, it should be noted that decisions made in this study to remove R or v_i or both from any equation of the system to be estimated are not as arbitrary as they might appear to be. Such decisions are based more so on this author's understanding of: (1) the relative importance of competing variables, given the period under review; (2) the dictates of I.O. theory; and (3) correlations between right-hand-side variables.

Visual inspection of the data suggests that, for circuit breakers and switchgear, the 3SLS approach will be successful in estimating the PCVs as parameters as distinct from the parameters of the PCVs which will also be estimated. However this success might not extend to the use of that approach with panelboards. In other words, it would not be surprising if, for panelboards, convergence is not achieved after as many as 75 iterations, or if, given the occurrence of convergence, the PCV estimates are meaningless.

Indeed, Figures III.1 through III.9 of Appendix III show that, while reasonable and expected intrafirm relationships exist between all book and transaction prices of each of the three goods, the same cannot be said for the interfirm relationships for panelboards. Figure

III.9 seems to suggest that one of the following three explanations is appropriate: (1) GE and Wh did not serve the same markets for panelboards over the period 1956-62; (2) given the same markets, then the panelboards sold by the two firms were the same good only in name; (3) the panelboards of the two firms were the same good in all respects, but the firms had used a very effective discount policy to create large transaction-price differentials so that most panelboards contracts would be collusively awarded to Wh during the period under review.

The first explanation is ruled out since the Courts have already established that the two firms served the same markets. Of the remaining two explanations, this author leans towards the collusive interpretation and turns to quantities sold of panelboards for supportive evidence. It is found that the ratio of the mean of GE's quantities of panelboards to that of Wh's is just 0.21. Yet, this striking result, although supportive, should not by itself be considered conclusive evidence that the collusive explanation holds. For the panelboards might have been highly differentiated. This paper will return to this discussion in Section 3.3 when the regression results have been analyzed.

Meanwhile, in anticipation of the possible failure of the 3SLS procedure to yield reportable results for panelboards, AR1 regressions with the "Fair option" added will also be run, using the maximum likelihood method. The AR1 estimator is expected to enhance the chances of obtaining meaningful estimates for panelboards.¹ If needed, the AR1 estimates will be used in conjunction with conjectural elasticities (CE_i) to determine the conjectures of the duopoly in the panelboards market. AR1 estimates will also be presented in Section 3.3

¹AR1 is a regression procedure which accounts for autocorrelated error. Estimates are obtained by using the ML method to impose "stationarity by constraining the serial correlation coefficient to be less than 1 [and by treating]...the first observation correctly rather than dropping it." Generally, this method converges faster than the "CORC" method which may also be used with the AR1 procedure. See: Hall, Bronwyn H., Rebecca Schnake and Clint Cummins (1986), *op. cit.*; Cochrane, D. and G. H. Orcutt.(1949). "Application of Least Squares Regression to Relationships Containing Autocorrelated Error Terms." *JASA* 44: 32-61; Fair, Ray C.(1970). "The Estimation of simultaneous Equation Models with Lagged Endogenous Variables and First Order Serially Correlated Errors." *Econometrica* 38: 507-16.

for circuit breakers and for switchgear to show the degree to which the 3SLS procedure with CERs imposed can worsen the statistical values which are usually reported.

For convenience, this paper will now change notation once more in order to present the system given by equations (3.2.1) through (3.2.7) in the form in which it will be estimated by 3SLS and AR1 procedures. On the one hand, the new notation for the 3SLS procedure will identify the three goods sold by the duopoly (pb for panelboards, cb for circuit breakers and sg for switchgear). On the other hand, the usual AR1 formulation and notation will be used to obtain separate estimates for panelboards.

The econometric model becomes:

3SLS Procedure:

$$qpb1 = apb01 + bpb1 * ppb1 + dpb1 * ppb2 + zpb11 * d24i56 \quad (3.2.8)$$

$$qpb2 = apb02 + bpb2 * ppb2 + dpb2 * ppb1 + mpb2 * R + tpb2 * v2 + zpb21 * dws567 \quad (3.2.9)$$

$$ppb1 = \frac{[-apb01 - dpb1 * ppb2 + (-bpb1 + dpb1 * PCVpb1) * mcpb1 - zpb11 * d24i56]}{(2 * bpb1 + dpb1 * PCVpb1)} \quad (3.2.10)$$

$$ppb2 = \frac{[-apb02 - dpb2 * ppb1 + (-bpb2 + dpb2 * PCVpb2) * mcpb2 - mpb2 * R - tpb2 * v2 - zpb21 * dws567]}{(-2 * bpb2 + dpb2 * PCVpb2)} \quad (3.2.11)$$

$$qcb1 = acb01 + bcb1 * pcb1 + dcb1 * pcb2 + zcb11 * der601 + zcb12 * d24i56 + dd12 * dum3 \quad (3.2.12)$$

$$qcb2 = acb02 + bcb2 * pcb2 + dcb2 * pcb1 + zcb21 * dws567 + dd22 * dum2 + dd23 * dum3 \quad (3.2.13)$$

$$pcb1 = \frac{[-acb01 - dcb1 * pcb1 + (-bcb1 + dcb1 * PCVcb1) * mccb1 - zcb11 * der601 - zcb12 * d24i56 - dd12 * dum3]}{(-2 * bcb1 + dcb1 * PCVcb1)} \quad (3.2.14)$$

$$pcb2 = \frac{[[-acb02 - dcb2 * pcb1 + (-bcb2 + dcb2 * PCVcb2) * mccb2 - zcb21 * dws567 - dd22 * dum2 - dd23 * dum3]}{(-2 * bcb2 + dcb2 * PCVcb2)} + dm5924 \quad (3.2.15)$$

$$qsg1 = asg01 + bsg1 * psg1 + dsg1 * psg2 + zsg11 * d24i56 + zsg12 * dumq61 + dd13 * dum2 + dd14 * dum4 \quad (3.2.16)$$

$$qsg2 = asg02 + bsg2 * psg2 + dsg2 * psg1 + tsg2 * v2 + zsg21 * dws567 + dd24 * dum1 + dd25 * dum3 \quad (3.2.17)$$

$$psg1 = \frac{[-asg01 - dsg1 * psg2 + (-bsg1 + dsg1 * PCVsg1) * mcsg1 - zsg11 * d24i56 - zsg12 * dumq61 - dd13 * dum2 - dd14 * dum4]}{(-2 * bsg1 + dsg1 * PCVsg1)} \quad (3.2.18)$$

$$psg2 = [-asg02 - dsg2 * psg1 + (-bsg2 + dsg2 * PCVsg2) * mcsg2 - tsg2 * v2$$

$$-zsg21*dws567-dd24*dum1-dd25*dum3]/(-2*bsg2+dsg2*PCVsg2) \quad (3.2.19)$$

AR1 Procedure:

$$\begin{aligned} qpb1 \quad & c \quad ppb1 \quad ppb2 \quad d24i56 \quad dum3 \\ & INST=(c,R,v2,dws567,mcpbq) \end{aligned} \quad (3.2.20)$$

$$\begin{aligned} qpb2 \quad & c \quad ppb2 \quad ppb1 \quad R \quad v2 \quad dws567 \quad dum3 \\ & INST=(c,d24i56,mcpbq) \end{aligned} \quad (3.2.21)$$

$$\begin{aligned} ppb1 \quad & c \quad ppb2 \quad mcpb1 \quad d24i56 \quad dum3 \\ & INST=(c,R,v2,dws567) \end{aligned} \quad (3.2.22)$$

$$\begin{aligned} ppb2 \quad & c \quad ppb1 \quad mcpb2 \quad R \quad v2 \quad dws567 \quad dum3 \\ & INST=(c,d24i56) \end{aligned} \quad (3.2.23)$$

where: pb, cb and sg identify the good represented in a given equation; the instruments for the AR1 procedure are listed; the AR1 procedure is tried only for panelboards and will include the "Fair option"; the 3SLS procedure imposes CERs on parameters of the price-reaction functions.

The variables for circuit breakers as well as the variables R and v_i and the eight dummy variables tried in the final run are described below in Table 3.2.1. Substituting "pb" and "sg" for "cb" in the table will give the relevant information about panelboards and switchgear. It should be noted that, of the eight dummy variables, three are specific to EMI, one is designed to capture economy-wide effects of a U.S. recession and four are expected to account for seasonality.

As referred to earlier, an important feature of the format of the 3SLS price-reaction models here is the flexibility achieved through algebraic manipulation in the substitution of the CERs into the functions. More specifically, the insertion of the CERs in the form of denominators to each price-reaction function leaves those equations open to easy manipulation in terms of adding and/or deleting variables.

But even more importantly, as Liang (1987) points out, the CERs "...are imposed on the estimation procedure by substitution to get a unique estimate of the price conjectures."¹ This is precisely why this author chose this procedure for estimating the model just presented.

Another pleasing feature of this econometric model is the fact that no price or demand equation contains more than three endogenous variables.² For, as econometricians point out, success in obtaining valid estimates is inversely proportionate to the number of endogenous variables contained in a model.

¹Liang (1987), op. cit., p.12.

²Technically, PCVs are parameters and not variables. But they are here estimated within the price equations as though they were variables.

Table 3.2.1. Regression Variables

<u>Variable</u>	<u>Description</u>
qcb1	Dependent variable, GE's demand function for CBs
qcb2	Dependent variable, Wh's demand function for CBs
pcb1	Dependent variable, GE's PR function for CBs
pcb2	Dependent variable, Wh's PR function for CBs
mccb1	GE's marginal cost, CBs
mccb2	Wh's marginal cost, CBs
der601***	U.S. Economic recession dummy variable: 1960:3-1961:1 = 1; 0 otherwise
d24i56*	2400 PSI innovation effects: 1956:1-1956:4 = 1; 0 otherwise
dws567**	Residual effects of EMI's 1955 white sale: 1956:1-1957:4 = 1; 0 otherwise
dumq61	EMI recession and indictments effects: 1961:1 - 1961:4 = 1; 0 otherwise
dum1*	Seasonal dummy: 1956:1,1957:1,...= 1; 0 otherwise
dum2*	Seasonal dummy: 1956:2,1957:2,...= 1; 0 otherwise
dum3*	Seasonal dummy: 1956:3,1957:3,...= 1; 0 otherwise
dum4*	Seasonal dummy: 1956:4,1957:4,...= 1; 0 otherwise

 Note: In Section 3.3., it is found that, given a one-tail test, five of the eight dummy variables above are significant at the 1% level (*), one at the 5% level (**) and one at the 10% level (***); PR means price-reaction; CBs means circuit breakers; substitutions of sg and pb for cb in the names of the variables above will give similar definitions for switchgear and for panelboards. Another dummy variable, dm5924, was used to deal with outliers. This is explained in Section 3.3.

3.3 Data and Analysis of Results

Unlike the perfect competitor or the monopolist, the oligopolist, even if he refrains from reacting to price and quantity strategies, must remain cognizant of his rivals behavior. In the absence of collusion, the oligopolist must strive to make accurate conjectures about rivals' responses if the firms' strategies are to return maximum benefit.

It was therefore incumbent upon students of oligopolies to find a way to model with accuracy the conjectures of oligopolists if they were to reflect the market behavior of these firms. Essential to the success of modeling market behavior is the availability of suitable data both at the firm and at the industry level.

I.O. economists have often been forced to conduct studies at the industry level when it would have been more appropriate to do so at the firm level. Fortunately, this author was able to obtain for this study firm data which had been used during the EMI court cases of the 1960's and which had since been used by another researcher for dissertation purposes.¹

However, the data obtained were far from complete and could not meet the needs of this study. Thus supplementary sources of official U.S. industry and firm data, including the Survey of Current Business² and this author's master's thesis,³ were tapped to fill most of the gaps. In only a few cases, interpolation was judiciously used to fill small gaps.

All monthly data are transformed into quarterly series and, where applicable, from nominal to real values. Apart from the introduction of the highly significant and effective dummy variable, dm5924, to "dummy out", for the period 1959:2 through 1959:4, outliers which were of doubtful validity, data "massaging" was avoided. But the raw data required a great deal of interpretation and of arithmetic manipulation before they could be included in

¹See Tomic (1985), op. cit.

²United States Foreign and Domestic Commerce Bureau.(1959-63). Survey of Current Business: vol.36-43.

³Husbands, Humphrey O.(1976). "The Phillips Curve and the United States Economy in Recent Years." Master's Thesis: Hunter College, City University of New York.

the data base. Among the dummy variables introduced were dum1 through dum4 to adjust for seasonality, d24i56 to capture innovation effects and dws567 to account for residual "white sale" effects (see Table 3.2.1). The period covered by data collection was dictated by the goals of this study.

The use here of disaggregated data is not only gratifying, but avoids the concealment of "inefficiencies" associated with the use of aggregates.¹ This is not to suggest that industry studies should not be conducted at the aggregate level. For it is seldom that I.O. researchers can obtain sensitive data at the firm level.

Perhaps, the greatest challenge regarding data collection and compilation for this study was determining how this paper would proceed to create marginal cost data which were unavailable from the two firms, GE and Wh. From the outset, this author was aware that proxies would have to be used for marginal cost and therefore tested a number of theories to this end. The final choice of two proxies, given by equations (3.1.1) and (3.1.2), is explained in Section 3.1.

In regard to estimation, the overall goal of this section is to obtain results that will lend empirical authority to the theoretical formulations of the price reaction models. As explained in the previous sections of this chapter, the econometric results to follow will feature estimates derived from both 3SLS and AR1 procedures.

The 3SLS results for circuit breakers and for switchgear sold by the duopoly are as follows:

$$\begin{aligned}
 qcb1 = & 11.773 + 0.0035343*pcb1 + 0.011186*pcb2 \\
 & (2.4442) (0.0004012) \quad (0.005679) \\
 & (4.8169) (8.8096) \quad (1.9696) \\
 & + 2.2835*der601 + 3.9995*d24i56 + 1.1775*dum3 \\
 & (1.6581) \quad (1.5670) \quad (1.2701) \\
 & (1.3772) \quad (2.5524) \quad (1.2701) \\
 R^2 = & 0.0002 \qquad \qquad \qquad (3.3.1)
 \end{aligned}$$

¹Dixit (1988), op. cit., p.164.

$$\begin{aligned}
 \text{qcb2} = & 26.524 + 0.016373*\text{pcb2} - 0.006047*\text{pcb1} \\
 & (5.3642) (0.004721) \quad (0.002436) \\
 & (4.9446) (3.4681) \quad (-2.4823) \\
 & + 5.3124*\text{dws567} + 1.6969*\text{dum2} - 1.1187*\text{dum3} \\
 & (2.8327) \quad (1.3725) \quad (1.6436) \\
 & (1.8754) \quad (1.2364) \quad (-0.6807) \\
 R^2 = & 0.15 \tag{3.3.2}
 \end{aligned}$$

$$\begin{aligned}
 \text{qsg1} = & 32.530 - 0.010412*\text{psg1} - 0.035226*\text{psg2} - 0.38837*\text{d24i56} \\
 & (7.4138) (0.004182) \quad (0.011434) \quad (0.78338) \\
 & (4.3878) (-2.4896) \quad (-3.0807) \quad (-0.49576) \\
 & - 0.070570*\text{dumq61} - 3.8797*\text{dum2} - 3.9610*\text{dum4} \\
 & (0.86846) \quad (1.3131) \quad (1.3127) \\
 & (-0.081259) \quad (-2.9546) \quad (-3.0176) \\
 R^2 = & 0.40 \tag{3.3.3}
 \end{aligned}$$

$$\begin{aligned}
 \text{qsg2} = & 15.229 + 0.018293*\text{psg2} + 0.0056599*\text{psg1} \\
 & (1.3625) (0.0023067) \quad (0.0026357) \\
 & (11.177) (7.9304) \quad (2.1474) \\
 & + 0.36011\text{E}-09*\text{v2} - 0.43670*\text{dws567} + 2.0800*\text{dum1} \\
 & (0.15488\text{E}-08) \quad (1.0040) \quad (0.51278) \\
 & (0.23251) \quad (-0.43496) \quad (4.0564) \\
 & + 1.8550*\text{dum3} \\
 & (0.63274) \\
 & (2.9318) \\
 R^2 = & .002 \tag{3.3.4}
 \end{aligned}$$

$$\begin{aligned}
 \text{pcb1} = & [- 11.773 - 0.011186*\text{pcb2} \\
 & (2.4442) (0.0056794) \\
 & (-4.8169) (-1.9696) \\
 & + (-0.0035343 + 0.011186*\text{PCVcb1})*\text{mccb1} - 2.2835*\text{der601} \\
 & (0.00040119) (0.0056794) \quad (0.17606) \quad (1.6581) \\
 & (-8.8096) \quad (1.9696) \quad (2.0035) \quad (-1.3772) \\
 & - 3.9995*\text{d24i56} - 1.1775*\text{dum3}] \\
 & (1.5670) \quad (0.92711) \\
 & (-2.5524) \quad (-1.2701) \\
 & /(-2 * 0.0035343 + 0.011186*\text{PCVcb1}) \\
 R^2 = & 0.003 \tag{3.3.5}
 \end{aligned}$$

$$\begin{aligned}
\text{pcb2} = & \left[\begin{array}{l} -26.524 - 0.016373*\text{pcb1} \\ (5.36421) (0.0047206) \\ (-4.9445) (-3.4684) \end{array} \right. \\
& + \left(\begin{array}{l} 0.016373 - 0.0060474*\text{PCVcb2} \\ (0.0047206) (0.002463) (0.97532) (2.8327) \\ (-3.4684) (-2.4822) (-2.8678) (-1.8754) \end{array} \right) * \text{mccb2} - 5.312*\text{dws567} \\
& - \left. \frac{1.6969*\text{dum2} + 1.1187*\text{dum3}}{(-2 * 0.016373 - 0.0060474*\text{PCVcb2})} \right] \\
& \left(\begin{array}{l} 1.3725 (1.6436) \\ (-1.2364) (0.68066) \end{array} \right) \\
& + 1095.1*\text{dm5924} \\
& \left(\begin{array}{l} 142.94 \\ (7.6613) \end{array} \right) \\
R^2 = & 0.63 \tag{3.3.6}
\end{aligned}$$

$$\begin{aligned}
\text{psg1} = & \left[\begin{array}{l} -32.530 + 0.035226*\text{psg2} + (0.010412 - 0.035226*\text{PCVsg1})*\text{mcsg1} \\ (7.4138) (0.01143) (0.004182) (0.011434) (0.051834) \\ (-4.3878) (3.0807) (2.4896) (-3.4896) (5.0777) \end{array} \right. \\
& + \left(\begin{array}{l} 0.38837*\text{d24i56} + 0.070570*\text{dumq61} + 3.8797*\text{dum2} \\ (0.78338) (0.86846) (1.3131) \\ (0.49576) (0.081259) (2.9546) \end{array} \right) \\
& + \left. \frac{3.9610*\text{dum4}}{(-2 * -0.010412 - 0.035226*\text{PCVsg1})} \right] \\
& \left(\begin{array}{l} 1.3127 \\ (2.9546) \end{array} \right) \\
R^2 = & 0.35 \tag{3.3.7}
\end{aligned}$$

$$\begin{aligned}
\text{psg2} = & \left[\begin{array}{l} -15.229 - 0.005699*\text{psg1} + (-0.018293 \\ (1.3625) (0.0026357) (0.0023067) \\ (-11.117) (-2.1474) (-7.9304) \end{array} \right. \\
& + \left(\begin{array}{l} 0.0056599*\text{PCVsg2})*\text{mcsg2} - 0.36011\text{E-}09*\text{v2} \\ (0.0026357) (1.4868) (0.15488\text{E-}08) \\ (2.1474) (2.2468) (-0.23251) \end{array} \right) \\
& + \left(\begin{array}{l} 0.43670*\text{dws567} - 2.0800*\text{dum1} \\ (1.0040) (0.51278) \\ (0.43496) (-4.0564) \end{array} \right) \\
& - \left. \frac{1.8550*\text{dum3}}{(-2*0.018293 + 0.0056599*\text{PCVsg2})} \right] \\
& \left(\begin{array}{l} 0.63274 \\ (-2.9318) \end{array} \right) \\
R^2 = & 0.45 \tag{3.3.8}
\end{aligned}$$

The AR1 results for panelboards are:

$$\begin{aligned}
 \text{qpb1} = & 4.917 + 0.040527*\text{ppb1} + 0.024927*\text{ppb2} \\
 & (8.0719) (0.016874) (0.023899) \\
 & (0.6085) (2.4017) (1.0430) \\
 & + 12.403*\text{d24i56} - 0.75105*\text{dum3} \\
 & (2.6253) (2.4556) \\
 & (4.7246) (-0.30585) \\
 R^2 = & 0.62 \tag{3.3.9}
 \end{aligned}$$

$$\begin{aligned}
 \text{qpb2} = & 108.14 + 1.3981*\text{ppb2} - 0.051367*\text{ppb1} \\
 & (23.925) (0.066465) (0.041721) \\
 & (4.5199) (21.035) (-1.2312) \\
 & - 11.049*\text{R} - 0.40493\text{E-}07*\text{V2} - 9.1990*\text{dws567} \\
 & (2.9431) (0.20068\text{E-}07) (5.1744) \\
 & (-3.7544) (-2.0178) (-1.7778) \\
 & + 6.7320*\text{dum3} \\
 & (6.2534) \\
 & (1.0765) \\
 R^2 = & 0.97 \tag{3.3.10}
 \end{aligned}$$

$$\begin{aligned}
 \text{ppb1} = & 475.44 + 0.068823*\text{ppb2} - 0.0017097*\text{mcpb1} \\
 & (25.948) (0.29396) (0.0014135) \\
 & (18.323) (0.23412) (-1.2096) \\
 & + 39.732*\text{dws567} + 42.410*\text{dum3} \\
 & (31.796) (27.755) \\
 & (1.2496) (1.5280) \\
 R^2 = & 0.27 \tag{3.3.11}
 \end{aligned}$$

$$\begin{aligned}
 \text{ppb2} = & - 38.822 + 0.014703*\text{ppb1} + 0.000264*\text{mcpb2} \\
 & (90.043) (0.13458) (0.000905) \\
 & (-0.43114) (0.10925) (0.29191) \\
 & + 4.4226*\text{R} + 0.16311\text{E-}06*\text{V2} + 9.5130*\text{dws567} \\
 & (11.799) (0.71974\text{E-}07) (22.042) \\
 & (0.37482) (2.2662) (0.43158) \\
 & + 17.254*\text{dum3} \\
 & (16.094) \\
 & (1.0721) \\
 R^2 = & 0.26 \tag{3.3.12}
 \end{aligned}$$

where the statistics under the coefficients give the standard errors and the t values, in that order.

The 3SLS and the AR1 procedures used here to make inferences about the duopoly's interfirm behavior are standard estimators. On the one hand, the 3SLS method imposes cross-equation restrictions (CERs) on the parameters, thus enabling direct estimation of the PCVs.¹ On the other hand, the AR1 estimator does not directly estimate the PCVs. However, the estimates from this procedure may be used in conjunction with what Crandall (1985)² calls conjectural elasticities to make inferences about market power. Since this author prefers 3SLS to AR1 as an estimator, precedence is here given to that estimator.

The 3SLS estimator yields good and expected results for circuit breakers and for switchgear but was unsuccessful in obtaining reportable PCV results for panelboards. This good will therefore be discussed in terms of the AR1 estimator. Table 3.3.1 presents a summary of the 3SLS estimates for PCVs and for elasticities (own, cross and conjectural) in regard to circuit breakers and switchgear, and a summary of AR1 estimates for panelboards.

It is clear from the table below that the major question to be resolved by this study has been answered by the 3SLS estimator, especially as far as switchgear are concerned. For circuit breakers, the table shows that GE, the industry's leader, perceives Wh as pricing the good collusively ($PCV_{cb1} = 2.0035$) while Wh perceives GE as pursuing a competitive pricing strategy ($PCV_{cb2} = -2.8678$).

In the case of switchgear, however, each firm perceives the other as following a collusive pricing strategy ($PCV_{sg1} = 5.0777$; $PCV_{sg2} = 2.2468$). What is more, all of the PCVs are highly significant and consistent (see Appendix I.10), two being reported at the 1% and

¹At this point, it should be made clear that the term price conjectural variations (PCVs) should not be interpreted in this model to mean anything more or less than, as Bresnahan (1989) puts it: "that theory of oligopoly [which] holds in the data."

²Crandall, Robert W. (December 1985). "Assessing the Impacts of the Automobile Voluntary Export Restraints upon U.S. Automobile Prices." Paper delivered at the Society of Government Economists.

**Table 3.3.1. Conjectures and Elasticities
EMI, 1956-62**

Var. or Param.	PCV Value	-----Elasticities-----			Est.
		Own	Cross	CEc	
PCVcb1	2.0035**	0.28**	0.14	0.002**	3SLS
PCVcb2	-2.8678*	0.20*	-0.49	0.11*	3SLS
PCVsg1	5.0777*	-0.29**	-0.68	0.02*	3SLS
PCVsg2	2.2468**	0.23*	0.10	0.01**	3SLS
ppb1	n.a.	0.66**	0.04	0.0075	AR1
ppb2	n.a.	0.48*	-0.16	0.1349	AR1

Source: 3SLS estimator and Author's calculations.

Note: * means significant at the 1% level, ** significant at the 5% level; CEc = Crandall's (Dec.1985) conjectural elasticity.

two at the 5% level since it is customary to do so. Given the data, this indeed is strong confirmation of the presence over the period 1956-62 of collusive pricing behavior in the industry.

It is interesting to note that, as expected, the duopoly exhibited both competitive and collusive behavior over the period 1956-62. On the one hand, since the results show that both firms of the duopoly perceived collusive pricing in their switchgear market, then collusive pricing of switchgear must have existed.¹ On the other hand, since the results for the circuit breakers market show that GE perceived collusive pricing behavior by Wh while Wh perceived competitive behavior by GE, then the combined behavior cannot be categorically collusive. Indeed, it is possible that both types of behavior coexisted in the circuit breakers market. For it appears that the market behavior adopted by the firms depended upon the intrinsic and

¹Incidentally, these data do not reveal Cournot behavior in any of the three markets.

customer-assigned characteristics of the good being purchased. However, if the PCVs for circuit breakers are evaluated in conjunction with the CEcs, then the perception of the two firms' market behavior becomes clearer: GE emerges as the market leader and Wh as the follower.

The elasticities reported in Table 3.3.1 as well as prices as explanatory variables in the demand equations also tell a corroborative story. Ignoring signs and panelboards for a moment, this study shows that all of the elasticities are small, suggesting that circuit breakers and switchgear were suitable goods for establishing market power through collusive behavior. In regard to rival prices, every one in the four demand functions given by (3.3.1) through (3.3.3) is significant, one at the 1% level and three at the 5% level.

The small elasticity values may also have implications for price discrimination in EMI. Demand theory teaches that small elasticity values may be associated with price discrimination in a given market.¹ This means that the more inelastic the demand for a good is, the more can one expect to find price discrimination associated with the sale of that good.

Regarding the performance of dummy variables, Table 3.2.1 of Section 3.2 shows that five of eight dummy variables were significant at the 1% level and one at the 5% level. Added to this, the dummy variable der601 shown in the table was significant at the 10% level. Thus seven of the eight dummy variables were tried with success.

Perhaps, the most interesting feature of the results returned for dummy variables is the fact that three of the significant ones point to important elements of I.O. theory. This is important since dummy variables reported here were chosen with I.O. theory in mind. Strangely enough, the dummy variable der601 shows a positive effect of the U.S. economic recession of 1960-61 on the sales of GE circuit breakers. It seems from this paper's market share analysis, however, that this positive effect registers a shift in sales away from Wh to GE

¹Chiang, Alpha C.(1984). Fundamental Methods of Mathematical Economics 3ed. New York: McGraw-Hill Book Company, p.358.

rather than the anomaly of increasing sales during a recession. As expected, d_{24i56} shows a positive effect of 2400 PSI technology on the sale of GE circuit breakers. Also, as expected, d_{ws567} for the 1956-57 residual effect of the 1955 "white sale" shows a positive effect only on the sale of Wh circuit breakers. The dummy variable d_{24i56} represents process innovation which reduces production costs.¹ As GE was regarded as the technological leader of the industry,² it is not surprising that this innovation dummy variable was successful only for that firm.

One of the major goals of this study is to determine by simple regressions and by summary statistics whether GE and Wh discriminated among their customers on the basis of the size of orders. The a priori notion is that, given what appears to be a standard policy of discounting book prices, it would have been possible for GE and Wh, wittingly or not, to have price discriminated against small orders.

Table II.1 of Appendix II, which is self explanatory, addresses this concern. It presents discounts allowed and total revenue data along with the results of simple linear regressions in which discounts off book prices are regressed on both small and large orders for the period 1956-62. For each good, the data are arbitrarily partitioned into small and large orders by the mean of each distribution, with values less than or equal to the mean being regarded as small orders. Book values are given in thousands of dollars.

The positive slope (M) and the intercept (B) of each distribution, all of which have been identified, are the key statistics for determining the presence of discrimination against small orders. In every case for circuit breakers and for switchgear, the slope for small orders is bigger than that for large orders. However, these slopes are not significantly different from zero and, within the relevant income range, the two regression lines do not cross. Therefore, the decision as to whether discrimination existed has to be made on the basis of the intercept

¹Tirole (1989), op. cit.

²See Sultan (1975), op. cit.

alone. Since the intercept for the large orders is greater than that for small orders, then small orders were discriminated against in the markets for circuit breakers and switchgear. In regard to panelboards, the same conclusions hold for GE, but it is indeterminate for Wh. The bigger intercepts for small orders imply that the two firms price discriminated against customers on the basis of small orders.

Returning to the question of the signs of the slope coefficients reported for demand curves, this paper must logically explain why only one of the six demand curves ($qcb1$, $qcb2$, $qsg1$ and $qsg2$ estimated by 3SLS; $ppb1$ and $ppb2$ estimated by AR1) has the expected negative sign. The demand curve with the expected sign is GE's $qsg1$ for switchgear.¹

One plausible explanation of the unexpected signs is that, given close substitutes² which are significant in the consumer's budget, then it is possible for the income effect to dominate the substitution effect leading to a direct relationship between price and quantity demanded.³

A second plausible explanation is that this study covers only a short period of seven years in the life of the duopoly. Sometimes, a short period coincides with a "wrinkle" in otherwise normal behavior, a wrinkle that would be ironed out in the long run thus preserving the integrity of the law of demand.

A third explanation is that, what is being observed is not an upward-sloping demand curve at all but repositioning on a series of higher and higher demand curves over seven years as the duopoly becomes sufficiently powerful to set both prices and quantities in their markets for very inelastic goods, as shown in Table 3.3.1. In this author's view, this explanation is the

¹Although AR1 is presented here for the specific purpose of providing estimates for panelboards, AR1 R² estimates in the entire model will also be presented for the purpose of making comparisons with similar 3SLS statistics.

²Avoiding the almost impossible task of calculating a multiplicity of elasticities for EMI which produces hundreds of products, this study follows a convention by assuming with good reason that, on the whole, the duopoly's products are substitutes.

³Chiang (1984), *op. cit.*

most appealing of the three. For example, Appelbaum's (1982) study of EMI among other firms includes the period of this study. Appelbaum found collusion by applying the quantity approach. This study also finds collusion but through the price approach. Economists modeling the quantity approach imply that the firms being studied set quantities while those applying the price approach imply that the firms set prices.

Shifting the focus on the AR1 estimator, this paper now analyzes the results for panelboards corresponding to the discussion so far for circuit breakers and for switchgear. Equations (3.3.9) through (3.3.12) show that none of the coefficients of rival prices is significant, not even at the 10% level. But all own prices are significant. This means that rival prices did not play a significant role in the duopoly's price-setting decisions for panelboards. This also explains the strange spatial detachment of the graphs of firm prices in Figure III.9 of Appendix III where GE's transaction prices for panelboards are contrasted against Wh's transaction prices.

For both 3SLS and AR1 procedures, the question of low values for R^2 should also be addressed. Now the corresponding AR1 R^2 -values for circuit breakers and for switchgear are: qcb1, 0.80; qcb2, 0.55; pcb1, 0.35; pcb2, 0.88; qsg1, 0.74; qsg2, 0.63; psg1, 0.43; psg2, 0.67. These statistics suggest that the advantages reaped by using 3SLS as an estimator with CERs imposed are associated with a trade-off in the form of poor R^2 -values. Moreover, the AR1 R^2 values are themselves typically lower than similar values yielded by the ordinary least squares estimator. This is because the AR1 procedure embodies rho transformations which depress R^2 values.¹

So given reliable PCV estimates which show the presence of collusion² and the potential for competition in the sale of two different types goods in EMI, Schmalensee's

¹Hall, Schnake and Cummins (1986), op. cit., p.29.

²See Tomic (1985), op. cit., who found that the industry (not the duopoly defined here) was collusive for the period 1957-59 and was competitive otherwise.

(April 1987)¹ comment about market share immediately comes to mind. Schmalensee claims that, in theory, collusion and "unstable [market] shares and ranks are inconsistent with effective collusion." Implicit in this comment is the notion that GE and Wh could not have effectively colluded if their market shares and ranks were unstable.

There can be no doubt about the stability of rank. For the Big Two, GE and Wh in that order, have been at the top of EMI for many years. Moreover, it seems to be a given in U.S. industry that market share confers rank. Nevertheless, there were legal ramifications which could have seriously destabilized market share in respect to circuit breakers and switchgear while leaving rank and collusion intact.

Table 3.3.2 which follows supports this view as it provides a detailed analysis of quarterly market share held by GE and Wh in regard to circuit breakers and switchgear. Over the period of this study, the table shows fluctuations in market share which appear to be a direct response to charges brought against EMI by the US. Department of Justice.

For example, before the Fuller investigation began in 1959, the average yearly two-firm concentration level for circuit breakers sold by the duopoly rose by 3.46 percentage points to 60.70% and then fell by 9.53 percentage points to 51.17%. These were modest changes which would probably have gone unnoticed. However, in the period after 1959 but before the indictments were handed down, the two-firm concentration level rose by 28.53 percentage points to its highest level for the period under review, and then fell by 24.08 percentage points to 55.62%. This is a large correction by any standard of market-share stability. After the indictments were handed down, the yearly average market share of GE and Wh combined continued to fall, first by 5.75 and then by 6.98 percentage points to its lowest level of 42.89 percent in the fourth quarter of 1962.

The average yearly two-firm market share for switchgear over the same period differed somewhat from that for circuit breakers, but the implications are the same. The level

¹Schmalensee (April, 1987), *op. cit.*

**Table 3.3.2. Quarterly Market Share in EMI
Circuit Breakers and Switchgear, 1956-62**

	Circuit Breakers				Switchgear			
	GE	Wh	GE+Wh	GE+Wh /Year	GE	Wh	GE+Wh	GE+Wh /Year
1956:1	63.87	1.94	65.81		59.71	23.46	82.17	
2	51.57	5.40	56.97		47.92	35.84	83.76	
3	45.07	1.43	46.50		35.75	42.01	77.76	
4	57.30	2.40	59.70	57.25	36.38	22.90	59.28	75.74
1957:1	52.27	5.59	57.86		56.84	28.19	85.03	
2	42.47	22.83	65.30		53.53	28.23	81.76	
3	54.07	5.07	59.14		41.40	53.43	94.83	
4	48.70	11.81	60.51	60.70	38.50	24.74	63.24	81.22
1958:1	47.60	2.68	50.28		36.46	43.53	79.99	
2	45.53	0.76	46.29		40.33	36.66	76.99	
3	48.77	0.74	49.51		35.08	38.98	74.06	
4	57.97	0.61	58.58	51.17	62.23	35.24	97.47	82.13

1959:1	38.06	47.33	85.39		34.53	35.71	70.24	
2	37.57	44.00	81.57		45.89	34.01	79.90	
3	27.42	38.67	66.09		26.33	24.87	51.20	
4	51.41	34.44	85.74	79.70	48.19	38.91	87.10	72.11
1960:1	46.33	0.33	46.66		31.57	48.33	79.90	
2	69.33	1.55	70.89		69.88	27.72	97.60	
3	58.00	0.56	58.56		44.83	42.64	87.47	
4	44.33	3.05	46.38	55.62	47.51	28.74	76.26	85.31
1961:1	59.67	3.66	63.33		31.58	45.72	77.30	
2	49.67	3.42	53.09		33.67	26.51	60.18	

3	39.00	6.08	45.08		27.55	42.77	70.32	
4	37.33	0.64	37.97	49.87	30.00	18.96	48.96	64.19
1962:1	46.00	1.61	47.61		49.67	18.67	68.34	
2	54.00	2.30	56.30		37.33	19.04	56.37	
3	40.33	0.99	41.32		35.33	21.06	56.39	
4	25.33	0.99	26.32	42.89	34.33	15.70	50.03	57.78

Source: Author's analysis using firm data.

Note: For circuit breakers, GE plus Wh falls below 50% market share (the Greer (1980) standard) only 10 times, and below 40% market share (the Scherer (1980) standard) only twice. For switchgear, these respective numbers are 1 and 0. The number of observations is 28. See Chart III.1, Appendix III. Similar data were not available for panelboards. The first underline in the table marks the year (1959) when Fuller began his investigation of the industry. The second underline draws attention to the period (1961) of indictments convictions of EMI representatives.

rose continuously between 1956 and 1958, first by 5.48 and then by only 0.91 percentage points to 82.22%. The Fuller investigation period of 1959-60 coincided with a fall in the duopoly's market share by 10.02 percentage points, but that period also registered a subsequent rise by 13.20 percentage points to the high for the period 1956-62 of 85.31%. During the post-indictments period, the two-firm concentration level plummeted, giving up 21.12 percentage points by 1961:4 and then falling by another 6.41 percentage points to its lowest level of 57.78% for the period under review.

But Table 3.3.2 tells another story. It supports this paper's contention that GE was dominant in EMI, at least in both circuit breakers and switchgear. Over the period under review, GE's average quarterly market share was 46.17% for circuit breakers and 40.42% for switchgear. Wh's corresponding averages were 8.65% and 31.12%.

It is important to note that while the ratio of GE's average to Wh's is 1.3 for switchgear, it is 5.34 for circuit breakers. But recall in Section 3.2 that a similar ratio for panelboards was 0.21. It seems reasonable to argue on the basis of these statistics that market partitioning was one of the duopoly's collusive strategies. Specifically, it appears that agreement had been reached between the two firms for GE almost to abandon the panelboards market to Wh (GE:Wh=0.21) and for Wh to compensate by almost abandoning the circuit breakers market to GE (Wh:GE=0.19).

The levels of the duopoly's concentration in the market studied here, as revealed by Table 3.3.2, are far higher than the levels independently proposed by Scherer (1980) and by Greer (1980) as evidence of the existence of duopoly. The two standards were 40% and 50%, respectively. Using these standards, Chart III.1 of Appendix III presents a comparison of the incidence of duopoly behavior over the years 1956-62. For example, the 1956 entry shows in part that this study observed duopoly behavior in the circuit breakers market for eight months of the year under the Greer standard and for eleven months of the year under the Scherer standard.

I.O. economists have tried many variables to determine the incidence of concentration in the U.S. economy. Some of the most popular concentration variables reported in I.O. studies have been cited in a study by Curry and George (March 1983).¹ Table 3.3.3 presents the seven most popular variables, as reported by these authors. Although it is not within the purview of this paper, it would be interesting to find out which of these seven variables played the most important role in establishing the high levels of concentration in EMI over the period 1956-62.

¹Curry, B. and George, K. D.(March 1983). "Industrial Concentration: A Survey." Journal of Industrial Economics vol.XXXI no.3: 203-255.

**Table 3.3.3. Determinants of Industry Concentration
in 11 Industry Studies**

<u>Variable</u>	<u>Frequency</u>	<u>Relationship to C_n</u>
Plant scale economies	10/11*	+
Plants per firm	4/11*	+
Initial capital regulations	4/11*	+
Advertising/sales ratio	3/11*	+
Industrial growth	3/11	Two -; one \pm
Industry size	2/11*	One +; one -
Average firm size	1/11*	+

 Source: An adaptation from Curry, B. and K. D. George.(March 1983). "Industrial Concentration: A Survey." Journal of Industrial Economics vol.XXXI, No.3: 203-255.

Note: The second column gives the frequency of use by 11 studies reviewed by Curry and George; * denotes significance at the 5% level; the signs in the third column denote the relationship between the variable used and concentration (C_n).

3.4 Summary and Remarks

In Section 3.1, this paper provides an overview of the goals and expectations of econometric modeling and testing of the market behavior of GE and Wh as a duopoly in the electrical machinery industry (EMI) over the period 1956-62. A preliminary discussion of the variables to be included in the econometric model and of the choice of estimating procedures is presented. The question of formulating a marginal-cost variable, as given by equations (3.1.1) and (3.1.2), is perhaps the most important feature of this section.

To Section 3.2 was assigned the important task of translating theory into an econometric model, using the price approach. This task is accomplished by the simultaneous systems given by equations (3.2.8) through (3.2.23).

It is gratifying to note the degree of success achieved in Section 3.3 by using the price approach to determine the market structure of EMI, as revealed by the data for the period 1956-62. The major goal of determining whether GE and Wh, as a duopoly, colluded in marketing their goods was satisfied by using 3SLS and AR1 procedures.

For switchgear, the 3SLS estimator has determined that GE and Wh engaged in collusive behavior. For circuit breakers, the 3SLS estimator has found a mixed market posture, with GE regarding Wh as collusive and with Wh regarding GE as competitive. In the case of panelboards, however, the results of the 3SLS procedure were meaningless. This led to the use of an AR1 estimation procedure which has determined that the data did not show that panelboards were either collusively or competitively marketed. What the AR1 regressions did show for panelboards was that neither firm's pricing policy affected the other firm's pricing policy for that good. This conclusion is supported by graphical analysis in Figure III.9 of Appendix III.

Apart from regression analysis, Section 3.3 makes use of summary statistics to discuss important I.O. topics such as market share, concentration, innovation, price discrimination by

size of orders and the incidence of duopoly. The conclusions reached from summary analysis provide useful insights into the behavior of GE and Wh as a powerful duopoly of EMI.

4.0 Conclusion

4.1 Summary and Implications

The purpose of this paper was to ascertain through rigorous empirical methods whether GE and Wh, as a duopoly of the electrical machinery industry (EMI), colluded by setting prices over the period 1956-62. That purpose has been met in regard to switchgear which is one of the three goods studied. The other two goods were circuit breakers and panelboards.

There was a dual incentive for revisiting EMI. First, history has shown that decisions of the Courts are often rejected by I.O. economists after those decisions have been subjected to rigorous empirical analysis. Second, previous studies of EMI by I.O. economists have supported the Courts decision, but this author grasped the opportunity to bring a different approach to the study of the industry. To the best of this author's knowledge, this is the first study of EMI to use a price-reaction approach which directly explains pricing behavior instead of a quantity approach which directly explains goods quota systems, as discussed in Chapter 1.

As with the quantity approach, the Courts' decision is supported by the price-reaction approach used here. But, given the data, this paper now confirms that administered pricing behavior was important in the marketing of the industry's goods.

Tangential to the finding of collusive pricing behavior within the data was the discovery that GE and Wh, as a duopoly, price discriminated against their customers on the basis of small orders. Apart from meeting these two major goals, this study has also confirmed from the data that GE and Wh were in fact a duopoly and that high levels of concentration were associated with the duopoly over the period under review.

Given the indictments and convictions handed down to EMI firms during the 1960s, I.O. economists should turn their attention to the behavior, not only of EMI, but of firms in general which continue to enjoy high levels of concentration during their post-trial years. For

the basic implication of the results of this study relates to whether researchers will find "business as usual" or a corrective change in market behavior.

Fisher (1987) suggests that successful prosecution of collusion cases does not necessarily affect actual collusive structure.¹ This comment particularly relates to tight oligopoly. But what this study considers more important is behavior, given the degree of concentration. So the question this paper poses is: should I.O. economists expect a change in market behavior during and beyond the years of the court trials?

Indeed, studies like this are important precisely because there are always lessons from the past to be learned for future guidance. But these lessons cannot be learned if data are not available to researchers. In this study, data limitations precluded the attainment of certain results that would normally be included in the presentation and analysis of data. For example, the unavailability of actual firm marginal cost data made it necessary for this study to use proxies for marginal cost, as has to be done in studies of this sort. Consequently, price-cost margins, the Lerner index and other equations dependent on marginal cost can only be as good as the proxies happen to be.²

Nevertheless, this author has confidence and finds gratification in the methods used and in the results presented here. Often, researchers of every field of study must either accept the second best or do no research at all.

¹Fisher (1987), *op. cit.*

²Calculations for such statistics may be carried out in Appendix I of this paper with the understanding that true marginal cost was not available to this author.

4.2 Future Study

Perhaps, the most technically challenging suggestion encountered by this author during the reading phase of the research for this study was Friedman's (1983) call for dynamic analysis on the effects of entry barriers on prices, production and profits. This author has not encountered any price approach or quantity approach, as defined by this study, which uses dynamic analysis. Attempts should be made to translate this challenge into reality for future study of EMI and of other industries.

Sociologically, however, future studies of EMI should look at profitability before tax, not only from the point of view of the level of profits earned during periods of collusive behavior, but also in terms of the impact of the collusive behavior on welfare. This, of course, involves either making firm-sensitive cost data available to I.O. economists or the development of a proxy for marginal cost that can generally be applied with confidence before testing. In terms of this study, it would also be interesting to determine by empirical analysis whether GE, as the duopoly's leader, earned higher profits than Wh over the period 1956-62, and if so, whether the higher level of profits could be directly linked to GE's leadership in the industry or to firm size.

Overall, this author believes that the NEIO approach to the study of industrial structures and behavior should be the mode of the future. I.O. economists using these methods should strive to obtain results which, given the data, are robust to reasonable variations in econometric methods and to variations in specification.

APPENDIX I

Mathematical Derivations

I.1. Determining PCV_i in parametric form by equating the F.O.C. of quantity-setting firms to the F.O.C. of price-setting firms, and then setting $QCV_i = -1$.

Perfectly Competitive Result

$$\frac{-\beta_j - \delta_i QCV_i}{\beta_i \beta_j - \delta_i \delta_j} = \frac{1}{-\beta_i + \delta_i PCV_i}.$$

Therefore,

$$\frac{-\beta_j + \delta_i}{\beta_i \beta_j - \delta_i \delta_j} = \frac{1}{-\beta_i + \delta_i PCV_i}$$

$$(-\beta_j + \delta_i)(-\beta_i + \delta_i PCV_i) = \beta_i \beta_j - \delta_i \delta_j.$$

$$\beta_i \beta_j - \beta_j \delta_i PCV_i - \beta_i \delta_i + \delta_i^2 PCV_i = \beta_i \beta_j - \delta_i \delta_j$$

$$-\beta_j \delta_i PCV_i + \delta_i^2 PCV_i = \beta_i \delta_i - \delta_i \delta_j$$

$$PCV_i(-\beta_j \delta_i + \delta_i^2) = \beta_i \delta_i - \delta_i \delta_j$$

$$PCV_i = \frac{\beta_i \delta_i - \delta_i \delta_j}{-\beta_j \delta_i + \delta_i^2} = \frac{\beta_i - \delta_j}{-\beta_j + \delta_i},$$

of ambiguous sign. This result would be strictly negative iff $\beta > \delta$ for all i and j . It is different from Liang's result because of the sequence of signs in the numerator. See Table 2.1.2.

I.2. Determining PCV_i , now setting $QCV_i = 1$.

Collusive Result

$$\frac{-\beta_j - \delta_i QCV_i}{\beta_i \beta_j - \delta_i \delta_j} = \frac{1}{-\beta_i + \delta_i PCV_i}.$$

Therefore,

$$\frac{-\beta_j - \delta_i}{\beta_i \beta_j - \delta_i \delta_j} = \frac{1}{-\beta_i + \delta_i PCV_i}$$

$$(-\beta_j - \delta_i)(-\beta_i + \delta_i PCV_i) = \beta_i \beta_j - \delta_i \delta_j$$

$$\beta_i \beta_j - \beta_j \delta_i PCV_i + \beta_i \delta_i - \delta_i^2 PCV_i = \beta_i \beta_j - \delta_i \delta_j.$$

$$\beta_i \delta_i + \delta_i \delta_j = PCV_i(\beta_j \delta_i + \delta_i^2)$$

$$PCV_i = \frac{\beta_i \delta_i + \delta_i \delta_j}{\beta_j \delta_i + \delta_i^2} = \frac{\beta_i + \delta_j}{\beta_j + \delta_i} > 0 \text{ for } \beta, \delta > 0.$$

I.3. Deriving equilibrium condition-- $cmr_1 = mc_1$.

$$\text{F.O.C.: } q_1 + (p_1 - mc_1) \left[\frac{\partial q_1}{\partial p_1} + \frac{\partial q_1}{\partial p_2} \frac{dp_2}{dp_1} \right] = 0 \quad (2.3.10)$$

$$\left[\frac{\partial q_1}{\partial p_1} + \frac{\partial q_1}{\partial p_2} \frac{dp_2}{dp_1} \right] = \frac{-q_1}{p_1 - mc_1}$$

Therefore,

$$-p_1 + mc_1 = 1 / [\cdot] (q_1)$$

$$mc_1 = p_1 + \{q_1 / [\cdot]\} \text{ at equilibrium.}$$

Therefore,

$$p_1 + \{q_1 / [\cdot]\} = cmr_1.$$

$$\text{Thus } cmr_1 = p_1 + \{q_1 / (-\beta_1 + \delta_1 PCV_1)\} \quad (2.2.11)$$

where $-\beta_1 = \partial q_1 / \partial p_1$; $\delta_1 = \partial q_1 / \partial p_2$; $PCV_1 = dp_2 / dp_1$.

I.4. Deriving PCV_1

Setting (2.3.9) = (2.3.10) gives the joint π -max. collusive result. This is also the own π -max. w.r.t. firm 1. Thus:

$$q_1 + (p_1 - mc_1) \frac{\partial q_1}{\partial p_1} + (p_2 - mc_2) \frac{\partial q_2}{\partial p_1} = q_1 + (p_1 - mc_1) \left[\frac{\partial q_1}{\partial p_1} + \frac{\partial q_1}{\partial p_2} \frac{dp_2}{dp_1} \right]$$

Canceling q_1 and rearranging the right hand side:

$$(p_1 - mc_1) \frac{\partial q_1}{\partial p_1} + (p_2 - mc_2) \frac{\partial q_2}{\partial p_1} = (p_1 - mc_1) \frac{\partial q_1}{\partial p_1} + \frac{\partial q_1}{\partial p_2} \frac{dp_2}{dp_1} (p_1 - mc_1).$$

Therefore,

$$\frac{p_2 - mc_2}{p_1 - mc_1} \frac{\partial q_2}{\partial p_1} = \frac{\partial q_1}{\partial p_2} \frac{dp_2}{dp_1},$$

after dividing through by $(p_1 - mc_1)$ and making obvious cancellations on both sides.

$$PCV_1 = \frac{[(p_2 - mc_2) / (p_1 - mc_1)] (\partial q_2 / \partial p_1)}{(\partial q_1 / \partial p_2)} = \frac{dp_2}{dp_1} = (PCM_2 / PCM_1) (\delta_2) (\partial p_2 / \partial q_1),$$

the same thing as equation (2.2.13).

I.5. Deriving PCV_2 .

$$PCV_2 = \text{inverse of } PCV_1 \text{ above.}$$

I.6. Deriving $Le_1 = \text{firm 1's Lerner Index.}$

$$\frac{\partial \pi_1}{\partial p_1} = q_1 + (p_1 - mc_1) \left[\frac{\partial q_1}{\partial p_1} + \frac{\partial q_1}{\partial p_2} \frac{dp_2}{dp_1} \right] = 0$$

Dividing throughout by q_1 to eliminate q_1 :

$$1 + (p_1 - mc_1) \left[\left(\frac{\partial q_1}{\partial p_1} \frac{1}{q_1} \right) + \frac{\partial q_1}{\partial p_2} \cdot \frac{1}{q_1} \cdot \frac{dp_2}{dp_1} \right] = 0$$

Multiplying by $p_1/p_1=1$ and by $p_2/p_2=1$ changes nothing. Thus:

$$\left[(p_1 - mc_1)/p_1 \right] \left[(\partial q_1/\partial p_1)(p_1/q_1) + (\partial q_1/\partial p_2)(p_2/q_1)(dp_2/dp_1)(p_1/p_2) \right] = -1$$

$$Le_1 = (p_1 - mc_1)/p_1 = -1 / \left[(\partial q_1/\partial p_1)(p_1/q_1) + (\partial q_1/\partial p_2)(p_2/q_1)(dp_2/dp_1)(p_1/p_2) \right] > 0;$$

or:

$$\begin{aligned} Le_1 &= -1 / \{ -\beta_1(p_1/q_1) + [\delta_1(p_2/q_1)] [PCV_1(p_1/p_2)] \} \\ &= -1 / [e_{11} + e_{12} \cdot CE_1] . \end{aligned}$$

Thus:

$$Le_1 = (-1/e_{11}) + (-1/e_{12} \cdot CE_1),$$

is dependent on CE_1 and > 0 for $(-1/e_{11}) > (-1/e_{12} \cdot CE_1)$.

Also:

$$Le_1 = -1 / [e_{11} + (\delta_1 PCV_1)(p_1/q_1)] .$$

I.7. Deriving firm conjectural elasticity, CE_1 .

From Le_1 , we can define CE_1 as:

$$CE_1 = PCV_1(p_1/p_2) > 0.$$

Also:

$$e_{12} = (\partial q_1/\partial p_2)(p_2/q_1); e_{21} = (\partial q_2/\partial p_1)(p_1/q_2).$$

From Appendix I.4., we see that $PCV_1(p_1/p_2)$ may be rewritten as:

$$CE_1 = \left[\left(\frac{p_2 - mc_2}{p_1 - mc_1} \frac{\partial q_2}{\partial p_2} \right) / (\partial q_1/\partial p_2) \right] \cdot (p_1/p_2) .$$

After further manipulation, we have:

$$CE_1 = \{ [(p_1 q_1 / p_2 q_2)(p_1 - mc_1) / p_1] / [(p_2 - mc_2) / p_2] \} [e_{12} / e_{21}]$$

$$CE_1 = \underset{(+)}{(R_1/R_2)} \underset{(+)}{(Le_1/Le_2)} (e_{12}/e_{21})$$

The sign of CE_1 depends upon the sign of Le_1/Le_2 . For $p_i > mc_i$, $CE_i > 0$, $i=1,2$.

I.8. Deriving $\partial p_i / \partial PCV_i$ in parametric form.

$$mc_i = p_i + [q_i / (-\beta_i + \delta_i PCV_i)] \text{ at equilibrium; } mc_i \text{ constant.}$$

$$p_i = mc_i - [q_i / (-\beta_i + \delta_i PCV_i)]$$

$$p_i = [mc_i(-\beta_i + \delta_i PCV_i) - q_i] / (-\beta_i + \delta_i PCV_i)$$

$$\partial p_i / \partial PCV_i = \{(-\beta_i + \delta_i PCV_i)(mc_i \delta_i) - [mc_i(-\beta_i + \delta_i PCV_i) - q_i] \delta_i\} / (-\beta_i + \delta_i PCV_i)^2$$

After cancellations:

$$\partial p_i / \partial PCV_i = \delta_i q_i / (-p_i \delta_i PCV_i)^2$$

By assumption, $q_i = \delta_i(\alpha_i - \beta_i p_i + \theta_i \nu_i + \delta_i p_j)$

Thus:

$$\partial p_i / \partial PCV_i = \delta_i(\alpha_i - \beta_i p_i + \theta_i \nu_i + \delta_i p_j) / (-p_i \delta_i PCV_i)^2$$

I.9. Evaluating the result in I.8.

Assume that we begin evaluation from the level of perfect competition. Then, in the equation immediately above, $p_i = mc_i$. Making that substitution yields:

$$\partial p_i / \partial PCV_i = [\delta_i(\alpha_i - \beta_i mc_i + \theta_i \nu_i + \delta_i p_j)] / (-\delta_i p_i PCV_i)^2 \geq 0,$$

where $\beta_i > \delta_i$ and $p_j = p_i = mc_i$. Approaching collusive behavior, then $\partial p_i / \partial PCV_i$ may be ≥ 0 . It is > 0 iff, in the numerator, $mc_i < (\alpha_i + \theta_i \nu_i + \delta_i p_j) / \beta_i$. So, in order for price to increase in PCV_i (i.e., for the upward sloping reaction function of firm i to shift to the right, the "iff" condition must be met.

I.10. Deriving $CPCV_i = \text{consistent } PCV_i$.

$$PR_i(p_j) = PR(p_j, mc_i, \nu)$$

$$PR_j(p_i) = PR(p_i, mc_j, \nu)$$

$$PCV_i = \partial PR_j / \partial p_i, i \neq j.$$

For example,

$$CPCV_1 = \partial PR_2 / \partial PR_1$$

where PCV_1 = price conjectural variation of firm 1.

$$\begin{aligned} PCV_i &= -\delta_j / [-2\beta_j + \delta_j(\phi_{i1})] \\ &= -\delta_j / \{-2\beta_j + \delta_j[-\delta_i / (-2\beta_i + \delta_i PCV_i)]\} \end{aligned}$$

Using the quadratic formula, we have:

$$CPCV_i = \{-\beta_i\beta_j + [(\beta_i\beta_j)(\beta_i\beta_j - \delta_i\delta_j)]^{1/2}\} / (-\beta_j\delta_i)$$

where, in the formula, "-b" = $-\beta_i\beta_j$; "b²" = $(\beta_i\beta_j)^2$; "-4ac" = $-(\beta_i\beta_j)(\delta_i\delta_j)$; "2a" = $-\beta_j\delta_i$.

I.11. Deriving the Lerner Index, industry level.

$$e_i = (p_i/q_i)(-\beta_i + \delta_i PCV_i)$$

$$e_i = (-\beta_i p_i + \delta_i PCV_i p_i) / q_i \Rightarrow$$

$$-1/e_i = -q_i / (-\beta_i p_i + \delta_i PCV_i p_i)$$

$$Le = \Sigma(-1/e_i) \cdot s_i = \Sigma[-q_i / (-\beta_i p_i + \delta_i PCV_i p_i)] \cdot s_i \geq 0.$$

APPENDIX II

Table II.1. Price Discrimination in EMI
 Based on Size of Order
 for Period 1956:1 1962:4
 (\$ in thousands)

%:	(1) GCBDSO	(3) GCBDLO	(5) GSGDSO	(7) GSGDLO
\$:	(2) GCBRSO	(4) GCBRLO	(6) GSGRSO	(8) GSGRLO
GE-----				
H	(1) 28.03	(3) 45.58	(5) 25.92	(7) 31.31
H	(2) 56489	(4) 181845	(6) 8995	(8) 28992
μ	(1) 14.29	(3) 27.28	(5) 16.39	(7) 19.28
μ	(2) 37510	(4) 104694	(6) 5844	(8) 16460
Md	(1) 13.25	(3) 26.56	(5) 16.01	(7) 20.48
Md	(2) 42697	(4) 93572	(6) 5304	(8) 12169
SD	(1) 7.91	(3) 10.21	(5) 5.76	(7) 6.85
SD	(2) 15236	(4) 32743	(6) 2339	(8) 7752
r	0.73	0.50	0.38	0.26
M	0.0004	0.0002	0.001	0.0002
B	0.12 <	10.91	10.96 <	15.55
Oi	17	11	19	9

%:	(9) GPBDSO	(11) GPBDLO
\$:	(10) GPBRSO	(12) GPBRLO
GE-----		
H	(9) 24.98	(11) 24.98
H	(10) 16438	(12) 39887
μ	(9) 16.17	(11) 16.53
μ	(10) 14350	(12) 22192
Md	(9) 15.96	(11) 17.43
Md	(10) 15085	(12) 19096
SD	(9) 4.37	(11) 6.72
SD	(10) 1869	(12) 7768
r	0.19	-0.48
M	0.0004	-0.0004
B	9.83 <	25.16
Oi	20	8

Partitioning 28 Oi into Small & Large Orders

Firm Good	Partition: μ 28 Oi \$	Variables (SO)	Variables (LO)	
GE	CB	63904	(1), (2)	(3), (4)
	SG	9260	(5), (6)	(7), (8)
	PB	16590	(9), (10)	(11), (12)
Wh	CB	10248	(13), (14)	(15), (16)
	SG	9031	(17), (18)	(19), (20)
	PB	13996	(21), (22)	(23), (24)

Price Discrimination in EMI (contd.)

%:	(13) WCBDSO	(15) WCB DLO	(17) WSGDSO	(19) WSGDLO
\$:	(14) WCBRSO	(16) WCBRLO	(18) WSGRSO	(20) WSGRLO
Wh:-----				
H	(13) 36.65	(15) 46.39	(17) 26.30	(19) 25.82
H	(14) 8412	(16) 60242	(18) 8127	(20) 18079
μ	(13) 21.42	(15) 24.21	(17) 13.17	(19) 16.84
μ	(14) 2655	(16) 38090	(18) 6000	(20) 12527
Md	(13) 23.24	(15) 20.03	(17) 14.94	(19) 19.49
Md	(14) 2115	(16) 38978	(18) 5522	(20) 12114
SD	(13) 11.73	(15) 16.45	(17) 8.18	(19) 7.51
SD	(14) 2252	(16) 18148	(18) 1348	(20) 2384
r	0.10	0.03	0.39	-0.04
M	0.001	0.00002	0.002	-0.0001
B	20.05	< 23.28	-1.10	< 18.39
Oi	22	6	15	13

%:	(21) WPBDSO	(23) WPBDLO
\$:	(22) WPBRSO	(24) WPBRLO
Wh:-----		
H	(21) 17.98	(23) 27.60
H	(22) 13250	(24) 78567
μ	(21) 11.67	(23) 15.95
μ	(22) 6370	(24) 30097
Md	(21) 9.97	(23) 13.56
Md	(22) 5436	(24) 24556
SD	(21) 3.82	(23) 5.75
SD	(22) 3448	(24) 18991
r	-0.01	0.26
M	-0.00001	0.0001
B	11.25	< 13.58
Oi	19	9

Source: Author's adaptation from his data base.

Note: This table contains descriptive statistics calculated by this author for 24 variables. G at the beginning of a variable stands for GE and W for Wh; CB, SG and PB, respectively, stand for circuit breakers, switchgear and panelboards; R stands for total revenue, given book price, and D for the percent discount allowed. SO means small orders and LO large orders. H is the high of the distribution, μ the mean, Md the median and SD the standard deviation. Parameters M and B, respectively report slope and intercept values when discounts are regressed on both small and large orders, and r is the coefficient of correlation. Oi is the number of observations.

Price Discrimination in EMI (contd.)

REGRESSION DATA

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<u>GCBDSO</u>	<u>GCBRSO</u>	<u>GCBDLO</u>	<u>GCBRLO</u>	<u>GSGDSO</u>	<u>GSGRSO</u>	<u>GSGDLO</u>	<u>GSGRLO</u>
7.99	44651	17.02	103343	8.87	8221	15.14	12169
17.94	48978	17.61	120134	14.53	8995	10.40	11706
17.37	54002	14.14	93342	11.03	8332	14.32	24548
21.04	39165	22.82	70745	16.44	8451	20.75	28992
13.25	29878	26.56	93572	14.70	4804	12.12	13397
5.68	7745	45.58	118205	16.01	5379	23.90	12069
1.49	21702	41.89	181845	11.32	4013	20.48	9382
0.90	12955	20.27	78743	21.26	8529	31.31	26128
7.17	44788	32.40	132293	8.65	2982	25.07	9751
28.03	46381	30.22	91041	10.46	4638		
20.92	51201	31.53	68369	21.60	7347		
11.88	18794			25.92	8967		
12.55	25369			19.76	3774		
18.53	42697			19.98	4088		
11.94	39483			7.75	1627		
21.85	56489			14.03	2973		
24.41	53390			21.93	5245		
				22.04	5304		
				25.14	7466		
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
<u>GPBDSO</u>	<u>GPBRSO</u>	<u>GPBDLO</u>	<u>GPBRLO</u>	<u>WCBDSO</u>	<u>WCBRSO</u>	<u>WCBDLO</u>	<u>WCBRLO</u>
7.48	15844	8.44	39877	30.20	993	41.59	11478
11.78	16169	9.00	20414	26.37	8412	9.24	27490
10.72	15609	9.39	16965	-7.16	1986	46.39	51375
11.17	9771	11.37	25917	11.21	2791	24.32	60242
12.43	11453	18.53	17273	21.34	2978	7.97	30108
14.86	14283	21.01	17606	19.65	8296	15.74	47847
18.11	12020	24.06	21696	31.06	2447		
18.38	11370	24.13	17777	34.41	899		
16.33	15624			20.09	510		
14.20	15581			36.65	1392		
15.28	14680			0.00	364		
14.74	13450			18.47	2774		
15.59	15102			34.72	504		
16.63	15067			28.20	4723		
17.13	14494			30.56	4456		
18.63	13295			29.44	4452		
20.16	15126			3.20	2967		
21.16	15839			14.41	643		
23.61	16438			13.87	1624		
24.98	15754			25.14	2243		
				19.44	12598		
				20.90	1696		

Price Discrimination in EMI
Regression Data (Contd.)

(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
<u>WSGDSO</u>	<u>WSGRSO</u>	<u>WSGDLO</u>	<u>WSGRLO</u>	<u>WPBDSO</u>	<u>WPBRSO</u>	<u>WPBDLO</u>	<u>WPBRLO</u>
8.47	6840	4.16	12564	9.95	5083	8.82	22939
-6.85	4748	12.92	12737	9.97	6263	12.14	20068
16.22	7792	7.08	10920	6.63	4771	18.43	24556
18.64	7254	8.94	11952	7.49	3500	19.24	16061
9.20	4741	9.97	16043	9.66	4382	27.60	30099
1.13	5558	15.23	12439	8.18	10091	13.56	18456
14.94	5105	25.82	10240	8.80	13250	11.50	27074
12.58	7696	22.50	10243	10.16	7792	12.91	33051
11.65	5391	24.37	18079	17.09	10324	19.37	78567
16.11	7165	25.26	12114	15.79	9506		
13.22	4867	21.63	14101	17.69	10003		
23.60	5522	21.60	9629	14.18	3931		
15.88	3816	19.49	11795	11.33	6456		
26.30	8127			9.68	5436		
16.42	5380			7.32	1886		
				9.02	11061		
				17.98	2811		
				14.84	2274		
				15.95	2202		

APPENDIX III

Figure III.1. GE Circuit Breakers

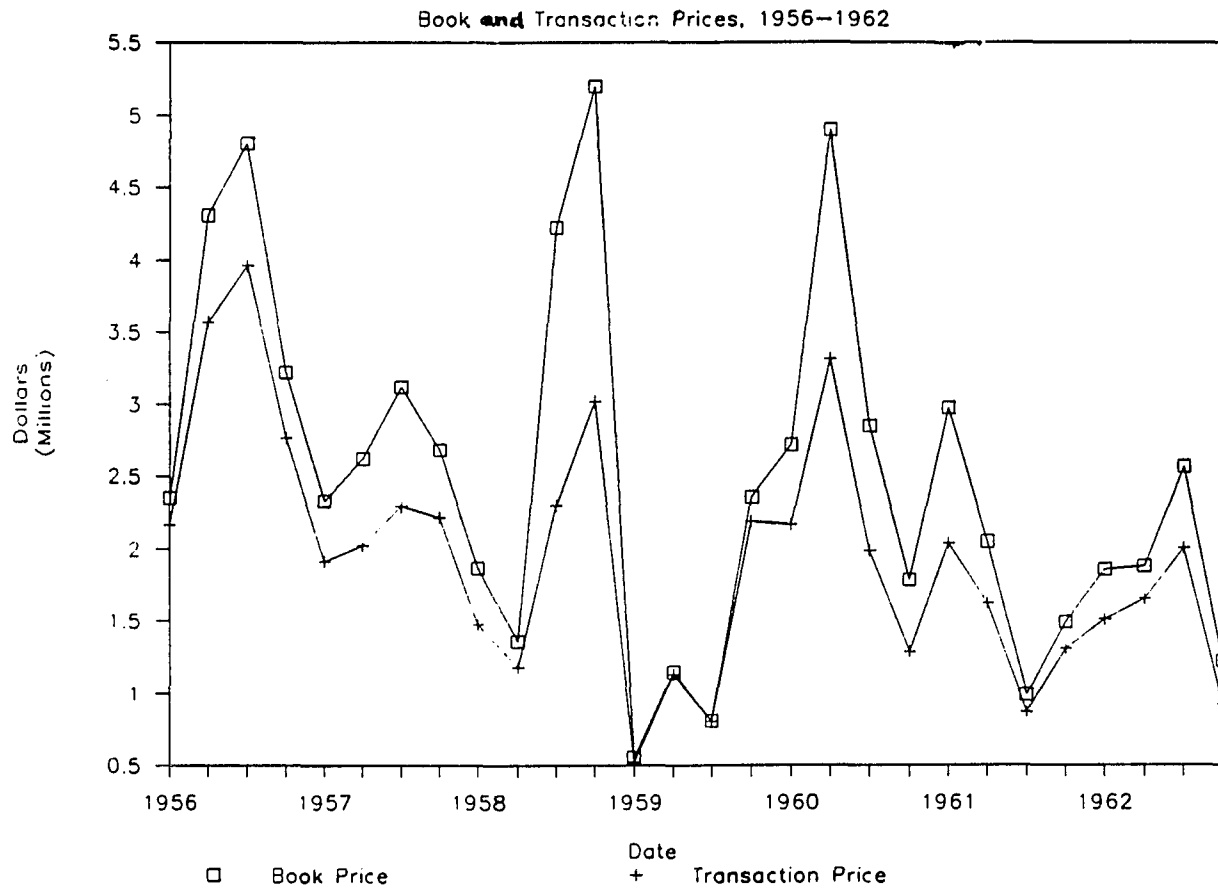


Figure III.2. Wh Circuit Breakers

Book and Transaction Prices, 1956-1962

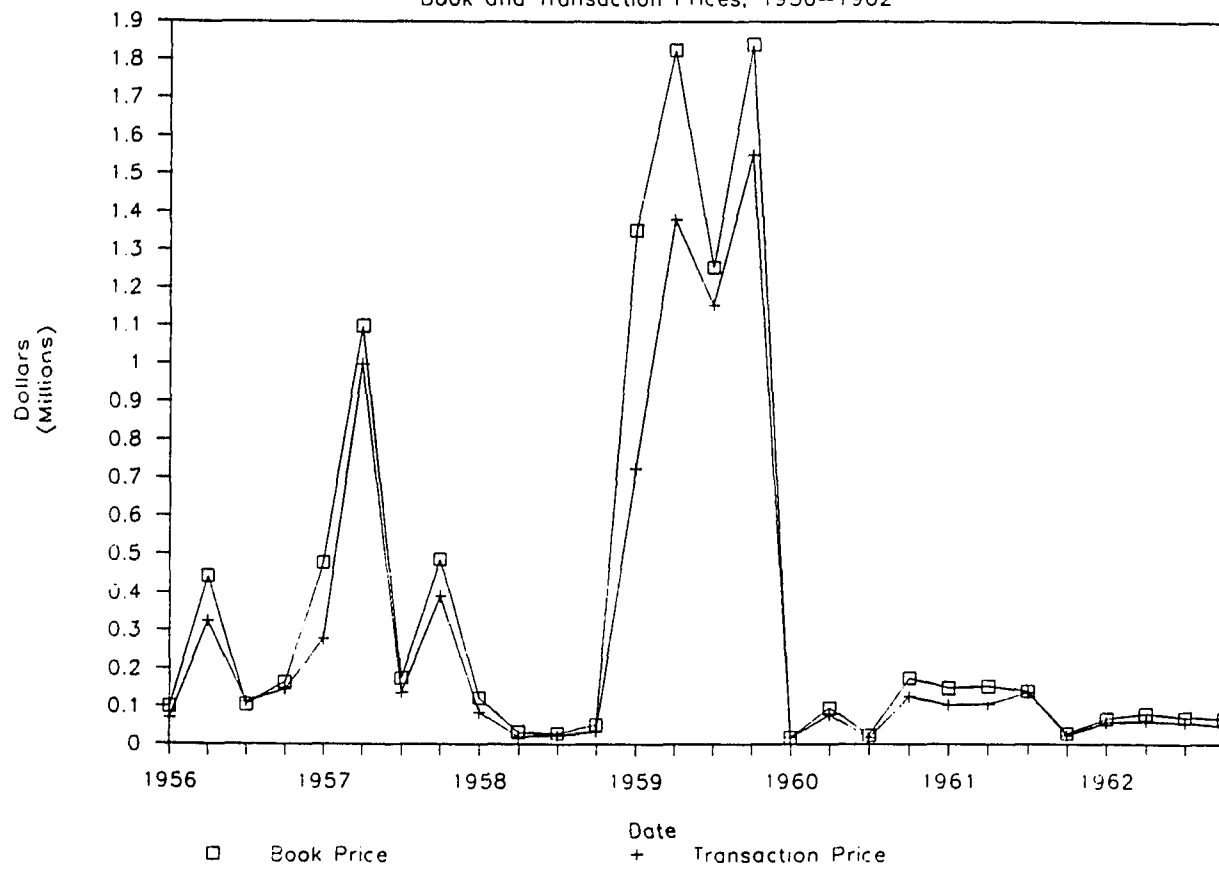


Figure III.3. GE Switchgear

Book and Transaction Prices, 1956-1962

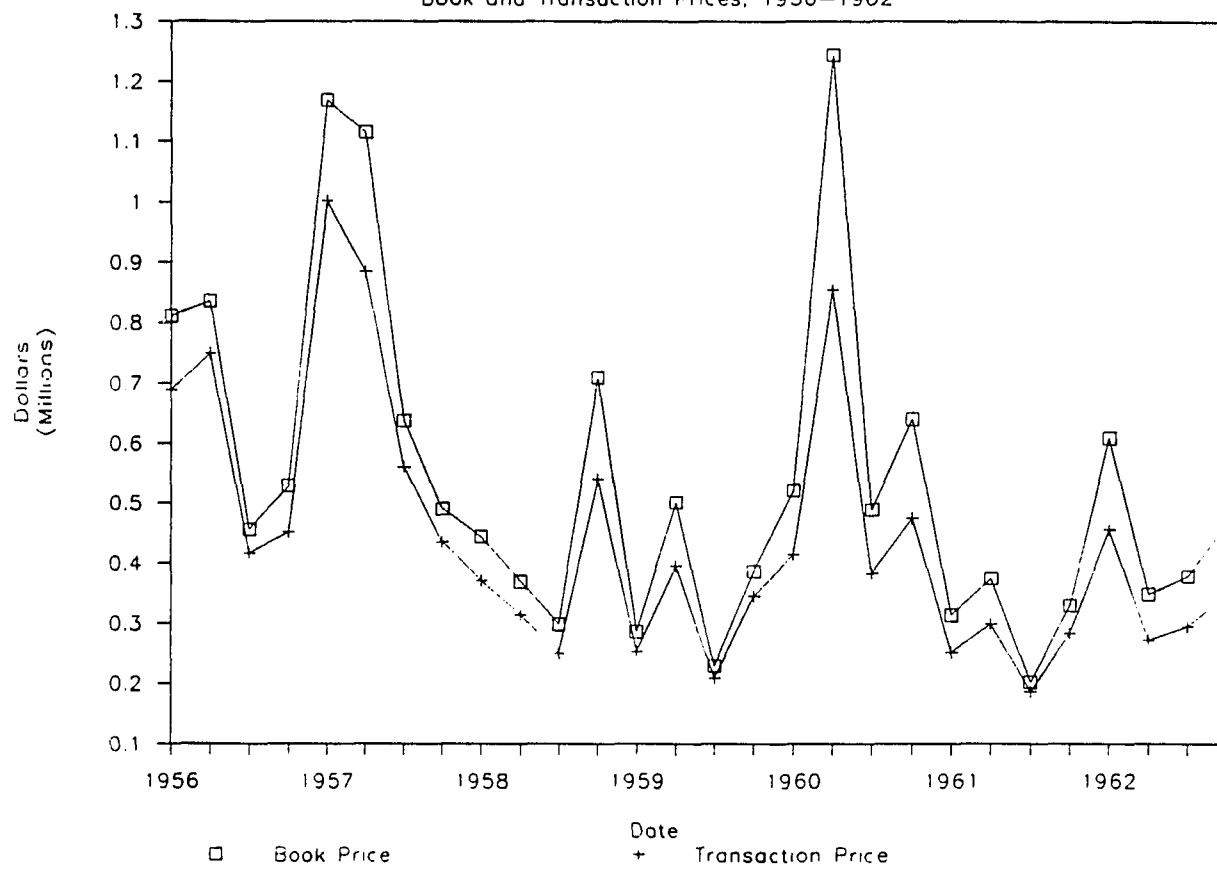


Figure III.4. Wh Switchgear

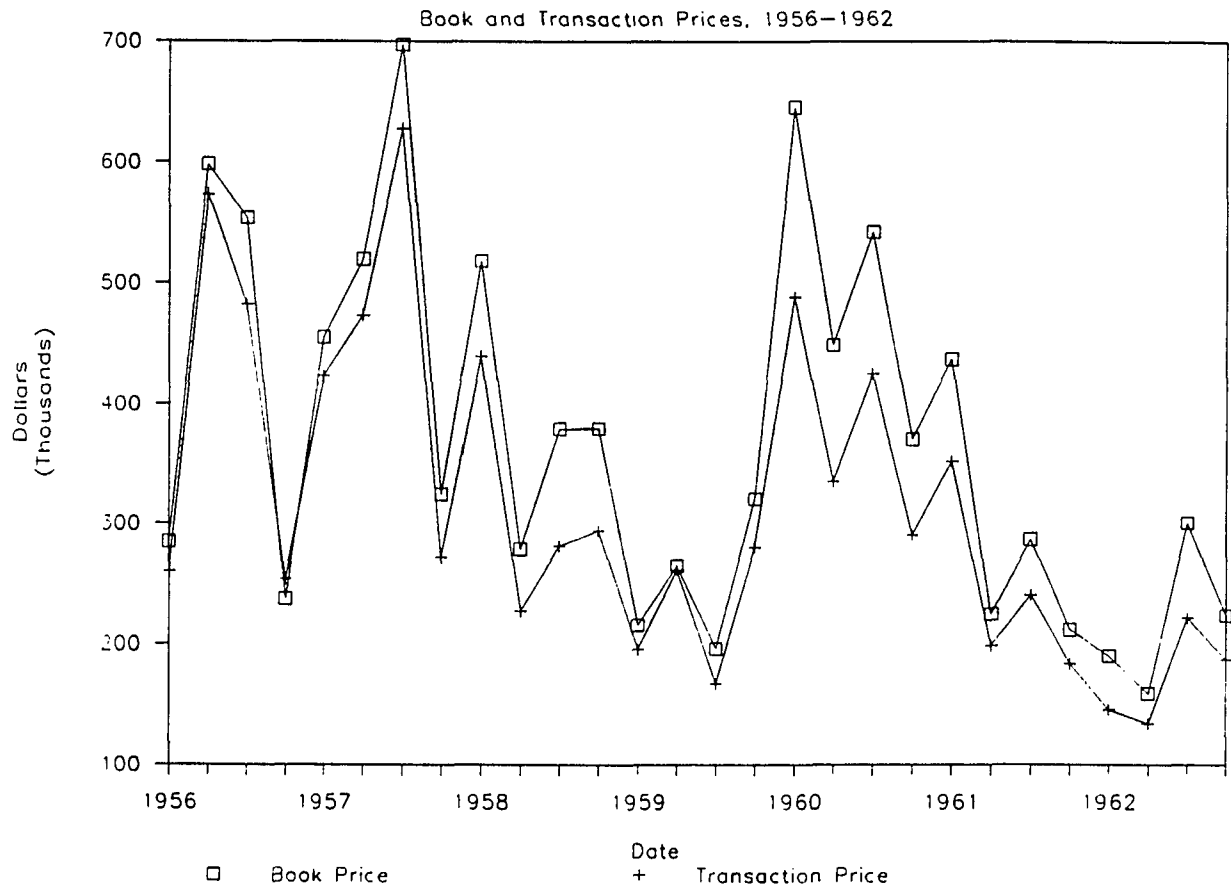


Figure III.5. GE Panelboards
 Book and Transaction Prices, 1956-1962

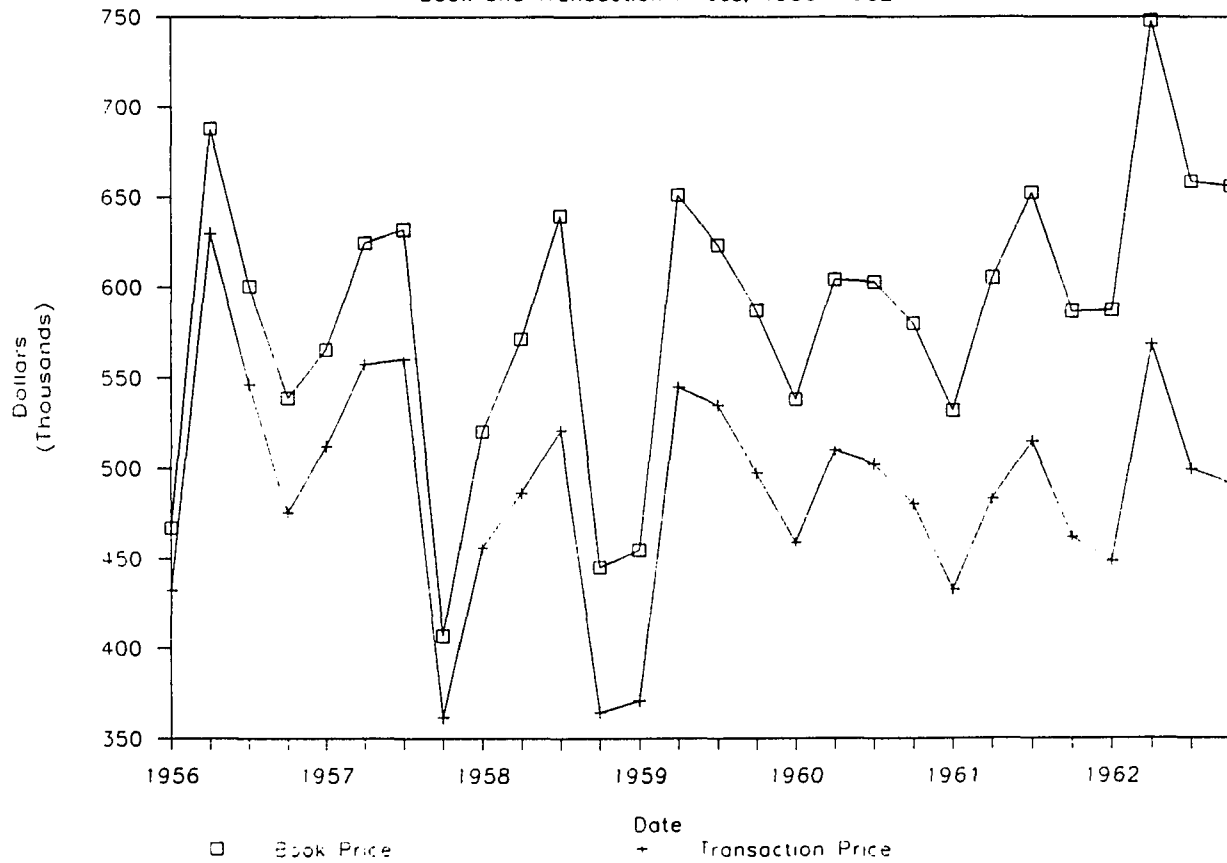


Figure III.6. Wh Panelboards

Book and Transaction Prices, 1956-1962

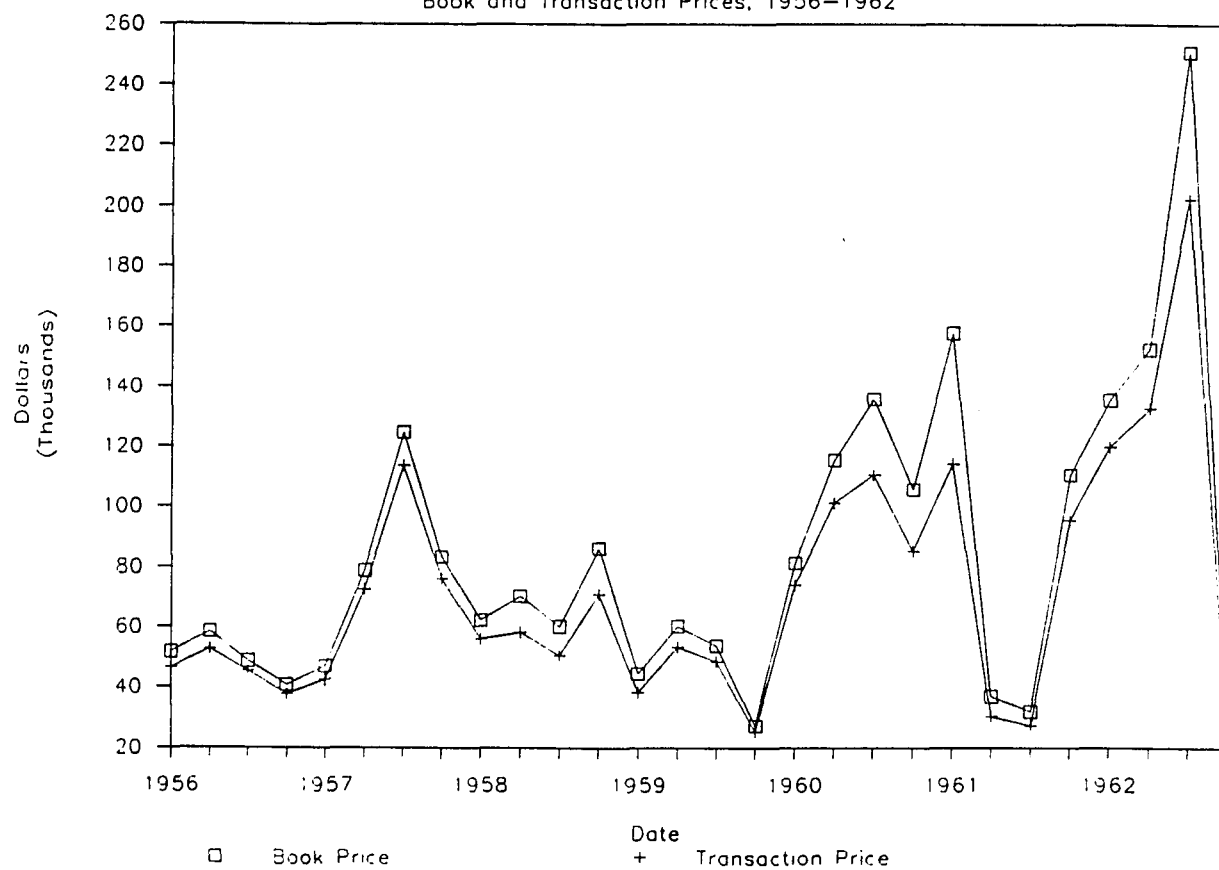


Figure III.7. Transaction Prices, CBs

GE and Wh Circuit Breakers, 1956-1962

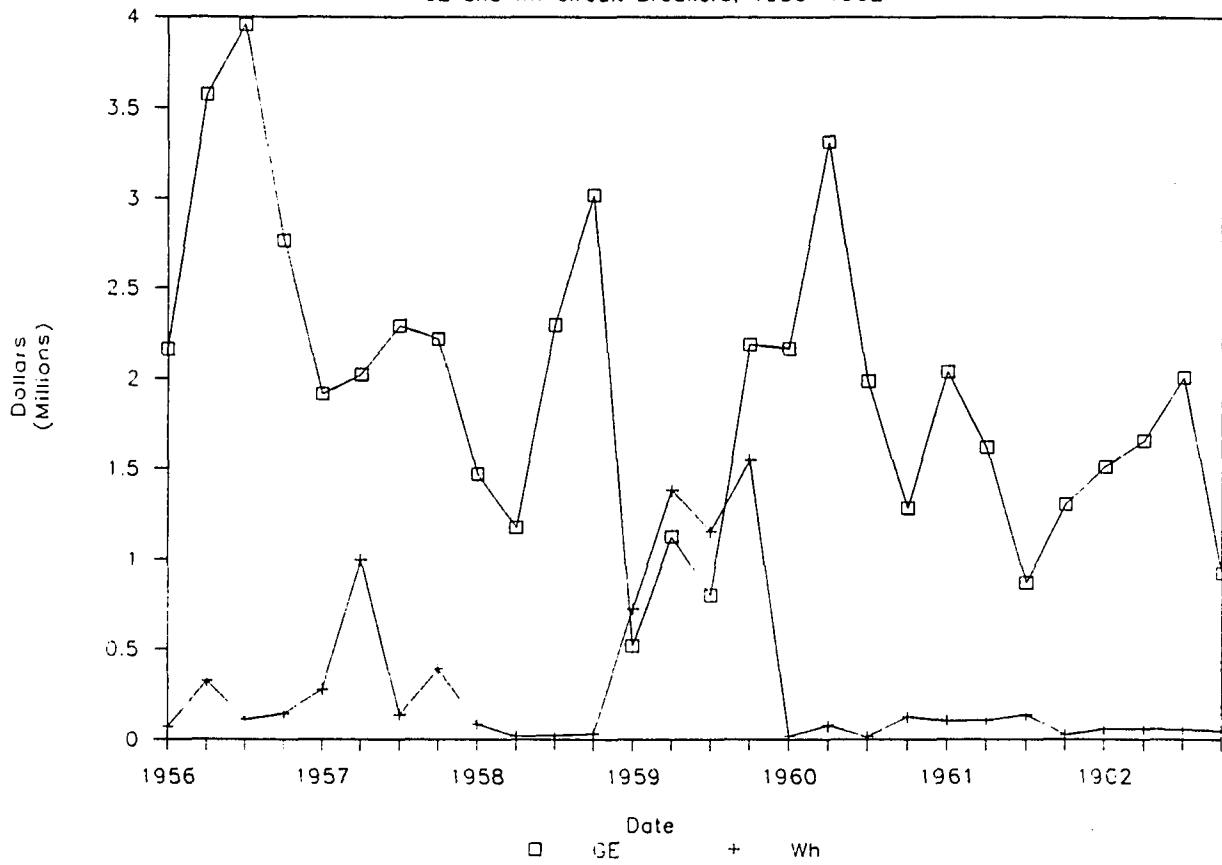


Figure III.8. Transaction Prices, SG

GE and Wh Switchgear, 1956-1962

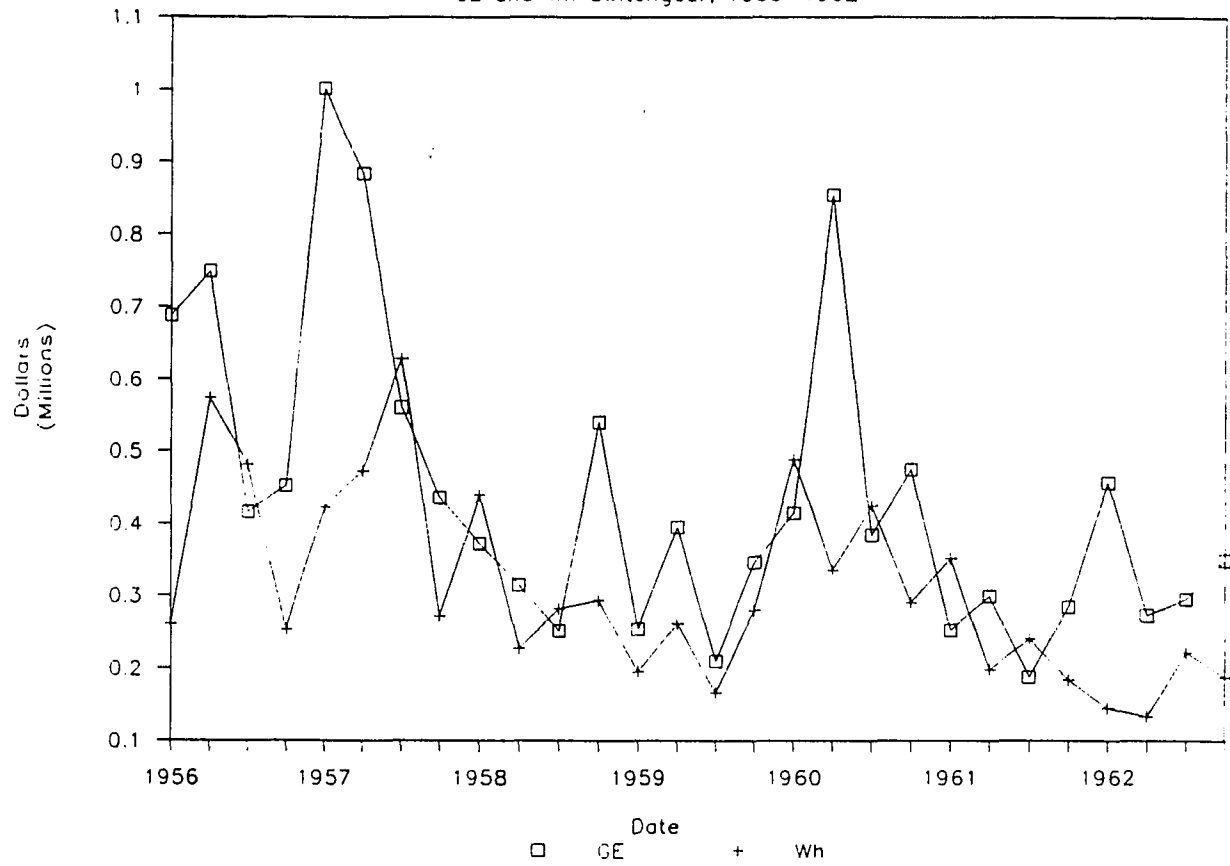


Figure III.9. Transaction Prices, FBs

GE and Wh Panelboards, 1956-1962

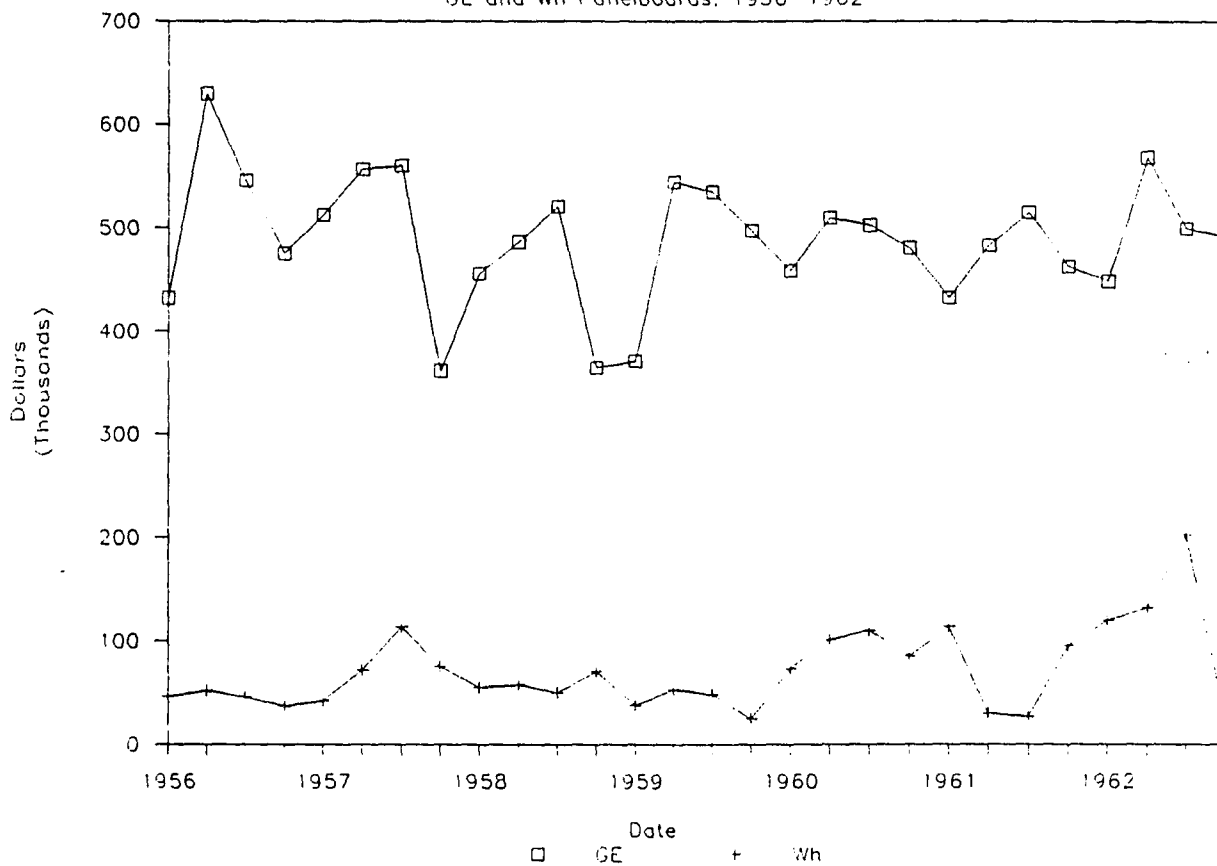


Chart III.1.

Incidence of Duopoly Behavior

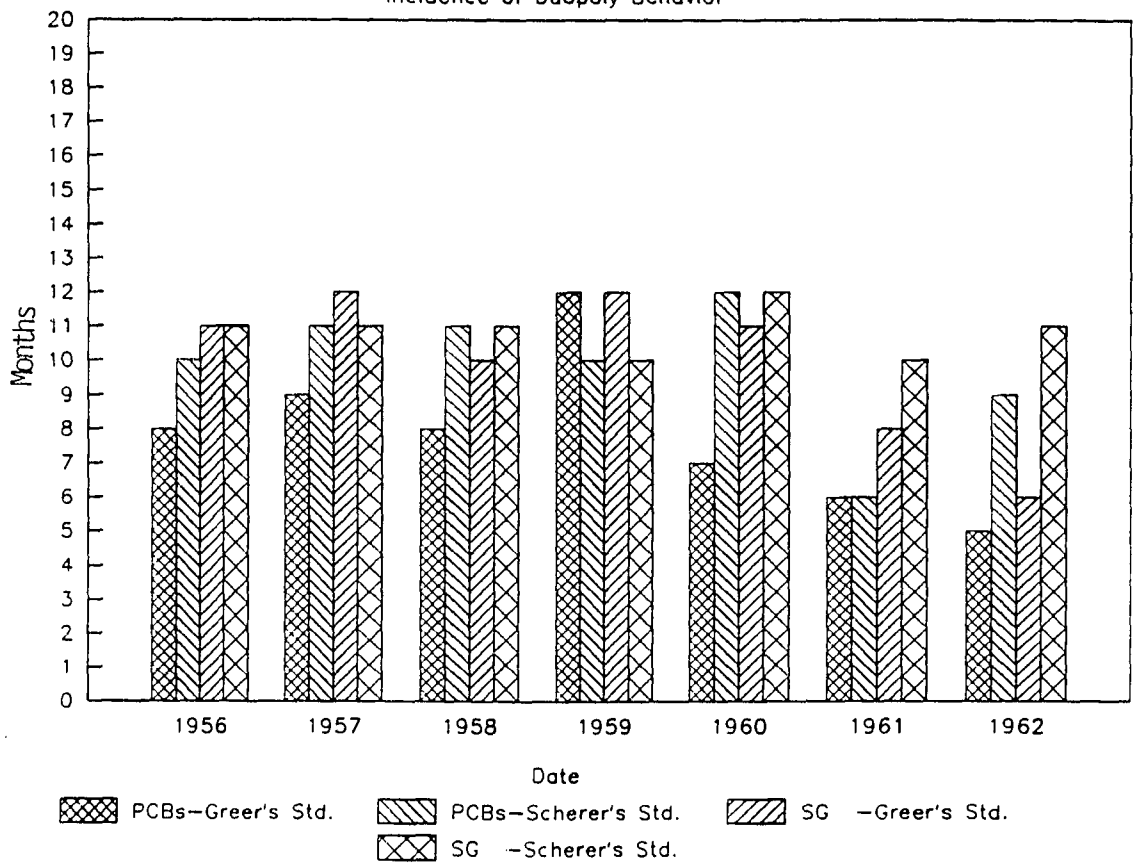


Table III.1. The Philadelphia Cases: EMI

<u>Date</u>	<u>Case No.</u>	<u>Product</u>	<u>Def.</u>		<u>All Defs. of EMI^a</u>
			<u>GE</u>	<u>Wh</u>	
2.16.60	20235 ^b	Oil Circuit Breakers	■	■	5
2.16.60	20236	Low-Voltage Power Circuit Breakers	■	■	3
2.17.60	20238	Insulators	■		8
2.17.60	20239	Lightning Arresters	■	■	7
2.17.60	20240	Open-Fuse Cutouts	■	■	8
2.17.60	20241	Bushings	■	■	4
5.19.60	20348 ^b	Power Switching Equipment	■	■	8
5.19.60	20349	Isolated Phase Bus	■	■	4
5.19.60	20350	Navy and Marine Switchgear	■	■	3
5.25.60	20361	Power Transformers	■	■	6
5.25.60	20362	Distribution Transformers	■	■	7
5.25.60	20363	Network Transformers	■	■	6
5.25.60	20364	Instrument Transformers	■	■	3
6.22.60	20398 ^b	Industrial Control	■	■	6
6.22.60	20399 ^b	Power Switchgear Assemblies	■	■	5
6.23.60	20400	Low-Voltage Distribution Equipment	■	■	6
6.29.60	20401 ^b	Turbine-Generator Units	■	■	3
6.29.60	20402 ^b	Condensers		■	7
9.15.16	20488	Power Capacitors	■	■	6
10.20.60	20508	Watt-hour Meters	■	■	3
		Total	<u>19</u>	<u>19</u>	<u>108</u>

Source: Adapted from Tomic (1985), Table A-1, pp.141-42.

Notes: (a) Defs. means defendants and EMI means Electrical Machinery Industry; (b) These are cases in which the DOJ opposed nolo contendere pleas; ■ identifies cases involving either GE or Wh or both firms.

Table III.2. U.S. Regions Served by EMI, 1957-62

<u>Good</u>	<u>SIC</u> ^a	<u>Regions</u>
Panelboards	3611	Northeast: Massachusetts; Connecticut; New York; Pennsylvania. East North Central: Ohio; Illinois; Wisconsin. West North Central. South: Florida. West: California.
Switchgear including Circuit Breakers	3613	New England: Connecticut. Middle Atlantic: New York; New Jersey; Pennsylvania. East North Central: Ohio; Indiana; Illinois; Michigan; Wisconsin. West North Central. South: Texas. West: Oregon; California.

Source: Adapted from U.S. Bureau of the Census.(1957 ed.). "Electrical Transmission, Distribution and Industrial Apparatus." 1958 Census of Manufacturers: Table 2, 36A-8,9.^b

Note: (a) SIC means standard industrial classification.
(b) Table 2 presents "General Statistics by Regions and States."

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