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Price variation in spatial oligopolies

Fik, Timothy Joseph, Ph.D.

The University of Arizona, 1989

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PRICE VARIATION IN SPATIAL OLIGOPOLIES

by

Timothy Joseph Fik

A Dissertation Submitted to the Faculty of the
DEPARTMENT OF GEOGRAPHY AND REGIONAL DEVELOPMENT

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

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A handwritten signature in dark ink, appearing to be "Ruth J. J. J.", written over a horizontal line.

ACKNOWLEDGEMENTS

This author would like to thank four people who have been close to this project since its conception. My sincerest gratitude goes out to Dr. Gordon F. Mulligan (Head of the Department of Geography and Regional Development, University of Arizona) - the wizard behind all the madness, and Dr. Ross D. MacKinnon (Dean of Social Sciences, State University of New York at Buffalo) for spiritual guidance. Special thanks go out to Caroline Brendel ("The Chief"), for her understanding; and Dr. Merle D. Faminow (Department of Agricultural Economics, University of Arizona) for his insightful suggestions and commentary. Also, I am indebted to Dr. Klaus Brendel for allowing me to complete this project on his computer system. The journey was long, but so are the many to come.

DEDICATION

"...man is a citizen of three worlds. Through his body he belongs to the world that he also perceives through his body; through his soul he constructs for himself his own world; through his spirit a world reveals itself to him that is exalted above the others."

Rudolf Steiner, (1961), page 5,
Theosophy, An Introduction to the Supersensible
Knowledge of the World and the Destination of Man.
Anthroposophic Press: New York.

This dissertation is dedicated to the two most important people in my life - my parents, who have taught me the value of patience, hard work, and scholarship. It is only now that I am beginning to understand my citizenship.

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ABSTRACT

As social scientists have become increasingly aware of the welfare implications of firms' locations in space there has been a considerable amount of renewed interest in the issues pertaining to the geography of price. In the short time since Hay and Johnston (1980) lamented the insufficient attention being given to the theoretical background of geographic pricing, there has been impressive amounts of progress in certain analytical areas. However, within this large body of literature, remarkably little is know about the determinants of geographic price variation in spatial markets containing numerous sellers (firms) and buyers (consumers). Perhaps this should not be surprising given that much of the current research is being carried out by economists (who generally tend to emphasize market process in classically constructed structural-conduct-performance modes) rather than geographers (who tend to emphasize market description and locational patterns/properties arising from spatially defined economic and behavioral market processes).

This dissertation focuses on geographic price variations in competitive oligopolies, where firms react under alternative pricing conjectures. Using computer-aided simulation, the analytics of equilibrium price levels are examined in one-dimensional bounded and unbounded markets to uncover the algebraic properties of spatial markets, the effects of firm density, firm location, and demand elasticity on prices, the perversities associated with consumer-related transportation costs, and the distorting effects of mixed or asymmetrical rivals' pricing strategies.

The modeling of spatial price competition is regarded as essential in the evaluation of equilibrium price as a function of boundary complications, market description, and the spatial arrangement of interdependent rivals. Long-run implications of spatial price competition are discussed with the intention of developing a model (beyond the scope of this dissertation) that not only recognizes rivals' price reactions, but also stresses locationally competitive strategies. Some empirical evidence on the nature of spatial price dependence amongst rival food chains in a metropolitan area is also examined.

CHAPTER 1

MODELING IMPERFECTLY COMPETITIVE MARKETS

Statement of Problem

This dissertation is concerned with the issues surrounding price competition in space. The focus is on the development of a realistic framework in which to model competition amongst geographically distributed firms varying in their pricing behavior. The motivations underlying this work are founded in my general dissatisfaction with existing research approaches that do not directly address many issues inherent to spatial competition, namely the effects of variation in pricing policy, the relative location of pricers, the degree of rivals' price interdependence, and the definition and delineation of geographic markets.

In order to proceed with a discussion of the inadequacies of existing spatial price competition models, the following section is set forth to introduce some relevant terminology and clarify the use of these terms as they relate to this dissertation. The remainder of this introductory chapter includes a brief overview of the

research objectives and a more detailed summary of the topics covered in each chapter.

Terminology

Price can be viewed as a mechanism which regulates the exchange of a good or service between producing and consuming factions within a market, where all transactions are assumed to take place (Hirshleifer, 1988). In "perfectly" competitive markets, buyers and sellers are viewed as "price takers"; that is, neither has the power to control or manipulate the direction and/or magnitude of price or the quantity transacted. The concept of perfect competition thus implies allocation and pricing efficiency, and the absence of "market power" among individual or aggregated economic agents (Shepherd, 1979).

Market equilibrium (in terms of price and quantity variables), within a perfectly competitive system, refers to the condition whereby economic agents are reluctant to change their positions since they are in agreement as to the price and the amount of a good or service exchanged. This is commonly denoted by the supply and demand relations within a market, and the intersection of supply and demand schedules as a function of price. This standard supply/demand model is largely void of spatial components (e.g., transportation costs).

In contrast, imperfectly competitive markets imply the existence of market power (the capacity to set prices and/or quantity marketed). Hence, equilibrium conditions are exogenously, as opposed to endogenously, imposed. The simplest case involves the presence of a monopoly or a single producing agent who manipulates the market outcome in order to maximize profit. An analogous argument can be made for a market containing a single purchasing agent (monopsony), but from here on, the term imperfectly competitive market will refer to markets comprised of controlling agents who are production oriented. Monopolistic entities equate their marginal cost of production with the marginal revenue as dictated by demand, yielding prices that deviate from the perfectly competitive solution (usually higher prices with a lower volume of product exchanged). Again, in this formulation there is no accounting for the geographic properties of the market.

This dissertation is concerned with competition among few firms as opposed to just one firm, or "oligopoly". In addition, the phrases "spatial competition" and "spatial oligopoly" will refer to the geographic expression of oligopoly, where a relatively small number of firms compete within a fixed geographic market or submarket. Inherently, geographic markets can be interpreted as

imperfectly competitive since they are composed of firms that are distributed over space and have the potential to compete for a share of that market area. This implies a localized definition of market power. Economists have coined the phrase "imperfectly competitive market" to denote price or quantity-setting ability. This term has dual meaning since markets can be perfectly competitive in theory and imperfectly competitive in reality since they involve competition over geographic markets. Hence, in regards to the description of competition within this work, the terms "imperfectly" and "spatially" are used interchangeably. The synonymous use of these terms is implicit in the fact that firms have the ability to change the extent of their service areas by their pricing behavior, and also have the capability (given their relative distribution over space) of acting as monopolists over their immediate or surrounding geographic submarket. The phrase "spatial oligopoly" is therefore be used in reference to competition among the few within a geographic market.

Moreover, the notion of a spatially competitive market implies price interdependence among firms vying for a share of a market comprised of numerous, geographically-distributed consumers (all assumed to be cost minimizers). These consumers are demand sensitive to both the prices

charged by the firms and the cost of acquiring the good in question (transportation costs). Thus, a firm's market area is defined with respect to prices set by competing firms and the sensitivity of its localized demand. The extent or reach of this market area is defined by the interaction of firm-specific, consumer-price ceilings (the maximum amount a consumer can expect to pay for a good or service), which is the sum of the firm's price and related transportation expenditures. From the consumer's perspective, the aggregation of firm's "mill" (free on board) price and transportation cost is identified as the delivered price. If consumers are cost minimizing in their purchasing, a firm's market area is known to contain all consumers who find a cost advantage in purchasing from that firm over all others (the lowest delivered price), at the quoted mill price and transport rate. The boundaries of a firm's market area are defined by consumers who are indifferent to the cost advantages offered by two or more competing firms (i.e., those points where delivered price advantage are equal for two or more competitors). In other words, the market area boundary is identified by that location where delivered price schedules for adjacent firms are identical. These boundaries are inextricably linked to the prices set by firms as they compete with their very nearest rivals. Hence, consumers absorb

transportation costs in the acquisition of goods in the market (i.e., whether consumption takes place at the firm or at home consumers must still bear the cost of overcoming the distance which separates them and the firm). Alternatively, if producers absorb the transportation cost a similar delivery price schedule can be identified. However, in this dissertation it is assumed that consumers are responsible for all travel costs associated with the acquisition or consumption of a good.

Spatial price competition can be viewed from the short run, where firms' locations are fixed (and they compete in price only), or alternatively, from the long run, where firms are able to compete by adjusting their prices and/or changing their locations (relative to other firms in the market). The short-run version of price competition assumes a fixed cost component and the existence of short-run profits, whereas in the long run firms' fixed cost components are absent and profits are competitively eroded away.

This dissertation focuses predominantly on the short-run pricing behavior of firms, although some mention is made of the implications of short-run equilibrium conditions as signaling devices for firm entry, exit, or relocation with respect to the long run. Since the concern of this dissertation is centered on price patterns in

spatial markets comprised of a fixed competitive spatial structure (i.e., a fixed location pattern of competing agents), which defines the geographic layout of rival firms in space, the short-run model seems to be most appropriate in dealing with the question of how the spatial distribution of rivals' pricing strategies affect the distribution of prices and profits at equilibrium.

The concept of spatial competition and its associated "spatial equilibrium" take on a more complex meaning than that of its aspatial counterpart. The spatial equilibrium includes the property that all firms are unwilling to change their price in relation to the location and prices set by other firms within the market, since they cannot be made better off (in terms of profit). The underlying premise to this condition lies in the behavioral tendencies of those pricing agents. Therefore, the definition given above should be modified to include some mention of (1) the pricing behavior of individual firms in terms of their expectations of how rivals will react and how the extent of their geographic markets will change as a function of those expectations; and (2) the spatial distribution of those pricing policies and their effects.

Lastly, a distinction can be made between pricing behaviors which are "ultracompetitive" and those that are "non-competitive". Ultracompetitive markets are those in

which competitors price in such a manner that both price levels and price differences are driven downward. In contrast, a non-competitive pricing behavior refers to strategies which involve either overt or tacit collusion and where price differences are driven to zero and general price levels are driven upward. Intermediate cases can be classified as moderately competitive.

Spatial Competition: The Economist vs. The Geographer

It is the contention of this author that the above issues have been largely ignored by economists, who tend to overlook the finite nature and boundedness of markets, firms' relative locations, and the distribution of firms' pricing policies. Economists tend to dwell on long-run equilibrium conditions for markets composed of firms that are symmetrical in behavior and location (i.e., firms that are identically price competitive and regularly or evenly distributed over the market). Furthermore, the market is assumed to be highly malleable with infinite spatial boundaries (i.e., it can be stretched to accomodate changes in the number of firms or market density as entering firms drive profits to zero). Economists tend to ignore the specifics of firm location (in both the absolute and relative sense) in the evolution of a

geographically competitive market. Economists also tend to overlook the distribution and interdependence of firms' pricing behaviors, and how these factors affect both the price reaction or adjustment process of each firm and the overall geography of price. Notwithstanding the limitations of such models, the question of sequential entry without attention to the relevance of spatial distribution of firm location and pricing strategy appears to be a major shortcoming. The neglect of economists to address these issues is the impetus/force behind the methodological and theoretical developments presented in this dissertation.

Economists seem to entertain a perspective of spatial markets which bears little resemblance to the real world, and can be construed as a very special case of a more generalized model where the extent of the geographic market is constrained and the locations and behaviors of competitive agents are not symmetrical or identical. Couching spatial price competition within this realm presents an interesting problem to the geographer who wishes to explain processes that underlie patterns observed (in this case, the pattern being the distribution equilibrium price and the process being price competition amongst firms that vary in their location and pricing behavior).

Geographers' concerns, should therefore, be more focused on the short-run aspects of price competition. This is not to say that the attainment path to long-run equilibrium is not of interest to them, for it is the contention here that it is inconceivable to speak of the evolution of a market toward the long run without understanding the implications of the short run. Hence, it is the commonality of space that attracts economists and geographers to model spatial price competition for imperfectly competitive markets, yet it is the geographer who wishes to examine more than just the symmetries and long-run aspects of that market. Geographic inquiry, that involves the examination of the irregularities and asymmetries in spatial price competition, provides a research design which is more realistic than the traditional approach taken in economics. In the description and assessment of spatial markets, the asymmetrical model of geographic price competition provides a workable framework with limitless potential in its ability to contribute to our understanding of spatial price theory.

Research Objective

The objective of this dissertation is to develop a model of spatial price competition which incorporates asymmetrical or irregular distributions of behavioral parameters. Such a model would allow a realistic approach in which to examine the analytical and spatial properties of price competition. The introduction of spatially variant pricing strategies amongst oligopolists vying for finite geographic markets provides the added flexibility to perform sensitivity tests on the relationships between the spatial distribution of behavioral parameters and equilibrium price. The inadequate treatment of this problem by economists suggests that a need exists to understand the workings of a price-competitive spatial market from the micro level (as tied to the pricing strategies employed at the individual firm level), as opposed to viewing the market (composed of identically behaving firms) in its aggregate form.

Summary of Contents

This dissertation develops a realistic model of price competition in the context of spatial oligopoly. Incremental complexities are introduced sequentially, chapter by chapter, resulting in a framework which is both highly flexible and fairly representative of the arrangements of real geographic markets.

The first chapter provides an overview of the problem and summarizes my dissatisfaction with previous attempts to address the spatial and behavioral issues that are of paramount importance to geographers. Chapter 2 reviews pertinent contributions within the literature from an interdisciplinary perspective, and shows how this dissertation fits within current research trends. Chapter 3 identifies the initial assumptions of the model and some important notational and mechanical qualities which serve as a basis throughout the remainder of the work. Chapter 3 also introduces the short-run model of price competition under symmetrical location and behavior (the commonly used version of this model) and presents computer simulation results of equilibrium conditions under various market descriptions. The distinction is made between linear (bounded) and circular (unbounded) geographic markets, and the implications of boundary

effects are noted. This analysis familiarizes the reader with the complexities of spatial price competition and the necessity of simulating price competitive markets for the purpose of understanding these complexities.

In Chapter 4, attention turns to modifying the model of spatial price competition to include variable price-behavioral parameters. Three of the most commonly cited pricing policies are reviewed. The purpose of this chapter is to assess the distance-decay properties and the analytics of price components under different behavioral assumptions for the case of inelastic consumer demand. The analysis contrasts equilibrium conditions for markets involving various numbers of firms and boundary effects. Chapter 5 explores the equilibrium conditions for bounded markets composed of numerous consumers (all relatively price elastic in demand) and asymmetrically behaving duopolists (i.e., the price competitive effects in markets composed of two equally spaced and symmetrically behaving competitors). Here, the emphasis is on testing the sensitivity of equilibrium price ratios and market areas to changes in transportation cost, demand elasticity, and the size of the geographic market.

Chapter 6 surveys the industrial organization aspects of spatial markets and asymmetrical pricing behavior. This chapter inspects the inadequacies of traditional

measurements of market concentration and competition, and calls for the reconsideration of those measurements for spatial markets involving asymmetrical pricing. Discussion in Chapter 7 proceeds to examine asymmetrical pricing behavior and competitive clustering (as denoted by the separation of firms in space). The agglomeration effects of interdependent (in price) competitors are analyzed for unbounded markets with varying degrees of clustering.

A topological approach to spatial markets is the topic of Chapter 8. The model is developed for a simple bounded spatial oligopoly and the effects of market centrality and market boundary are discussed. Equilibrium conditions are contrasted for topologically different markets containing two competing chains composed of many firms distributed over a network and the implications of network accessibility and firm-level cost efficiency are noted. Chapter 9 provides an empirical treatment of price competition among five retail food chains (using price data reported on cable television) for the Tucson metropolitan area. Inspection of the distributional characteristics of firms is summarized using a point-pattern analysis. Descriptive spatial statistics are computed using reported price levels and availability of in-store services. Regression analysis is used to test the correspondence between price and distance to nearest

competitor. The chapter ends with a discussion of retail competition and its complexities, as well as a brief comment on the indeterminacies of imperfectly competitive systems and some ideas for future research.

Finally, Chapter 10 summarizes the findings established within the body of this work. It attempts to formulate the salient features of spatial price competition into a conceptual model that integrates the economic, organizational, geographic, and behavioral forces fundamental to the proper elucidation of any spatially competitive system.

This dissertation sets the stage for the development of a long-run model of imperfect competition which, in its holistic design, appears to be a truly formidable research task. Given the foundation presented in this dissertation, however, the long-run extension is far from intractable. The modeling of spatial price competition where firms are able to compete in price and location, in the context of locational and behavioral asymmetry, forms the focal point of a discussion of future research goals.

CHAPTER 2

AN OVERVIEW OF THE LITERATURE AND RESEARCH AGENDA

Contributions from Economics, Geography, and Regional Science

There is now an abundant literature in geography and regional science which focuses on the geography of price, spatial (imperfect) competition, and the locational and behavioral aspects of firms in space (e.g., Beckmann, 1968, 1972; Teitz, 1968; Eaton, 1976; Paelinck and Nijkamp, 1976; Carruthers, 1981; Mulligan and Reeves, 1983; Ghosh and McLafferty, 1984; Stahl, 1985; Greenhut, Norman, and Hung, 1986; Norman, 1986). Beckmann and Thisse (1986) have summarized much of this literature in a recent review article (Nijkamp, 1986). Undoubtedly, given the vast array of research that has been generated over the last two decades, there has been considerable renewed interest in uncovering the principles and idiosyncracies of spatial price theory. Many of these developments have come in the decade since two social scientists lamented our insufficient attention to the fundamentals of geographic pricing (Hay and Johnston, 1980). Research in

the area of spatial price theory has not only transcended the discipline of economics (Holahan and Schuler, 1981; Graitson, 1982; Eaton and Kierzkowski, 1984; Neven and Philips, 1985; Ohta, 1988) but has also become an important topic in geography (Smith, 1977; Lentnek, Harwitz and Narula, 1981; Mulligan, 1982, 1983; Batten, 1986; Fik, 1988; Mulligan and Fik, 1989). This extensive research base has provided scholars with an improved understanding of the various social-welfare and policy implications of discriminatory price patterns, pricing systems, and the properties of consumer and producer surplus that arise in response to price variation in spatial markets (Campbell and Chisholm, 1970; Parr and Denike, 1971; Holahan, 1975; Greenhut and Ohta, 1975; Coates, Johnston, and Knox, 1977; Hay and Johnston, 1980; Heffley, 1980; Gronberg and Meyer, 1982; Philips, 1983; Bacon, 1984; Norman, 1986). In particular, some researchers have questioned the effectiveness of spaceless price theory in the assessment of geographically competitive markets (Capozza and Van Order, 1978; Benson, 1979; Faminow and Benson, 1985; Ohta, 1988), and the inability of these arguments to account for all social costs and benefits in relation to market inefficiencies which arise under free-entry (Benson, 1984).

In the spatial economics literature, many diverse works have emerged examining such issues as spatial supply and demand, optimal market size and shape, service area delineation, barriers to entry, the intensity of price competition, and the equilibrium properties of price as a function of market configuration, which serve as benchmarks for normative welfare analyses (Mills and Lav, 1964; Denike and Parr, 1970; Stern, 1972; Ballobas and Stern, 1972; Eaton, 1976; Eaton and Lipsey, 1978; Ohta, 1980; Mulligan, 1981, 1982; Batten, 1986). Still others have generated discussion on topics ranging from choice modeling of consumer behavior and hierarchical aspects of retail shopping. These developments include a contextual theory of demand which integrates consumers' decision-making processes with the elements of space, time, and situation (Lentnek, Harwitz, and Narula, 1981; Narula, Harwitz, and Lentnek, 1983; Ingene, 1984), and hierarchical patterns of demand which encompass multipurpose shopping, multi-stop consumption or purchasing activity, and trip chaining (Bacon, 1971; Eaton and Lipsey, 1979, 1982; O'Kelly, 1981, 1983a, 1983b; Bacon, 1984; Mulligan, 1983, 1984b, 1987; Thill, 1985, 1986; Ghosh, 1986; McLafferty and Ghosh, 1986; Thill and Thomas, 1987; Thill, 1988). In addition, a sound conceptual framework has been established for the

theoretics of spatial pricing and facility location under conditions of uncertainty and change (Webber, 1972, 1984; Greenhut and Ohta, 1975; Rushton, 1979; Fotheringham and Knudsen, 1986).

This rich literature has helped social scientists to gain insight into the mechanics and complexities of geographical market processes and the underlying tendencies of actors to locate, disperse, and price react (usually under the guise of rational economic choice and equilibrium analysis). This research represents a substantial evolution of the pioneering works of Weber (1909), Predöhl (1925), Hotelling (1929), Palander (1935), Lösch (1940, 1954), Smithies (1941), and Isard (1956). The recent contributions have expanded the base of knowledge with respect to the location of production activities, and the magnitude, malleability, and stability of competitive service areas. A number of important contributions have been forged in the tenets of central place theory (Christaller, 1933, 1966), and have been devoted to the identification of problems and formulation of economic theory within this realm (Parr and Denike, 1971; Eaton and Lipsey, 1982). Numerous studies have been formally constructed in the Christallerian sense, incorporating the spatial economic postulates of central place theory through the concept of outer range (the market area which

delimits consumer coverage) and the constraining effects of threshold (the minimum market area necessary for a firm to remain economically viable) (Clark, 1968; Mulligan and Reeves, 1983). Moreover, many central place type studies have specifically examined the implications of agglomeration on economic agents (the benefits or external economies which are associated with the clustering of firms) (Eaton and Lipsey, 1979; Graitson, 1982; Mulligan, 1984a; Beckmann and Puu, 1985; Borgers and Timmermans, 1986). In corresponding matters, exploration into the caveats of geographic distribution, the spacing of firms, and corresponding patterns of price and locational instabilities, in regards to Hotelling's original exposition on the stability of competition, has stimulated a host of writings which raise further questions regarding the differentiation of competition in the locational sense (the long-run) versus price and/or quantity variables (a shorter-run phenomenon) (Intriligator, 1971; Beckmann, 1972; d'Aspremont, Gabszewicz, and Thisse, 1979; Carruthers, 1981; Ohta, 1981; Graitson, 1982; Neven, 1985; Beckmann and Thisse, 1986; Dasgupta and Maskin, 1986; Okabe and Suzuki, 1987). Many authors have also toyed with perceptive sketches of firms' location decisions in the competitive placement of retail facilities and the

expected reciprocating perceptions of consumers (Curry, 1967; Rushton, 1971).

Recently, it has been suggested that price constitutes the logical competitive decision variable in short-run market adjustments as firms do not commit themselves to a fixed level of output (Jacquemin, 1987). The logic of price as a vehicle for competition has been well accepted in the Bertrandian school of thought as opposed to Cournot (Bertrand, 1883; Weskamp, 1985). The notion of short-run price adjustment stands in contrast to the work on long-run market equilibrium in terms of price, market density (number of competitors), and location (Ohta, 1988). These propositions have reinforced concerns over the effects of spatial price reaction and expected shifts in consumer patronage and/or change in geographic market boundaries from the combination of price and product information (Faminow and Benson, 1985). This concern has been the thrust of a distinctive pool of work which has inconclusively speculated on the significance of accurate price information and the dynamics of competitive price levels in retail food systems (i.e., competition amongst food chains for a share of retail patronage) (Devine and Marion, 1980; Lesser and Bryant, 1980; Hay and Johnston, 1980; McCracken, Boynton and Blake, 1982; Boynton, Blake, and Uhl, 1983; Hall, 1983; Lesser and Hall, 1983;

Black, 1984; Fik, 1988). From a retail or market area perspective, Black (1984) has outlined a methodology to model retail patronage based on a probabilistic account of consumer trip patterns as defined by "choice sets" or shopping opportunity. Early attempts at rationalizing retail price disparities noted the functional role of sale items as attractiveness measures in comparable market baskets between multi-commodity retailers vying for their share of finite geographic markets (Holton, 1957). Questions arise as to the potential for loss leadership, the gains in consumer surplus from internalized multipurpose shopping, and increased service options offered by those firms, as well as their ability to utilize limited spatial monopoly power (Benson and Faminow, 1985; Stahl, 1985).

Notwithstanding these developments, there is still much confusion over the concept of price or quantity competition with respect to geographically delineated markets. Moreover, the definition of market power becomes more nebulous when spatial issues are debated. This has been the forefront of a continuing search for new approaches to investigate industrial organization and market area analysis (Appelbaum, 1982; Roberts, 1984; Jacquemin, 1987; Coyte, et al., 1988).

Retail planning and policy implications of spatially competitive markets present further difficulties to the interpretation of competitive behavior among oligopolists when qualitative issues are introduced such as the tastes, preferences, and attitudes of consumers toward the size, quality, and selection of services offered by geographically competitive suppliers. Jansen (1982) has cautioned that description of market processes, from a policy-oriented perspective, may fail to reconstruct the realities that lie beyond the impersonal structure of physical layout and price (i.e., the emotional, social, and learned components of behavior). Jansen has suggested that the conceptualization of market processes suffers from the simple truth that modeling attempts have tended to oversimplify reality. Jansen's criticisms stem from the facts that

- (a) regularities in the spatial distribution of consumers and producers rarely exist;
- (b) there is always the potential for randomness in consumption patterns (unpredictable or stochastic behavior);
- (c) there exists contradictions, information inequities, and uncertainties in consumers' spatial and temporal perceptiveness and/or preference orderings; and

(d) most objective studies of competitive shopping environments ignore the subjective, experienced-based complexities of individual consumer units.

Similar arguments to (b), (c), and (d) can be constructed for the supply/production side.

Retail patterns in location and price may confirm the generalization that consumers are largely irrational in their regard for cost-efficiency (Buit and Nozeman, 1976). If such statements are valid, policy oriented research on retail competition and market area delineation must amplify the need to assess the subjective and behavioral limits of consumers and producers in order to create a clear and comprehensive picture of market operations. Notwithstanding the importance of consumer choice, this dissertation is mainly concerned with the other side of this argument. The focus of this work is on the examination of market imperfections or spatial inconsistencies in producer-related pricing behavior, and geographic distribution of pricing policies, to enumerate the distorting competitive effects of firms' expectations on the price response of rivals.

An Industrial Organization Approach

In related efforts, economists and agricultural economists alike have become increasingly involved in

research on spatial competition and the intrinsic quality of spatial price association, with the intent to specify the "integration" of spatially separated markets and the "efficiency" of those markets in terms of price competition (Blyn, 1973; Jones, 1974, 1976; Harriss, 1979; Gupta and Mueller, 1982; Monke and Petzel, 1984; Adamowitz, Baah, and Hawkins, 1984; Smirlock, Gilligan, and Marshall, 1984; Cotterill, 1986; Delgado, 1986; Heytens, 1986; Ravallion, 1986; Faminow and Benson, 1988). The degree of market integration is defined by the direction and velocity of price response of sub-markets which may or may not be integrated or competitively linked within a larger geographic market. Such investigations have been couched in the tradition of the structure-conduct-performance (S-C-P) framework of market competition and classical price theory (Bain, 1959, 1965; Stigler, 1957, 1964, 1966; McNulty, 1968; Shepherd, 1975, 1979), describing the relationship between a market's structure and firm conduct/behavior in the testing of market performance (i.e., how close a market is to the perfectly competitive model). S-C-P analysis investigates the statistical correlation between profit and market share. The efficiency of a market is thus determined by its ability to emulate a perfectly competitive market in terms of its structure and price mechanics where

participants account for a non-controllable fraction of total transactions (i.e., they are price takers), have complete knowledge of demand and supply conditions, do not have the capacity to promote arbitrage by the exchange of commodities over space, and act independently (Stigler, 1957, 1968; McNulty, 1968; Jones, 1976). Within this mindset, firms are evaluated by their market shares as defined by percentage of total sales. Most of these theoretical and empirical works largely have ignored any underlying geographic implications to competition (i.e., the extent of geographic market areas).

Traditional views hold that firms' market shares are directly proportional to their market power (or ability to extract monopoly rents), yet only a minimal amount of evidence has been produced to support this assertion (Marion et al., 1979; Cotterill, 1986). Most studies of this type tend to completely ignore the relevance of any spatial elements and are thus highly suspect due to their incompleteness, given that the spatial economic model of price competition has been shown to have potential in its capacity to explain geographic price differentials (Tomek and Robinson, 1981; Faminow and Benson, 1985). On the contrary, alternative interpretations of these S-C-P tests have shown market share to be associated with a firm's operational efficiency (Demsetz, 1973; Carter, 1978;

Smirlock, Gilligan, and Marshall, 1984). Nonetheless, very few of these so-called market area analyses interject elements of competitive spatial structure directly (i.e., they do not address the important issues of location, positioning, and pricing behavior in the evaluation of price setting ability).

In a conceptual model of monopoly power, Benson (1979) has criticized the use of S-C-P measures which fail to prove the proposition that larger market shares are directly caused by price collusive activity and excessive market power. Models of spatial competition have produced inconsistencies which refute the traditional beliefs that competition between many as opposed to few results in lower price and profit levels, particularly where suppliers and consumers are geographically dispersed and separation is costly. Moreover, little has been done to link these S-C-P models to the pricing behavior of spatially competitive firms (Benson and Faminow, 1985; Faminow and Benson, 1985).

Many of these works have received attention in the controversy over the definition and extent of a geographic market, particularly within an anti-trust context (Elzinga and Hogarty, 1973; Benson, 1980, 1984; Dobson, Breen and Hurdle, 1984; Benson and Faminow, 1984, 1988; Klein, Rifkin, and Uri, 1985; Uri and Rifkin, 1985). Many of

these research endeavors has centered around the lagged serial dependence in cross-market pricing (sometimes with an emphasis on central or leading markets) using a Granger causality criterion in the evaluation of price interdependence over time and space. In other words, price levels are tested for the likelihood of cross-market hauls or spatial arbitrage. However, there are some fundamental problems in the interpretation of short- and long-run intermarket integration when geographic dispersions and/or variable length feedbacks are taken into consideration, rendering an uncertainty as to the make-up of the pricing system being evaluated (Benson and Faminow, 1988; Benson, Faminow and Fik, 1989).

Spatial Price Competition: A Contemporary Approach

Recent interdisciplinary contributions have focused on spatial competition using price interdependence approach to markets classified as spatially or imperfectly competitive oligopolies (Capozza and Van Order, 1977; Benson, 1980; Eaton and Kierzkowski, 1984; Benson and Faminow, 1985; Greenhut, Norman and Hung, 1986; Mulligan and Fik, 1988, 1989). However, remarkably little is known about price variation in spatial markets involving both numerous sellers and buyers, partly due to the failure of researchers to develop an "adaptable, micro-level,

decision-oriented conceptual" model which fully recognizes the complexities of spatial demand and price reactions amongst interdependent rival firms (Mulligan, 1988, p.1).

Mulligan and Fik (1988) have cited a need to pursue analysis of spatial competition through modeling efforts that adequately capture the ranges of individual and/or group price response, to account for variability in price patterns which stem from behavioral elements such as revealed preference orderings (of consumers) (Rushton, 1969; Bacon, 1984) and pricing policies (of spatially competitive retailers) (Beckmann, 1976; Ohta, 1980), and non-behavioral elements such as an already established geographic layout of firms servicing a known density of consumer demand. Therefore, although much has been learned about the nature of spatial price theory as a byproduct of market conditions, a great deal of work and synthesis remains to be done in simultaneously assessing the impacts of geographic market structure, concentration, and competitive price reaction at the firm level in conjunction with geography of price and its associated "perversities" (which refers to the idiosyncratic behavior of equilibrium prices as a function of demand parameters, transportation outlays, the locational characteristics of the market) (Beckmann and Thisse, 1986). With this in mind, it is apparent that current research agendas must

clarify the relationships that exist between firms' equilibrium price levels and their relative locations, in order to identify the price patterns which arise from a spatially competitive market process or the cumulative effect of individual pricing strategies. Thus, not only must geographic variation in prices be considered as an outgrowth of a competitive spatial structure (the organization of firms in space), but also as a realization of the integrating of consumers' responses with producers' interdependent price reactions.

Specifically, price competition amongst mutually interdependent rivals, vying for the annexation of juxtaposed territory, must be viewed as a chain-like set of linkages, where the price of any one firm is subject to the direct influence of proximate rivals and the indirect or secondary impact of more distant competitors (Mulligan, 1988). This has been defined as the chain-like structure of price interdependence. Yet it can be perceived as part of three simultaneously operating systems which determine market price-- the integration of demand-side and supply-side conditions along with the underlying behavioral properties of market actors at the micro level. Since a geographic market is comprised of segmented and adjacent sub-markets, the chain-like structure of demand assures that the price of any one firm is inextricably tied to the

arrangement and size of market segments as determined by the pricing policies of competitors intertwined in space (Mulligan and Fik, 1988).

Future Research Needs

The inadequacies of the approaches outlined above suggests that spatial price theory be advanced from a market-oriented approach, which combines both locational and behavioral attributes of market agents, by incorporating price-reaction strategies at the firm level and the elements of a spatially competitive market structure at the aggregate level. If this is accomplished, it will help close the now present gap between traditional aspatial structure-conduct-performance approaches and micro-oriented behavioral modeling of competitive forces in the spatial genre. Such a contribution could potentially lead to a substantive reconstruction of price theories that have largely ignored the overriding importance of space and firm-level behavior, thus providing many avenues for future discussion and exploration. Up to this point it is not surprising that many of the spatial implications of price competition have been largely ignored given that most of the work on this subject is carried out by economists who have deep-rooted interests in S-C-P processes. Economists have repeatedly

ignored the effects of location and behavior in the price adjustment process in the attainment of market equilibrium. Their failure to capture a realistic impression of competition stems largely from the fact that they assume away the very features of reality that are present in any market exchange: the behavioral and locational attributes of interdependent market agents. Assuming that these properties have no bearing on the short- or long-run equilibrium or the path of adjustment toward that equilibrium is both intuitively unappealing and scientifically unacceptable. Geographers, however, have much to offer in the way of such discussion, given their concerns over the locational ramifications of market processes and market boundaries. Geographically based contributions to price theory may be key to the redevelopment of S-C-P theory, a theory which simultaneously recognizes the spatial elements of market structure and the behavioral and geographical components of firm conduct in the testing of market performance.

Research Agenda

In view of these neglected issues the research agenda presented in this dissertation is given with the intention of examining the idiosyncracies of geographic price

patterns in markets comprised of spatially competitive oligopolists under (a) two unique spatial settings: the one-dimensional linear (bounded) market and the circular (unbounded) market; (b) a distinct temporal horizon (the short run); and (c) two entirely different consumer-demand conditions (the inelastic versus elastic case). This dissertation will attempt to add to the body of knowledge in models of spatial price competition by improving our understanding of how geographical market processes such as the intensity of competition (as denoted by the number and relative positioning of firms), the elasticity of demand, rivals' price reactions (and expectations on the counter-price reactions of competitors), and consumer travel expenditures (as represented by the transportation rate structure and delivered price schedule), influence equilibrium price configurations in spatial markets.

Furthermore, the following points will be highlighted:

1. How price variation in models of competitive oligopoly is influenced by external geographic boundaries, i.e., does a linear bounded market show potential for higher comparative price levels at peripheral locations in comparison to the circular unbounded market description-- where no periphery exists;

2. How price levels are affected by the density (the number and relative locations of firms) and the arrangement (spatial distribution) of sellers in such markets;
3. How, in a spatially competitive sense, equilibrium price schedules and profit levels adjust and distribute under varied market descriptions and demand elasticities; and
4. How the features of a market are altered when behavioral components, such as firms' profit-maximizing reaction strategies, are mixed or asymmetrical (as opposed to the commonly used identical or symmetrical reaction assumption).

Using computer simulation, a sensitivity analysis is performed to contrast equilibrium average mill (f.o.b.) price levels for the short-run (i.e., where the number and location of firms are fixed and firms are unable to change their present capacities), where the spacing of competitors is constrained to be either equidistant or evenly distributed (i.e., every firm is equidistant to its nearest competitor and/or market boundary) or irregularly or unevenly distributed (i.e., a non-equidistant distribution of firms). This analysis includes a brief discussion of the implications of a long-run version of

this procedure (i.e., where firms have the ability to enter, relocate, and/or exit the market).

Although the focus of this dissertation is on the assessment of short-run conditions, the conceptual understanding of the implications for the long-run model will provide added insight as to the importance of short-term behavior in both the price adjustment process and the final distribution of price (a precursor to the long-run model). In other words, the underlying behavioral aspects of firms' pricing policies are seen as crucial in the evolutionary process of the market, leading to a host of possible long-term results as an outgrowth of an indefinite number of spatial arrangements of behavioral and locational components on both the demand and supply sides.

Firm's pricing behavior is explicitly tied to the competition over a fixed geographic market in which firms may price react in order to compete/erode away the market shares of their adjacent rivals. Given a spatial distribution of pricing policies for the short run, equilibrium conditions for the market will be established (i.e., a distribution of prices in which no firm has the incentive to change). Equilibrium prices are established through the profit-maximizing behavior of firms under various price reactionary formats which include either

symmetric or mixed geographic variation of pricing conjectures, (which by definition refers to firms' expectations about the price response of competitors). Three commonly used price conjectural variations provide the basis for firms' pricing policies; namely,

- (I) Hotelling-Smithies (or Bertrand) - where firms act as though the price and location of proximate rival firms are given and unchanging, commonly referred to as the zero-conjectural variation argument (Hotelling, 1929; Smithies, 1941);
- (II) Löschian Competition - where firms price under the expectation that proximate rivals will exactly meet their price changes (a supposition that parallels the idea that firms have the capability of setting price levels as tacit colluders) (Lösch, 1954); and
- (III) Greenhut-Ohta - where firms expect their immediate rivals to act in a price reciprocating manner, i.e., any price changes are exactly offset in the opposite direction by proximate rivals resulting in a constant boundary price (Greenhut, Huang and Ohta, 1975).

These well-known behavioral conjectures are accepted as being special cases of a more general model of pricing behavior. The indeterminacy of price relations in

oligopolistic settings stem directly from the integrated workings of linked price strategies which exist and vary within these special class intervals (i.e., the intermediate cases). Distance-decay properties of spatially interrelated prices have already been established as offshoots of price conjectural variations under symmetrical behavior for the case of inelastic demand (Mulligan and Fik, 1989), yet more analysis needs to be done on the complications which arise from asymmetrical or mixed conjectural behavior. Advances to this end have already been established in the identification of distance-decay and boundary effects for a generalized system of conjectural pricing in one-dimensional spatially competitive markets (Mulligan and Fik, 1988b). This is explained further in the forthcoming discussion contained in the body of this dissertation.

Spatial price equilibrium is said to be established when no price change for any firm will increase that firm's level of expected profits, *ceteris paribus*. Since pricing conjectures are involved in the determination of expected returns, the path of price adjustment and resulting equilibrium prices are known to behave in dramatically different ways; and are highly dependent upon the behavioral characteristics of interactive rival firms and their cost structures (Mulligan, 1988). Even though

such advancements in theory have already been made, much additional work needs to be done on this topic in order to fully comprehend the geography of price from a mixed conjectural/behavioral standpoint as noted earlier. Any attempts at modeling this phenomenon must further disclose the implications of mixed conjecture price reaction by isolating these effects in terms of direction and intensity of price response (and the associated comparative statics), the influence of firms' geographic distribution (relative locations), and distortions of boundaries in conjunction with a competitive non-malleable or fixed (malleable or adaptable) spatial structure for the short- (long-) run model.

In sum, this dissertation addresses the issues of price competition as a spatial and behavioral phenomenon by integrating, in the short run, the geographic features of market concentration with the behavioral characteristics of market actors in the short run. It must be stated at the onset that understanding the adjustment process and equilibrium conditions in the short run (where firms locations are fixed in space), for various geographic distributions of pricing conjectures, is crucial to the eventual development of a long-run model which captures competition in both price and location. The long-run model is not seen as a direct extension of its short-run

counterpart since there exists the potential for feedback amongst firms' location and price conjectural parameters.

This dissertation focuses mainly on price competition in the short run, where firms compete in the Bertrandian sense (i.e., price react as opposed to output react). An analytical treatment of price competition in space is undergone in the search for spatial regularities in price pattern as a function of price elasticity of demand, the density and separation of retail establishments, and the chain-like properties of price interdependence amongst spatially competitive oligopolists that operate under mixed or asymmetrical conjectures.

Furthermore, an empirical analysis is conducted on retail level rival food chains within the Metropolitan Tucson area over a short duration, to test the validity of the spatial model of price competition and verify the price-distance relationships reported in an earlier paper (Fik, 1988). From this study area, a micro-market composed of a small number of independent and somewhat agglomerated establishments (the clustering of firms in sub-markets) is monitored for price interdependence for a set bundle of consumer products. The patterns of price are then contrasted to a larger market window, which is less affected by agglomerative forces, in order to describe the overall geographic variation in price.

The objectives of this numerical exercise are threefold. Firstly, the locations of firms (rival chains) will be plotted in space by coordinates and the point pattern described statistically. Secondly, attention will be paid to the geographic distribution of prices and its statistical correlates with an emphasis on investigating the covariation between price levels and the socio-economic attributes of consumers within those geographic markets. Thirdly, price levels of individual outlets and average prices of rival chains are tested against the degree of separation between those competitive entities, to expose any potential statistical relationship between chain-level pricing and distance to a nearest and next-nearest rival. The goal of this exercise is to validate distance as a relevant explanatory variable for price. Finally, the spatial variation of price amongst proximate rival chains (as defined by contiguous market areas through the construction of Thiessen polygon) is critically analyzed for its spatial autocorrelative properties. Since pricing conjectures are not readily observable -- and are therefore purely speculative -- explicit identification of average price movements and their respective spatial covariations are seen as necessary in evaluating the competitiveness of suppliers in a market to form reasonable speculations as to the

essence of those behavioral tendencies in price reaction as a function of separation. Again, I must stress that price patterns are not truly indicative of pricing behavior (or conjectures) since many other explanatory variables may be involved (e.g., varying price levels over space may reflect differences in firms' costs of production). However, if these variables are controlled for by the inclusion of cost information, and if distance-decay properties of the price competitive model are resolved, this will reduce the remaining indeterminacies which influence those price levels (one ultimately being conjectural and part of firms' price reaction functions).

The bulk of this dissertation rests on the modeling of spatial markets which are artificial in their composition (i.e., the one-dimensional configuration and product homogeneity assumptions discussed in Chapters 3 and 4 are proposed as abstractions and simplifications of real-world markets); yet a great deal of knowledge can be gained from the use of such abstractions to uncover the non-obvious or intangible mechanics of market processes. Since a model can be loosely defined as an idealized representation of reality which assists in the elucidation of salient features and/or functions of a complex process (Haggett, 1965), it is my wish to model the determinants and properties of spatial price competition through the use of

mathematics and computer aided simulation, and not to propose that the assembled model bears a complete semblance of reality; many qualitative issues will be assumed away. The underlying objective of such an endeavor is purely an exercise in the incremental expansion of knowledge on the normative aspects of spatial price theory.

The simplified assumptions of this one-dimensional model are relaxed as the dissertation progresses. Ultimately, the model moves from symmetry in price conjecture (for the linear and circular markets), to the introduction of asymmetrical pricing conjectures in markets containing firms which are evenly and unevenly distributed in space, and then progress will be made toward a topological framework based on the distribution of rival chains in a network. Hence, the modeling effort in this work is developed with the intention of presenting an increasing realistic picture of price competition through the (1) examination of asymmetrical relations; and (2) inclusion of competitive linkages (with consideration of adjacency in market areas or segments, market connectivity, and market boundary). The combination of these factors produces a much more palatable framework in which to model spatial price competition since the combination alleviates major shortcomings found in the

economists' version of the spatial model (Capozza and Van Order, 1978; Ohta, 1988), which imposes equilibrium under the assumptions of symmetry in location and price conjectures while ignoring the distorting effects of boundary and connectivity.

The accompanying empirical section is added only to test if, in actuality, the basic principles of spatial competition are observable. Since price levels (and location information) are symptomatic of intertwining spatial and behavioral market characteristics (and are readily obtainable), even if disequilibrium conditions prevail, it can be posited that such price information embodies the essential interactive properties of competitive forces; and is therefore a necessary ingredient in the numerical analysis of geographic market areas. Although the intentions of consumers (as designated by price elasticities of demand) and strategies of competing producers are not explicitly defined by spatially comparative price levels, they serve as an implicit guide to the resultant forces at large. Spatial and temporal patterns in price movements between adjacent firms competing for adaptable service boundaries may provide some indication of competitors' pricing policies in relation to distance (especially over the short run, where

locations and output are fixed and the attributes of consumers are fairly stable).

The next chapter reviews the pertinent notation used throughout this project, and the mechanics of price competition in space from an approach which can be thought of as jointly behavioral and geographic. Chapter 3 is devoted to the development of methodology which serves as a basis for the remainder of the work. Some preliminary findings are reviewed for the simple case of the zero-order pricing conjecture for spatial oligopolies composed of symmetrically behaving and symmetrically distributed firms (a model favored by economists). The resultant short-run equilibrium conditions under various circumstances and market compositions (i.e., a price sensitivity analysis of market length, transportation and demand parameters, and the number of firms), are discussed and the implications noted.

CHAPTER 3

ASSUMPTIONS, NOTATION, AND MECHANICS

Consider a one-dimensional spatial market of known length A , where consumers are assumed to be uniformly and continuously distributed with unit demand density. Suppose that a sufficient number of competing firms n , $n \geq 3$, enter this market and locate in space as competitive oligopolists such that all consumers are serviced (i.e., no consumers are priced out). Firms are restricted to locate in such a manner that they exist far enough apart as to eliminate the possible repercussions of overlapping and unstable service areas that are associated with competitively induced clustering and price instability found in the short run (Smithies, 1941; d'Aspremont, Gabszewicz, and Thisse, 1979). Subsequently, firms' locations are such that all equilibrium market segments are mutually exclusive and collectively exhaustive. For the sake of simplifying the analysis, all initial simulations are conducted for an evenly spaced distribution of competitors. It is also assumed that no firm adopts a pricing policy as to drive competitors' revenues to zero and no potential exists for spatial

arbitrage (i.e., the transportation costs between contiguous firms exceeds their mill-price differential). Some of these restrictions will be relaxed later.

Two distinct market configurations are proposed: 1) the spatially bounded or linear market; and 2) the spatially unbounded or circular market. These configurations are the one-dimensional counterparts of markets defined on a plane or sphere, respectively. Within these markets, suppose that the forces of demand and supply are operative with respect to one homogeneous or composite commodity made available by all firms (i.e., there is no differentiation in product quality amongst rival firms). The following set of assumptions are also made:

- (1) the market exhibits a mill (f.o.b.) pricing system with consumers bearing the full burden of transportation costs;
- (2) there are no distinguishing features on the line which would cause transport rate differentials and/or congestion; i.e., there is equal ease of movement in either direction (excluding, of course, the limiting properties of the bounded market);
- (3) all consumers practice price-minimizing behavior; that is, they purchase a homogeneous good where their delivery price is minimized;

- (4) the market is comprised of identical consumers distributed evenly at unit demand density; and
- (5) all firms are profit-maximizers, and their total cost of output (in the production of that homogeneous good) is an additive function of their fixed (overhead) cost and a known constant marginal cost of production (for a given level of output).

In equation form, each consumer's delivery price schedule p_i^d can be stated as

$$p_i^d = p_i + tx, \quad (1)$$

where p_i equals the mill price of the i -th (closest) firm which satisfies consumers' price minimization criterion, t is the transportation rate per unit distance, and x is the distance travelled in acquisition of the good. In turn, any firm's cost equation can be expressed as

$$C_i = F_i + k_i Q_i, \quad (2)$$

where total cost C_i is composed of a fixed cost F_i , constant marginal cost k_i per unit output, and Q_i is the level of firm output.

Any given firm (except for the two exterior firms in a bounded market) must be located between two neighboring competitors and, therefore, it is always possible to identify a left-hand and a right-hand

component to an interior firm's market area. Suppose, for $n \geq 3$, the i -th firm ($1 \leq i \leq n$) locates at X_i where $0 \leq X_i \leq A$, producing goods (on a per unit basis) at price p_i . The firm's total service area a_i is composed of the left-hand market segment a_{iL} and the right-hand market segment a_{iR} , or

$$a_i = a_{iL} + a_{iR}. \quad (3)$$

In the case of the unbounded (circular) market each firm is interior, being surrounded by two rivals. The condition of complete consumer coverage is given by

$$A = \sum_{i=1}^n a_i, \quad (4)$$

where the i -th (interior) firm shares a market area boundary at the intersection of delivery price schedules or adjacent firms; i.e., the location where delivery prices are identical. Hence, the intersection points are

defined by $p_{i-1}^d = p_i^d$ and $p_i^d = p_{i+1}^d$. The boundary

between firms $i-1$ and i ($X_{i-1} < B_{iL} < X_i$) is denoted by

$$B_{iL} = (1/2)t (p_i - p_{i-1} + tX_i + tX_{i-1}), \quad (5)$$

while the boundary between firms i and $i+1$ ($X_i < B_{iR} < X_{i+1}$)

is denoted by

$$B_{iR} = (1/2)t (p_{i+1} - p_i + tX_{i+1} + tX_i) . \quad (6)$$

Subsequently, the spatial extent of the i -th firm's market area or segment length is, by previous definition,

$$a_i = B_{iR} - B_{iL} \quad (7)$$

$$= (1/2)t (p_{i+1} - 2p_i + p_{i-1} + tX_{i+1} - tX_{i-1}) .$$

See Figure 1 for clarification of this property.

Methodology and Proposed Exploration

The Case of Inelastic Demand

Under the principles of inelastic demand, consumers are known to be insensitive to price changes (such as in the purchasing of necessities as opposed to luxury items). Assume, however, that a consumer purchases but one unit of a specific good, implying that the spatial extent of each firm's market area simply equals the number of consumers

Figure 1. Prices, Locations, and Market Area Boundaries in a Spatial Market. Note that the market is not in equilibrium.

in that market area. Profit level Z_i for the i -th (interior) firm can be determined as follows:

$$\begin{aligned} Z_i &= (p_i - k_i)Q_i - F_i \\ &= (1/2)t_i(p_i - k_i)(p_{i-1} - 2p_i + p_{i+1} - \\ &\quad tX_{i-1} + tX_{i+1}) - F_i. \end{aligned} \quad (8)$$

If the firm maximizes its profit while anticipating no price or locational response from either neighboring firm (the short-run zero price conjecture), it follows that the firm's optimal mill price p_i can be solved from the first order condition of setting the partial derivative of profit with respect to price equal to zero: $\delta Z_i / \delta p_i = 0$. It is easily demonstrated that

$$p_i = (1/4)(p_{i-1} + p_{i+1} - tX_{i-1} + tX_{i+1} + 2k_i). \quad (9)$$

It is apparent the profit-maximizing price for an interior firm depends upon the given prices and locations of its two closest rivals as well as its own marginal cost of production. This axiom has been well developed in the theory of the firm in space, where market area boundaries are established by the arrangement of competitors subject to the central place constructs of threshold and range (Mulligan and Reeves, 1983). Mapping of market areas as a

function of own marginal cost and nearest rivals' prices and locations has implications for the expansion of higher order price interdependence for two-dimensional market area analyses (Eaton, 1976; Carruthers, 1981; Okabe and Suzuki, 1987). This topic is certainly deserving of attention, but beyond the scope of this dissertation.

For illustrative purpose, consider the scenario of three competitive firms located in an unbounded (circular) market. If all three firms simultaneously practice profit-maximizing behavior, then it follows from the profit-maximizing equation (9) above that

$$\begin{bmatrix} 4 & -1 & -1 \\ -1 & 4 & -1 \\ -1 & -1 & 4 \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix} = \begin{bmatrix} tX_2 - tX_3 + 2k_1 \\ tX_3 - tX_1 + 2k_2 \\ tX_1 - tX_2 + 2k_3 \end{bmatrix},$$

or in matrix notation

$$C P = V.$$

C and V represent the zero-order price conjectural weights and locational/cost matrices respectively. The geographic implications of these matrices will be discussed further in the course of this dissertation, when the behavioral aspects of firms' price reaction strategies are considered.

Through matrix inversion, the equilibrium price vector must be

$$\begin{bmatrix} p_1^* \\ p_2^* \\ p_3^* \end{bmatrix} = \begin{bmatrix} 0.3 & 0.1 & 0.1 \\ 0.1 & 0.3 & 0.1 \\ 0.1 & 0.1 & 0.3 \end{bmatrix} \begin{bmatrix} tX_2 - tX_3 + 2k_1 \\ tX_3 - tX_1 + 2k_2 \\ tX_1 - tX_2 + 2k_3 \end{bmatrix},$$

from the matrix relation

$$P^* = C^{-1} V. \quad (10)$$

Thus, in the case of firm 1 the optimal price p_1^* is

$$p_1^* = 0.2t(X_2 - X_3) + 0.2(3k_1 + k_2 + k_3).$$

The equilibrium price vector P^* reveals individual mill price levels when all firms are simultaneously optimizing, i.e., a firm's price depends upon the spacing of its two nearest neighbors (weighted by the transportation rate) and the marginal costs of its own and its nearest neighbors' outputs, and not upon the prices set by those rivals!

This exercise can be extended and generalized for $n > 3$ firms, and/or the analysis adapted to the bounded market by the inclusion of boundary adjustments. In the former, zero elements are introduced to the $n \times n$ weighting matrix on the left-hand side of matrix C (e.g., in the case of five firms the elements along the first row of the

matrix would be $4, -1, 0, 0, -1$). The location of these zero elements is critical in determining the equilibrium configuration of weights solved for in the $n \times n$ (n -th order) coefficients matrix C^{-1} (obtained by matrix inversion).

In the bounded (linear) market, the elements of the matrices above must be respecified for the left-hand exterior firm, such that, $a_1 = Q_1 = B_{1R}$; with similar adjustments made for the right-hand exterior firm where $a_n = Q_n = A_{nL} - B_{nL}$. Note that each of the peripheral firms in the linear market has only one neighboring firm. This however, will in no way affect the logic of the above argument, only the distribution of the weights attached to locations and marginal costs in the $n \times n$ matrices C^{-1} . See Table 1 for an example of some numerical solutions involving bounded and unbounded markets containing $n=3$ firms.

As noted earlier, p_i^* refers to the profit-maximizing firm price and B_{iR} to the right-hand market area boundary when the entire spatial market is in equilibrium (i.e., all three firms are producing at their equilibrium price-output combination). Note the asymmetry in equilibrium prices for the bounded market.

Table 1
Equilibrium Prices for Three Firms
in a Spatial Market

Market Description:

	Unbounded (Circular)	Bounded (Linear)
p^*_1	6.781	6.962
p^*_2	6.781	5.000
p^*_3	6.781	6.962
B^*_{1R}	6.664	13.037
B^*_{2R}	19.995	26.962
B^*_{3R}	33.330	n.a.

Note: $A = 40$; $t = .5$; $a = 15$; $b = 1$; $k_1 = k_2 = k_3 = 3$.

Firm Locations: $X_1 = 0$; $X_2 = 13.333$; $X_3 = 26.667$.

When firms with fixed locations reach a Bertrand (price competitive) equilibrium in a spatial market, it is possible to specify the spatial distribution of (mill) prices given only the knowledge about the locations and marginal cost structures of those firms and the transportation rate facing consumers. However, many of the inherent perversities of this system are not self-evident and warrant the need for further discussion. In the generalized analytical framework for n firms, in both the bounded and unbounded market cases, certain properties of the spatial market need to be explored, including:

(1) clarification of the role of boundary effects in spatial pricing (e.g., are such effects important? do they depend upon the number and/or spacing of firms or the size of the market? how do they affect the geography of price?);

(2) identification of the direct and indirect effects on price due to the nearest, next-nearest, ..., and n -th nearest rival firms (i.e., what is the nature of distance decay in consumption and production or the field of influence of competing firms? at what distance does a firm's influence become negligible?);

(3) examination of how location-specific changes in transportation rates (e.g., from an increase in the ease of access or movement, say from a transportation

improvement) or marginal costs (e.g., labor cost or rent level) can have system-wide repercussions on the spatial distribution of prices; and

(4) inspection of the aggregate or macro-level properties of price patterns as affected by the micro-level decision-making processes and interdependencies in price schedules.

The Case of Elastic Demand

Consider the case where consumers possess identical linear demand curves, a common assumption for the specification of elastic consumer demand in location theory (e.g., Beckmann and Thisse, 1986), although some criticism is warranted (Long, 1971)¹. For our purpose of simplifying the analysis, we will assume that consumers have identical preference ordering and therefore place equivalent cost evaluation on distance. Notwithstanding the usual criticisms, the commonly used identical and linear demand assumption will be used in this study to simplify notational matters and avoid intractable problems in computation.

1. Long (1971) has convincingly argued that consumer's partial demand functions are not spatially invariant, and that it is restrictive to assert that all location-specific demand functions are well-behaved and/or identical in space.

In particular, assume that consumer demand q is specified formally as

$$q = a - bp^d, \quad (12)$$

where the demand intensity parameters $a, b > 0$, and p^d represents their delivered price. Note that this is a simplified variation of the linear demand function used by Eaton (1976), where demand can be bifurcated into a fixed amount (a) and a variable component which is negatively related to delivery price p^d through parameter b .

The demand function facing each firm in the entire market can now be identified. For any interior firm i , in either the bounded or unbounded market, it follows that aggregate demand Q_{iL} on the left-hand side of the firm's market is

$$Q_{iL} = \int_0^{X_i - B_{iL}} [a - b(p_i + tx)] dx, \quad (13)$$

while aggregate demand Q_{iR} on the firm's right-hand segment of the market is

$$Q_{iR} = \int_0^{B_{iR} - X_i} [a - b(p_i + tx)] dx. \quad (14)$$

Integrating the aggregate demand equations for Q_i and Q_{iR} and then summing leads to the total demand Q_i of the i -th firm. Thus,

$$Q_i = (a - bp_i)(B_{iR} - B_{iL}) - (bt/2)[(B_{iR} - X_i)^2 + (X_i - B_{iL})^2] \quad (15)$$

Again, it is desirable to specify conditions for profit-maximizing behavior on the part of the firm, by ensuring that the following first-order condition holds:

$$\delta Z_i / \delta p_i = (p_i - k_i)[\delta Q_i / \delta p_i] + Q_i = 0,$$

where $\delta Q_i / \delta p_i$ and $\delta Z_i / \delta p_i$ indicate how the firm's aggregate demand Q_i and, in turn, profit level Z_i responds to changes in the firm's own mill price p_i . Note that consumers base their purchasing decisions on delivery price schedules p^d , whereas the firm adjusts to changes in profit with respect to mill price. By considering this property, it is obvious that demand varies in two ways with price changes: (1) at the market margins, since both B_{iL} and B_{iR} are functions of mill price p_i ; and (2) inside the already captured market (since consumer demand is elastic). As before, $\delta Z_i / \delta p_i$ is specified by

taking prices (p_{i-1} , p_{i+1}) and the locations of

both nearest neighboring firms (X_{i-1} , X_{i+1}) as constants.

This framework is relaxed in a later discussion of a more generalized model which allows for alternative expectations in rivals' price adjustment.

Using a certain amount of algebraic manipulation, a quadratic reaction function can be established for the optimal price p_i of the i -th firm:

$$18p_i^2 - p_i(16a + 12bk_i + 4bA_i) + \{8ak_i + (4a + 2bk_i)A_i - b(A_{iL}^2 + A_{iR}^2)\} = 0, \quad (15)$$

where the following market segment identities hold:

$$A_{iL} = p_{i-1} - tX_{i-1} + tX_i,$$

$$A_{iR} = -tX_i + p_{i+1} + tX_{i+1},$$

and

$$A_i = A_{iL} + A_{iR} = p_{i-1} - tX_{i-1} + p_{i+1} + tX_{i+1}.$$

The above quadratic equation describes a trajectory of profit-maximizing prices for an interior firm under the supposition that spatial rivals will not react to any prices changes initiated by that interior firm. This is known as the Hotelling-Smithies pricing conjecture. This is equivalent to the conditions set in a Bertrand

equilibrium (also known as the zero-order pricing conjecture). A similar argument can be made for firms that compete in quantity-- a Cournot equilibrium (based on quantity as opposed to price reaction functions). Although it is recognized that the implications of the Cournot model of competition are equally important to that of its Bertrandian counterpart, it will not be directly addressed in this dissertation since the focus is mainly on price competition.

In the section which follows, simulation results are presented for the case of zero-order price conjectural variation. The objective of this section is to establish the sensitivity of equilibrium prices and profits under varying parameters and geographic market conditions.

Simulation Design and Some Preliminary Findings

The next step is to establish sequentially the optimal price p_i for each of the n firms for the entire spatial market. This is a simulation problem where each firm in turn establishes its equilibrium price-output combination (p_i^*, Q_i^*) ; that is, a recursive chain-reaction process is followed until each firm has no further incentive to change its own mill price and the equilibrium combination

(p_i^*, Q_i^*) has been reached for all n firms. This recursive adjustment process of price-output equilibrium attainment is charted for $n = 3$ firms in Table 2. The simulation procedure was initiated with firm 2 and proceeds (in an iterative fashion) to firm 3, 1, 2, 3, 1, ..., etc., until price convergence occurs for all three firms (i.e., where each firm's price has stabilized and cannot be altered without risking reduced profits). The number of iterations to price convergence may vary as the number of firms become numerous (as the market becomes satiated) and/or the conditions of the market change; therefore requiring computer-aided simulation to reduce computational effort.

This numerical approach can be used to analyze both the process underlying the spatial distribution of equilibrium prices as well as the properties of that final price equilibrium itself. This directly reactive (first-order) convergence process is only one of many potential price adjustment paths that can be simulated. This sequential approach will be utilized so that comparisons of the velocity of price adjustment can be made between bounded and unbounded market descriptions. More complex price reaction scenarios can be imagined (e.g., higher order or group price adjustment algorithms), but will not be explored at this time.

Table 2
Simulation of Optimal Mill Prices in an
Unbounded Spatial Market

Iteration	Firm 1	Firm 2	Firm 3	Change(Firm)
1	5.000	5.000	5.000	n.a.
2	5.000	6.409	5.000	+.409 (2)
3	5.000	6.409	6.565	+.565 (3)
4	6.728	6.409	6.565	+.728 (1)
5	6.728	6.757	6.565	+.348 (2)
6	6.728	6.757	6.774	+.209 (3)
7	6.778	6.757	6.774	+.050 (1)
8	6.778	6.780	6.774	+.023 (2)
9	6.778	6.780	6.781	+.007 (3)
10	6.781	6.780	6.781	+.003 (1)
11	6.781	6.781	6.781	+.001* (2)

Note: $A = 40$, $a = 15$; $b = 15$; $t = .5$; and $k_1 = k_2 = k_3 = 3$.

Price convergence factor = .001 .

Short-run equilibrium is attained when firms are reluctant to change their mill price, since they conclude that no alternative price pattern exists whereby profits will rise. In other words, firms cannot increase their level of expected profits. This is typically referred to as a Nash equilibrium, and by definition must hold for each and every firm (Eaton, 1976). Under the Nash equilibrium condition, firms operate under the premise that they have absolutely no manipulative power over their competitors, thus precluding the potential for predatory or price-warring behavior (Williamson, 1977; Milgrom and Roberts, 1982; Issac and Smith, 1985; Von Hohenbalken and West, 1986) for motivations which extend beyond the short-run.

Simulation Objectives

Specifically, a series of simulations were run to:

- (i) examine the price-convergence process for a symmetrical spatial market operating under the zero-conjectural pricing policy (i.e., to test whether or not the equilibrium state is independent of the specific path or starting point of the reaction sequence);
- (ii) clarify to what degree the adjustment time (or the number of rounds in the simulation) depends upon

- the number of rivals in the spatial market;
- (iii) study the boundary effects by comparing price equilibria in the linear and circular markets (e.g., is the effect more or less pronounced in the case of elastic demand?); and
 - (iv) generalize about the spatial configuration of equilibrium prices in spatial markets; i.e., to establish the roles of the transport rate t , demand parameters (a,b) , and firms' equidistant locations X_i , $i=1,\dots,n$ (including analysis on the number and spacing of firms within that market) in determining the overall average mill price and profit levels for geographically interacting and interdependent firms.

The impact of increasing transportation costs and firm density on average mill price was simulated for an imposed market size (market length $A = 80$ units), contrasting bounded and unbounded spatial markets under elastic and inelastic demand. The results of these simulations are summarized in Figures 2 through 15. The output for the two market descriptions are discussed in turn, with attention on the effects of parameter changes on average mill price, profits, and the speed of equilibrium price convergence. A listing of all parameters used in the simulation is given in Table 3. Firm locations are restricted to be

regular in terms of separation (i.e., they are equidistant from nearest neighbors and/or market boundaries) and unchanging. This restriction (equally spaced firms) will be relaxed later to account for the effects of agglomerative spatial structures. However, since this chapter is concerned with assessing the effects of market density, transportation rates, and market length, it will be assumed that firms are evenly distributed over the length of the market to control for any inherent locational influences that may bias the results (e.g., the effects of price competition amongst firms who are clustered in space). The number of firms n is used to denote market/producer density.

Table 3

Parameters Used in Simulation Experiment

Demand Constant $a = 15$ units
Constant Marginal Cost $k_i = 3.0$ for all i firms
Demand Intensity Parameter $b = 0.5$ (relatively inelastic)
Demand Intensity Parameter $b = 1.5$ (elastic)
Number Of Firms $n : 3 \leq n \leq 11$
Transport rate $t : .25 \leq t \leq 2.25$
Price Conjecture: Hotelling-Smithies

Note: Price convergence factor = .001 .

Equilibrium Conditions

Linear (Bounded) Market

Increasing consumer transportation expenditures as an increasing function of t (for the case of elastic demand) tends to have a considerable negative effect on average mill price when the number of firms in the market is small (Figure 2). This result is not surprising given that accessibility to any one firm increases (in terms of aggregate travel distance) as the market becomes more dense (i.e., as n becomes large). As n approaches ∞ firms the price-suppressing effect of added travel expenditure becomes minimal. This implies that, as the number of equidistantly spaced competitors increases (and the space between those competitors decreases) consumers become less sensitive to delivery price schedules. In the limit, as the market fills to be everywhere dense with competing suppliers, consumers' demand functions would approach $q = a - bp$. Hence, as the number of firms within a market of invariable size goes up, transportation rate increases are shown to have only modest effects on equilibrium price levels.

If transportation costs represent a relatively high proportion of the total consumption expenditure (e.g., when $t \geq 2.0$), there is a significant reduction in

Figure 2. Simulated Average Mill Price vs. (t)
in a Linear Market (elastic demand).

equilibrium mill prices when relatively few firms compete (Figure 3). As t and n both rise, prices are shown to converge (in this case around 4.7 dollars). There is also evidence of a slight downward trend in price as t increases. This is no doubt due to the limiting influence of market density, and can be construed as a logical outcome when consumer demand is defined as elastic (and as firms adjust accordingly to that elasticity).

For the case of inelastic demand, the effects of increasing values of t on price are not so clearly defined. Initial increases in t yield higher equilibrium mill prices, with a faster rate of increase (and later decrease) for relatively few firms as opposed to many firms (Figure 4). As the t parameter increases beyond 1.0, the rate of reduction in average mill price is shown to be more pronounced when n is small and becomes relatively unchanging as n grows larger (leveling off at about 6.3 dollars as t declines). As consumer demand is less responsive to price changes the convergent average firm price level proves to be higher than that of the case of elastic demand. This is an intuitively appealing and sensible result given the conditions imposed. However, the resulting impact of increasing market density does not carry such a straightforward property. In fact, the simultaneous increase in t and n reveals a mild perversity

Figure 3. Simulated Average Mill Price vs.the Number of Firms in a Linear Market (elastic demand).

Figure 4. Simulated Average Mill Price vs.(t) in a Linear Market (inelastic demand).

Figure 5. Simulated Average Mill Price vs. (n) in a Linear Market (inelastic demand).

in equilibrium price patterns (Figure 5). Notice the slight upward trend in price convergence for the simulation where $t=2.0$.

Thus, for the linear market example, it is obvious that there exists a substantial difference in the behavior of price patterns under varying market conditions. This volatility obviously needs to be explored deeper.

Circular (Unbounded) Market

A distinctly different pattern emerges for the case of elastic demand in the circular market (Figure 6). Equilibrium mill prices are shown to continuously decline only for increases in t associated with $n=3$ firms. As the number of firms increase, price levels are shown to rise and then fall or stabilize. Thus, when the geographic market is defined in such a way as to make all firms internal (as each firm has a competitor to the left and to the right in the circular market), increasing transportation costs produce a region of increasing mill prices and equilibrium prices which are less likely to converge at a lower level. In fact, as n and t increase together average equilibrium mill prices are demonstrated to behave similarly under linear and circular market descriptions, yet the circular case yields average mill

Figure 6. Simulated Average Mill Price vs.(t) in a Circular Market (elastic demand).

prices which tend to be higher than its linear counterpart (Figure 7). This is counterintuitive, since the circular market is viewed as more competitive in terms of having a total of $2x(n)$ intersecting delivery price schedules as opposed to $2x(n-2)$ intersection points for the linear (bounded) market; especially for the case of inelastic demand. However, from this result, it can be surmised that as firms become increasingly interdependent in the spatially competitive sense their pricing reactions become more a function of their proximate rivals and less sensitive to the inherent market demand components (e.g., the price elasticity of demand). Thus, price levels are not only sensitive to the number of firms competing, but are also sensitive to the number of competitive boundaries.

This situation of spiraling price trajectory as an increasing function of the number of competitive market boundaries is exacerbated for the case of inelastic demand as average mill price goes from being an increasing function of t within its limited range (for relatively few firms) to a strictly increasing function of t as n becomes large (Figure 8). Again, equilibrium mill prices tend to be much higher than for the bounded market (as would be expected under inelastic demand). The interesting finding here lies in the behavior of peaking equilibrium prices,

Figure 7. Simulated Average Mill Price vs.(n) in a Circular Market (elastic demand).

Figure 8. Simulated Average Mill Price vs. (t) in a Circular Market (inelastic demand).

where the peak average mill is shown to be highly variable and extremely sensitive to both market density of competing firms and the transportation rate (Figure 9). As t increases, the highest average equilibrium mill price is shown to be associated with a larger number of firms! This assuredly goes against the conventions of price theory in the non-spatial models of competition developed in economics, and can be attributed to the perversities caused by demand impediments which are associated with transportation costs in the acquisition of a good.

Given the market parameters investigated, increased competition under varying transport rates and inelastic demand produces higher average mill price levels in the more competitively price linked or interactive circular (unbounded) market in comparison to the linear (bounded) market. This leads one to question the relevance of assessing the competitiveness of markets without having knowledge of the spatial characteristics of that market (e.g., consumer responsiveness to transportation factors involved in the acquisition of a commodity and boundary effects).

In short, space not only matters but so does the context in which it is viewed (the cost of overcoming spatial constraints - what geographers have termed "the friction of distance"); this includes boundary conditions

Figure 9. Simulated Average Mill Price vs.(n) in a Circular Market (inelastic demand).

and the degree of interdependent forces which are found within that space. In the case of our simulated market, equilibrium price patterns are shown to express wide variation in the nature of price levels as a function of consumers' delivered price, elasticities of demand, as influenced by the combination of transportation expenditures and market density (the accessibility of consumers to firms).

Profit Levels and Price Convergence

Profit levels are shown to be highly dependent upon the geography of the market, transportation cost margins, and the delivered price elasticity of demand (see Figures 10 through 13). The circular market shows wide variations in profits with transportation-rate-specific price convergence. For elastic (inelastic) demand, profits tend toward zero (an increasingly positive level) as n and t increase in the boundless market. Thus, even though average mill prices remain higher (in the circular versus the linear market), average profit demonstrates a tendency to be driven down toward zero as the market becomes supplier dense and/or as travel expenditures rise. In contrast, the linear market shows a dual pattern of profit convergence which distinguishes between interior and

Figure 10. Simulated Average Profits vs.(n) in a Circular Market (elastic demand).

Figure 11. Simulated Average Profit vs.(n) in a Circular Market (inelastic demand).

Figure 12. Simulated Profit Levels vs. (n) in a Linear Market (elastic demand).

Figure 13. Simulated Profits vs.(n) in a Linear Market (inelastic demand).

exterior firms. Profits are driven downward in both cases (toward some positive amount), with spatial patterns that behave in dramatically different ways based on the interior or exterior quality of the firm (Figures 10 and 11). Exterior firms demonstrate the ability to draw higher short-run profits when transportation costs are relatively low (Figures 12 and 13). This outcome is most likely due to the boundary conditions that exist in the linear market specification, where exterior firms exhibit a moderate amount of market power in the competitive spatial structure (i.e., they act as monopolists over peripheral market areas). This phenomenon reinforces the idea that models of price competition be couched within a format that jointly considers market concentration (i.e., the number of firms and the extent of their service area or profit share) and a description of the spatial structure (i.e., the organization of firms in space and the influence of boundaries on the distribution of price and profit).

The speed of short-run equilibrium price convergence is also shown to be sensitive to the geographic layout of the market (Figures 14 and 15). Linear markets tend to display a much faster rate of convergence, a convergence that is, in fact, a linear function of the number of firms which compete in the market (*ceteris paribus*). This convergence

Figure 14. Number of Iterations to Equilibrium in a Linear Market (elastic,inelastic demand).

Figure 15. Number of Iterations to Equilibrium in a Circular Market (elastic, inelastic demand).

is, on the otherhand, insensitive to demand intensity and/or transportation cost parameters, indicating that the chain-like structure of price interdependence in the linear market seems to operate as a strictly monotonically increasing function of firm density. This may be attributed to the susceptibility of pricing mechanics to the limiting effects of geographic boundaries (no doubt accentuated by the sequential convergence process).

In comparison, the circular market is both highly sensitized to consumer-demand-related parameters and the effects of boundlessness through slower rates of convergence as t increases and/or b decreases (i.e., as transportation expenditures rise and/or demand becomes more inelastic). Increased competitive price interaction in the circular market has impeded the attainment of equilibrium, implying that the duration of short-run market stability may have a variable meaning given that equilibrium conditions are highly dependent upon geographical properties. The absence of boundary effects and the increased interactive behavior (as a function of intersecting delivered price schedules) is shown to have a dampening effect of the price-convergence process.

It would be interesting to see whether the velocity of convergence is affected when pricing conjectures are asymmetrically distributed in time and/or space. Given the

likelihood that price conjectures are subject to change in response to fluctuations in price/profits as firms learn the difference between expected and realized price reactions (Benson and Faminow, 1988), it is possible to envisage a scenario in which geographic markets never reach an equilibrium, but operate instead within a steady state-- one which is a function of interdependent price conjectures which evolve with respect to the constraining nature of the physical characteristics of the market and its agents. Alternatively, if boundary effects exclude the possibility of reaching an equilibrium, it is feasible to think of a market which has multiple equilibria. Such patterns may arise when firms are receptive to change as the extent of competitive market segments are altered or asymmetrical firm locations and/or conjectures are imposed and the potential for "adaptive" conjectural change is realized within the price-adjustment period.

Regarding the question of own-price convergence, the equilibrium state is found to be independent of the path or sequence of price reaction (i.e., in the iterative process of price reaction among adjacent firms, the starting point in the sequential resolution of equilibrium prices is demonstrated to be irrelevant under the assumptions of fixed equidistant firm location and conjectural symmetry). Therefore, when firms' locations

are specified as regularly spaced, the market is found to exhibit constancy in the adjustment or convergence of price. Notwithstanding these results, it remains to be proven that this will be true for unevenly distributed firms (particularly, for the circular market) that operate under mixed conjectural modes.

Summary

In the comparison of general competitive price levels for markets involving symmetrical zero-conjectural pricing behavior, it is not at all clear (by the results gathered here) that increased intensity of competition (through the inclusion of additional firms and/or a circular unbounded market description) is necessarily associated with lower overall average equilibrium mill prices. In fact, the opposite may be true (as demonstrated by the simulations performed in this chapter). The results presented in this chapter suggest that models of competition in spatially dependent markets must account for the influence of geographic structure on price. It has been demonstrated that both the degree of competition and the boundedness of geographic markets have radical impacts on patterns of price and profit, and therefore must be carefully scrutinized.

Variations in average mill price are shown to display opposing tendencies in bounded versus unbounded spatial markets. Bounded markets, although less competitive (in terms of having less adjacent rivals or competitive market boundaries that were determined through the intersection of delivered price schedules), were shown to yield equilibrium price levels that were below that of the unbounded markets (regardless of the elasticity of demand). Disparities in average equilibrium mill prices are shown to be highly variant for cases involving inelastic demand.

Thus, spatial price competition must be viewed as a market process that is sensitive to the relative locations of competitors, the attributes of consuming entities, and the extent of geographically delimited market segments and boundaries (as a function of price reaction and/or the physical traits of the market itself). These results are not directly derivable by the non-spatial model of price competition, leading one to question the relevance of S-C-P analyses which exclude spatial content. When changes in consumer and producer welfare are considered (Benson, 1984), a distinction must be made between price/profit levels as a function of competitive market forces (from a behavioral and density perspective) and price patterns as a by-product of a physical and behavioral spatial

structure (from either friction of distance or boundary effects). The implications and complexities of boundary effects become further apparent when asymmetrical distributions of firms are conceptualized.

As a corollary, the direct and indirect linkages in rival pricing policy must be interpreted within the context of a "spatial" market from a holistic point of view, one which encompasses geographic, conjectural, and/or behavioral realities. In weighing the merits of spatial price theory, many of these issues must be brought to the forefront to challenge models which ignore the implications of space. This theme is the focus for inspection in chapters that follow. Chapter 4 turns toward the topic of price conjectural variation, by reviewing three of the most widely cited firm-pricing policies and their associated properties of expectation. Moreover, some of the basic algebraic properties will be discussed and simulation results presented for the case of inelastic consumer demand. This sets the stage for the progression of a more realistic version of spatial price competition in markets involving asymmetry.

CHAPTER 4

PRICE REACTION IN SPATIAL MARKETS (INELASTIC DEMAND)

Price Conjectural Variations

Löschian Competition

Under Löschian behavior, firms believe that adjacent rival firms will not allow their market segments or service areas to be altered. In the event of a price change, prices of adjacent rivals will always be matched exactly and immediately. It is assumed that the response time among competitors is of a zero lag, and that individual firms' geographic market delineations are stable or fixed. By definition, Löschian competition is said to exist if all firms treat their market areas as an exogenous condition. This standard space-filling and space-fixing model is known to yield the highest mill prices and the least industry output (Ohta, 1980; Mulligan, 1988). The long-run equilibrium state is exemplified by the largest possible number of entrants and final retail outlets, coinciding with the lowest average transportation costs to consumers (Faminow and Benson, 1985; Benson and Faminow, 1985).

In the short-run, Löschian behavior among firms will produce the highest temporary profits for an initial number of competitors. However in the long-run, such profitability would soon be suppressed by the attraction of new entrants into the market, shrinking the size of firm's service areas (some below that which is required to sustain production, causing exiting). The Löschian equilibrium is obtainable when firms cease to enter or exit the market, and the following conditions prevail:

- (1) individual firms are under the restriction of zero-profit;
- (2) each firm operates under profit-maximization where marginal cost and marginal revenue are equated;
- (3) the density of firms in the market is the highest allowable; and
- (4) all consumers are served, yielding efficient maximum coverage (Mulligan, 1981).

As each firm assumes its market segment or service area to be fixed, it establishes price as if it were a monopolist within that market area. However, since a firm's actions are not independent of the nullifying responses of adjacent rivals, price-reaction functions are assumed to be well-behaved and stable since the market boundary is known and invariable. This is illustrated

nicely in Figure 16 for the case of spatial duopoly for two firms (located at distances s_1 and s_2) with a given market boundary s^* . Any shift upwards or downwards in price by one competitor is exactly matched, yielding no change in s^* (i.e., there are no patronage shifts by consumers along the linear market denoted by line segment $s_1 s_2$). Here, if demand is relatively inelastic, the Löschian conjecture results in the highest spatial pricing of any possible pricing strategy.

The geographic interpretation of Löschian competition takes on a different meaning from the price conjectural definition given above, in that it focuses on the properties and shapes of market areas. For example, in the two-dimensional setting, a Löschian single-good equilibrium results in market-packing configurations composed of identical space-filling hexagons. Mills and Lav (1964) have argued that in the case of unprofitable and/or high fixed-cost industries, only non-space-filling configurations could satisfy the Löschian equilibrium requirements. Stern (1972) was able to point out that this is only true if consumer demand is constrained to non-negative levels. Mulligan (1981, 1982) has further established that given the zero-conjectural variations assumption (where each firm takes the price and location of all other firms as given), the Löschian equilibrium can

Figure 16. Lösschian Competition in a Spatial Duopoly.

Firm 1's expectation: mill price change will be equally matched by competitor, leaving market boundary unchanged.

only be strictly satisfied through social planning or direct market intervention by a central market directing agency. Thus, the Löschian equilibrium is seen purely as a normative concept. In comparing four possible alternative market shapes (the square, triangle, hexagon, and circle), it has been demonstrated that when hexagonal packing arrangements cover an industry's fixed cost level, that it is indeed the most efficient market configuration (Mulligan, 1981). For special cases involving non-space filling market areas, where the circular market description typifies the limiting state in a high fixed cost industry, a continuum of rounded hexagons is found to also satisfy the two-dimensional Löschian equilibrium criteria. In terms of efficiency, this can only be true for industries where the fixed cost constraint is overcome by the rounded hexagonal design and the non-negative consumption requirement is not violated. The former as opposed to the latter definition (which stresses the long run) of Löschian competition will be used throughout the remainder of this dissertation (i.e., the emphasis will be on the Löschian price conjecture where firms price as if market areas were exogenous).

Capozza and Van Order (1978) have stated that the Löschian model violates many of the traditional aspects of competition in one-dimensional markets, namely

- i. as transportation costs approach zero, prices should approach marginal costs (tending toward the perfectly competitive solution), as demonstrated in the previous chapter;
- ii. as fixed costs approach zero, spatial monopoly power is diminished;
- iii. as costs rise, prices rise;
- iv. as demand density rises, firms should be able to take advantage of economies of scale in production and/or distribution, causing long-run prices to fall; and
- v. as more firms enter the industry, competition should increase and prices decline (this condition may be violated under certain circumstances as shown earlier).

Furthermore, Capozza and Van Order (1978) add that the Löschian equilibrium conditions are only met if transportation costs are a large proportion of delivery price schedules, or if average demand is elastic with respect to transportation costs, or if the fixed costs of the industry are so large that firms are barely viable (denoting a strong barrier to entry). Such conditions, they feel, would seem to be highly unlikely in the case of retail operations involved in the marketing of necessity

items (e.g., retail food establishments), constituting the exception rather than the rule.

Benson (1980) has countered these findings by stating that Capozza and Van Order's conclusions are based solely on the nature of their demand function. In fact, Benson argues that their criticism of Löschian competition is certainly unwarranted given the restrictive nature of linear demand. Benson has shown that Löschian competition does not violate the spatial character of competition when a negative exponential demand relation is tested. These findings support the need for empirical evidence in describing the attributes of consumer demand.

From a social-welfare standpoint, the implications of Löschian arrangements are contestable given the inherent trade-off between higher mill prices and lower transportation costs for consumers as the market becomes satiated with competitors. With higher spatial concentrations of retail outlets, the overall net benefit to consumers is unclear since consumers may be willing to pay higher prices for the sake of convenience vis-à-vis greater accessibility to those sites. Therefore, Löschian competition is not necessarily undesirable providing, of course, there is free entry (Faminow and Benson, 1985). Consequently, the causal linkage between high prices and high profits along with lower consumer benefits is not

intuitively obvious when accessibility arguments are interjected.

Finally, it has been suggested that, if one accepts the assumption of Löschian competition, it is logical to conclude that "firms raise and lower their mill prices in unison either because of collusion or price leadership" (Capozza and Van Order, 1978). Yet, if firms realize the competitive nature of geographic market boundaries, the incentive to counter price leadership or underprice colluding firms negates the stability of Löschian behavior, i.e., if firms begin to switch their pricing conjectures. Within this mind-set, statistical analyses of spatial price covariation need to verify the potential for collusive behavior through the examination of price movement and change among adjacent competitors.

Hotelling-Smithies Behavior

The Hotelling-Smithies (HS) conjectural framework operates under the assumption that a competitor views the price of rival firms as fixed (and therefore, sees the geographically competitive market boundary as malleable). The HS pricer anticipates the capture of borderline service area by lowering prices (relatively speaking). The HS conjecture operates under the perception of elastic

consumer demand with respect to delivery price. Firms presuppose that the given price structures of adjacent competitors remain static, believing that their boundaries will expand at the peripheries as determined by shifts in delivery price schedules in relation to mill-price differentials. In other words, firms believe that they can encroach upon or annex the fringe market areas of adjacent competitors simply by attracting some of their customers away at the competitive market boundaries through relatively lower prices.

Since each firm assumes that prices of competitors are constant, each expects to capture a share of its competitors' markets by undercutting its rivals at boundary locations. This can be depicted graphically (Figure 17). Assume that an HS pricer decides to lower its mill price (say for the firm located at s_1), where the new "expected" market boundary shifts from s^* to s^{**} (therefore yielding an expected annexation of market segment $s^{**} - s^*$ by firm 1). Under the assumption of this zero-pricing conjecture, HS or Bertrandian competition has been labelled as a spatial equivalent to Chamberlain's model of monopolistic competition (Chamberlain, 1933). By ordering the spatial market as a linked oligopoly, individual firms become cognizant of their competitors' strategies through falling profits. Later, as firms

Figure 17. Hotelling-Smithies (Bertrand)
Pricing Behavior in a Spatial Duopoly.

Firm 1's expectation: mill price change will go unchallenged by competitor, i.e., there is no expected rival price change. Note shift in market boundary.

realize their interdependence they may mutually follow a course of action which is found to be suitable to counter any competitive strategy. This realization is acquired with experience in price setting policy, and the monitoring of profits, distinguishing HS behavior as more of a short-run behavioral phenomenon (Issac and Smith, 1985; Benson and Faminow, 1988).

Greenhut-Ohta Competition

Under Greenhut-Ohta (GO) competition, the firm regards neither its own market area nor its rival's mill price as fixed. Firms treat these elements as highly variable. A firm's expectation, however, is that border price (i.e., that price which is determined by the intersection of delivery price schedules for adjacent firms) is assumed to be constant (Ohta, 1980). Thus, firms act in a price-reciprocating manner to rival price changes, exactly offsetting the magnitude of price change in the opposite direction. Constancy in market boundary price can be equated to that of a competitively defined price ceiling. A constant market boundary price can easily be seen by graphing a typical GO price reaction (Figure 18). If the market is defined through a linear demand specification, the radius change for GO behavior is known to be equivalent to the radius change under a spatial monopoly.

Figure 18. Greenhut-Ohta Competition in a Spatial Duopoly.

Firm 1's expectation: mill price change will be exactly offset in a reciprocal manner (equally, in the opposite direction) by its' competitor, leaving market boundary price unchanged.

The spatial monopolist's market, however, will extend to the point where delivered price equals the maximum price a consumer is willing to pay according to the properties of the demand curve. In an overall assessment of the Greenhut-Ohta pricing conjecture, it "does not appear to have a non-spatial analog" (Capozza and Van Order, 1978). Imposition of a set border price between adjacent competitors delimits the extent of competitively determined market segments whereby, in the long-run, total revenues fluctuate in such a way that the ceiling is driven downward as firms enter the market (depressing the total revenues associated with each firm's service area). This will inevitably bring about a situation of even lower mill prices and larger industry output than does HS competition, and conceivably the "maximum consumer welfare" (Ohta, 1980). Ohta states that

"price ceiling competition creates the least profit for individual firms. It therefore restricts new entry and in effect requires the strongest concentration in terms of the number-size of the firms in the long run."
(Ohta, 1980, p.9)

A Conjectural Pricing Framework

Discussion now turns toward the analytics of conjectural pricing in spatial markets involving n firms ($n \geq 3$) under inelastic consumer demand. Assume that under

such conditions, consumers are constrained to purchase one unit of a homogenous commodity. Since we have specified the extent of a firm's market area as being determined by the interaction of delivery price schedules (equation 1), the total number of consumers contained within that market (at unit density) comprise a firm's total market segment a_i , with short-run profits determined by the first-order condition associated with maximization of profit with respect to price (using equation 8). If a firm conjectures on its adjacent rivals' pricing behaviors (i.e., maximizing profits while anticipating a price response from each of its two nearest neighboring competitors), the first-order condition must be restated as

$$\frac{\delta Z_i}{\delta p_i} = (p_i - k_i) \left[\frac{\delta Q_i}{\delta p_i} \right] + Q_i = 0, \quad (15)$$

where the change in demand (through the expected readjustment of market areas as conjectured by the firm) as a function of the change in mill price, $\frac{\delta Q_i}{\delta p_i}$, can be decomposed into a function which describes the anticipated responses of those rivals. Hence,

$$\begin{aligned} \frac{\delta Q_i}{\delta p_i} &= (1/2t) \left[\left(\frac{\delta p_{i-1}}{\delta p_i} \right) - 2 + \left(\frac{\delta p_{i+1}}{\delta p_i} \right) \right] \\ &= (1/2t) \left[\phi_{i,i-1} - 2 + \phi_{i,i+1} \right], \end{aligned} \quad (16)$$

where $\phi_{i,i-1}$ and $\phi_{i,i+1}$ symbolize the respective pricing conjectures of firm i in relation to its expectations regarding rivals' responses (for the left-side nearest neighbor $i-1$, and the right-side nearest neighbor $i+1$). These expectations are simply representative of the surmised price changes for the $(i-1)$ st and $(i+1)$ st firms, respectively. Following the procedure used in the derivation of equation (8), using equations (15) and (16), a new price reaction function for an i -th (interior) firm can be restated as

$$p_i [4 - (\phi_{i,i-1} + \phi_{i,i+1})] = p_{i-1} + p_{i+1} - tX_{i-1} + tX_{i+1} + [2 - (\phi_{i,i-1} + \phi_{i,i+1})]k_i. \quad (17)$$

This equation shows the direct effects upon a firm's price due to (i) the prices and locations of its nearest competitors; (ii) the anticipated price response of those competitors; and (iii) the firm's own marginal cost of production (Mulligan and Fik, 1988). The above price reaction function may be generalized to include expectations about next-nearest neighbors or those twice, three,...etc. times removed (i.e., higher-order or indirect price expectations). This can be accomplished using a weighted function of (17) which sums over all

other $n-1$ firms in the market (where the weighted influence of price conjecture is stated as a decreasing function of distance). Equation (17) displays price reaction only in terms of first-order or direct pricing expectations with respect to adjacent rivals. This is the simplest case of the more generalized price reaction formulation, something that will not be addressed in this work. Suffice it to say that, the velocity of simulated price convergence may be altered dramatically if firms not only speculate on their nearest-neighbors' responses but also on the wave of responses that are set off from that initial price change throughout the entirety of the market (as all firms respond).

The second-order condition: $\delta^2 Z_i / \delta p_i^2 < 0$ is satisfied when the sum of the conjectural parameters is such that:

$$(\phi_{i,i-1} + \phi_{i,i+1}) < 2 .$$

Unless noted otherwise, it will be assumed that all firms act internally symmetric in their expectations, i.e., firms anticipate similar responses from rivals on either side. Subsequently, each firm's optimizing behavior is conditional upon a single conjectural statement

$$\phi : \phi_i = \phi_{i,i-1} = \phi_{i,i+1} .$$

This implies that the second-order condition remains satisfied for a price conjectural parameter $\phi : \phi < 1$.

In this way, the term symmetrical conjecture represents a firm's internal consistency in expectations.

Internal vs. External Symmetry

Symmetry in conjecture can be a confusing concept, because of its dual meaning: (1) its reference to the internal symmetry as shown in the singularity of an individual firm's conjectural parameter; and (2) the possibility that more than one firm (or all firms) operates under the same conjectural parameter (i.e., a symmetrical market conjecture). Therefore, the use of the phrase "symmetrical conjecture" must be differentiated into two separate terminologies which are identifiable by scale: (I) the internalized symmetry in conjecture (at the firm level); and since one can picture a market composed of n firms who are internally symmetric in their expectation yet their individual price-conjectural parameters may be different (i.e., $\phi_i \neq \phi_j$); and (II) the externalized symmetry in conjecture (at the market or industry level). It will be assumed for the present that all firms have internal symmetry in pricing conjectures and that there exists congruency among all firms (a symmetrical market conjecture). The former assumption will hold throughout this dissertation (given that it is more

likely to be encountered in a real world setting than the second assumption); while the latter is modified for the case of mixed or asymmetrical market pricing conjectures (i.e., where competing firms' conjectural parameters are not symmetrical).

In the sections which follow, price-conjectural testing is imposed on alternative spatial market compositions. First, the circular market description for odd and even number firms is analyzed and simulation results reviewed. Secondly, a similar exercise is undertaken for the linear market with some remarks made on the comparative aspects of the components of price and the effect of boundary. The algebraic properties of these systems are discussed at length.

Circular Spatial Market

Given the logic of the arguments presented above, the three special case pricing conjectures (reviewed earlier in this chapter) are summarized in Table 4. Within the price reaction function of an i -th firm, the conjecture is made on the behavior of adjacent rivals j , where $j = i-1$ or $i+1$.

Table 4

Price Reaction Parameters Under Various Conjectures

Conjecture	Reaction Parameter $\phi = \delta p_j / \delta p_i$
L (Löschian)	$\phi_L = \phi = 1$
HS (Hotelling-Smithies)	$\phi_{HS} = \phi = 0$
GO (Greenhut-Ohta)	$\phi_G = \phi = -1$

It is a straightforward exercise to substitute these reaction parameters into equation (17) and construct the corresponding equations which denote price optimality for an i -th interior firm under each of these special cases. Formally, this can be expressed as a series of price reaction relationships under the assumptions of internal symmetry in pricing conjecture, and written as follows:

$$L: p_i = 1/2 (p_{i-1} + p_{i+1} - tX_{i-1} + tX_{i+1}) ; \quad (18)$$

$$HS: p_i = 1/4 (p_{i-1} + p_{i+1} - tX_{i-1} + tX_{i+1} + 2k_i) ; \quad (19)$$

$$GO: p_i = 1/6 (p_{i-1} + p_{i+1} - tX_{i-1} + tX_{i+1} + 4k_i) . \quad (20)$$

The reaction parameter weights as represented by the fractions $1/2$, $1/4$, and $1/6$ can be interpreted as behavioral (response) intensity coefficients for price competition based on expectations. Notice that these fractions do not directly fall out from the reaction parameter ϕ . In the case of Löschian behavior, the inclusion of ϕ_L nullifies the firm's own marginal cost component. Thus, Loschian pricing can be viewed an upper-limit to alternate competitive pricing strategies. Written in their least common denominator $\{6/12, 3/12, \text{ and } 2/12\}$ it is easily recognized that these fractions are functionally related to ϕ , and can also be written as a transformation of the marginal cost weight (w) , from $(w)k_i$ in (18) through (20), as $1/(w+2)$. Yet, the values and interpretation of these fractions are highly variable since they depend upon many factors, namely, price of nearest neighbors, own marginal cost (with the exception of Löschian behavior), and the transportation cost weighted effects of distance as determined by the location of competitors. Hence, given the enormous variability in such factors, simulation and sensitivity analysis of price reaction is certainly necessary and justifiable.

Remember the short-run equilibrium state is established when all firms have no incentive to alter their prices (and have satisfied the first- and second-order conditions

stated above), thereby establishing a vector of prices p^* which, by the argument given previously. This equilibrium-price vector synthesizes the performance of each firm in terms of its nearest neighbors (i.e., the direct effects) and the properties of more distant competitors (i.e., the indirect effects) (Mulligan and Fik, 1989). The summation of direct and indirect influences on price is a function of the chain-like structure of price dependence in space, where the behavior of all firms are ultimately linked through the composition of equation (17) while simultaneously complying with the equilibrium condition.

For the purpose of expressing equation (17) in matrix notation, let $\alpha = 4-2\phi$, and $\beta = 2-2\phi$, and consider the case of an unbounded market with $n = 5$ firms. Equation (9) can thus be rewritten in matrix form as

$$\begin{bmatrix} \alpha & -1 & 0 & 0 & -1 \\ -1 & \alpha & -1 & 0 & 0 \\ 0 & -1 & \alpha & -1 & 0 \\ 0 & 0 & -1 & \alpha & -1 \\ -1 & 0 & 0 & -1 & \alpha \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \end{bmatrix} = \begin{bmatrix} tX_2 - tX_5 + \beta k_1 \\ tX_3 - tX_1 + \beta k_2 \\ tX_4 - tX_2 + \beta k_3 \\ tX_5 - tX_3 + \beta k_4 \\ tX_1 - tX_4 + \beta k_5 \end{bmatrix} \quad (21)$$

or

$$\underline{C} \underline{p} = \underline{X} ,$$

where $\underline{C}$ is the 5x5 symmetrical matrix of price coefficients as defined by the behavioral characteristics

of firms, $\underline{p}$ is the 5×1 vector of prices, and $\underline{X}$ is the 5×1 vector associated with firm location and cost structure. The optimal price vector $\underline{p}^*$ is derived as before, and written as

$$\underline{p}^* = \underline{C}^{-1} \underline{X}, \quad (22)$$

identifying the short-run optimal mill price schedules for each of the $n = 5$ firms.

Following the procedures outlined in Mulligan and Fik (1989) some of the general properties of this pricing system need to be summarized. Denoting the number n of firms in the market by attaching superscripts on the various vectors identified above, some algebraic relationships between the properties of markets containing $n-1$ firms to those of markets having n firms can be identified (where the number $n-1 \geq 3$, or $n \geq 4$). Property 1 can be stated as

$$\begin{aligned} \underline{p}^*{}^n &= (\underline{C})^n{}^{-1} \underline{X}^n \\ &= [1/\det(\underline{C})^n] \underline{B}^n \underline{X}^n, \end{aligned} \quad (23)$$

where $\det(\underline{C})^n$ is the determinant of matrix $\underline{C}^n$ and $\underline{B}^n$ is the adjoint matrix of $\underline{C}^n$. Examination of $\det(\underline{C})^n$

discloses the existence of the following sequence
(Property 2):

$$\det(\underline{C})^3 = \alpha^3 - 3\alpha - 2$$

$$\det(\underline{C})^4 = \alpha^4 - 4\alpha^2$$

$$\det(\underline{C})^5 = \alpha^5 - 5\alpha^3 + 5\alpha - 2$$

or in general the relationship between successive determinants can be written as

$$\det(\underline{C})^n = \alpha \det(\underline{C})^{n-1} + 2 - \det(\underline{C})^{n-2} - 4, \quad (24)$$

for $n \geq 5$ firms. For example, under HS behavior ($\phi=0, \alpha=4$) the sequence of determinants is found to be 50, 192, 722, 2700, 10082, 37632, etc. (a multiplicative function which converges around an approximate value of 3.73x as n becomes larger); and 196, 1152, 6724, 39200, 228484, 1331712, etc. for GO behavior ($\phi=-1, \alpha=6$) (with a multiplier which converges around an approximate value of 5.82x as n becomes larger). Note, that when firms assume the Löschian pricing conjecture ($\phi=1, \alpha=2$) the determinant sequence process is indeterminate since $\det(\underline{C})^n = 0$ for all values of n . Therefore, to approximate the sequence of determinants values of ϕ which are close to unity must be introduced into (24), this can be termed as near-Löschian

(NL) behavior (where L represents an upper limit to all possible pricing conjectures).

The next interesting feature has to do with the various elements of the adjoint matrix $\underline{B}^n$ in (23). Given the symmetry of the price coefficients matrix $\underline{C}^n$, a related symmetry exists in the elements of $\underline{B}^n$. The third important property of equation (23) can be described by the following correspondence:

$$\underline{B}^n = \begin{bmatrix} b_{11}^n & b_{12}^n & . & . & . & b_{1,n-1}^n & b_{1n}^n \\ b_{21}^n & b_{22}^n & . & . & . & b_{2,n-1}^n & b_{2n}^n \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ b_{n1}^n & b_{n2}^n & . & . & . & b_{n,n-1}^n & b_{nn}^n \end{bmatrix}, \quad (25)$$

or

$$\underline{B}^n = \begin{bmatrix} b_{11}^n & b_{12}^n & . & . & . & b_{1,n-1}^n & b_{1n}^n \\ b_{1n}^n & b_{11}^n & . & . & . & b_{1,n-2}^n & b_{1,n-1}^n \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ b_{12}^n & b_{13}^n & . & . & . & b_{1n}^n & b_{11}^n \end{bmatrix}.$$

Note that the arrangement of elements in the i th row of $\underline{B}^n$ (as in $\underline{C}^n$) is identical to the arrangement of elements

in the $(i-1)$ st row with the exception that all i th-row elements are displaced one cell to right of their $(i-1)$ st row locations. Hence, having knowledge of the 1st-row elements of $\mathbf{B}^n$ it is possible to specify the complete matrix $\mathbf{B}^n$ by consecutive row displacement.

Odd Number of Firms

Consider the identification of the 1st-row elements of

$$\mathbf{B}^n : b_{1j}^n \quad (1 \leq j \leq n) \text{ when the number of firms is odd}$$

(i.e., $n = 3, 5, 7, \dots$). It is always possible to define the two smallest elements of that row (u^n) located in columns $(n+1)/2$ and $(n+3)/2$, and establish a series of values for successive elements occupying adjacent locations within that row; thus revealing Property 4:

$$\begin{aligned} b_{1, (n+1)/2}^n &= b_{1, (n+3)/2}^n = \delta_1 u^n = u^n \\ b_{1, (n-1)/2}^n &= b_{1, (n+5)/2}^n = \delta_2 u^n = (\alpha - 1)u^n \\ b_{1, (n-3)/2}^n &= b_{1, (n+7)/2}^n = \delta_3 u^n = (\alpha^2 - \alpha - 1)u^n. \end{aligned}$$

In general this property can be written as

$$\delta_j = \alpha \delta_{j-1} - \delta_{j-2} \quad (\text{for } j \geq 3) \quad (26)$$

with

$$b_{1, (n+1-2j)/2}^n = b_{1, (n+3+2j)/2}^n = \delta_{j+1}^n u_{j+1}^n \quad (27)$$

for $j \leq (n-3)/2$, and

$$b_{11}^n = \delta_{(n+1)/2}^n u_{(n+1)/2}^n. \quad (28)$$

Expressions (26) through (28) yield values for all 1st-row elements of $\underline{B}^n$ once the smallest elements u^n are established (where u^n are known to vary with the order n of $\underline{B}$). Furthermore, it has been shown that these elements behave as follows (for an increasing number of odd firms):

$$u^3 = \alpha + 1$$

$$u^5 = \alpha^2 + \alpha - 1 = \alpha u^3 - 1$$

$$u^7 = \alpha^3 + \alpha^2 - 2\alpha - 1 = \alpha u^5 - u^3,$$

or in general (Property 5)

$$u^n = \alpha u^{n-2} - u^{n-4} \quad (29)$$

for $n \geq 7$ and odd (Mulligan and Fik, 1988).

Even Number of Firms

A similar set of properties can be derived for b_{1j}^n ($1 \leq j \leq n$) when n is even (i.e., $n = 4, 6, 8, \dots$). As before it is possible to specify the smallest element v^n in the 1st-row of B in column $(n+2)/2$, and establish the succession of the residual elements through the following relationships:

$$\begin{aligned}
 b_{1, (n+2)/2}^n &= v_1^n = v^n \\
 b_{1, n/2}^n &= b_{1, (n+4)/2}^n = v_2^n = (\alpha/2) v^n \\
 b_{1, (n-2)/2}^n &= b_{1, (n+6)/2}^n = v_3^n = [(\alpha^2 - 2)/2] v^n,
 \end{aligned}$$

or in general expressed as

$$b_j^n = \alpha^{j-1} v_{j-2}^n \quad \text{for } j \geq 4, \quad (30)$$

with

$$b_{1, (n+2-2j)}^n = b_{1, (n+2+j)/2}^n = v_{j+1}^n \quad (31)$$

for $j \leq (n-2)/2$, and

$$b_{11}^n = v_{(n+2)/2}^n. \quad (32)$$

The smallest values v^n are also known to behave by the following rules:

$$v^4 = 2\alpha$$

$$v^6 = 2\alpha^2 - 2$$

$$v^8 = 2\alpha^3 - 4\alpha = \alpha v^6 - v^4,$$

where in general

$$v^n = \alpha v^{n-2} - v^{n-4} \quad (33)$$

for $n \geq 8$ and even (Mulligan and Fik, 1988).

Remarks

Equation (22) can be solved for the range of all possible conjectural variations among n competitors.

A generalized equilibrium price p_i^* for the i th interior firm in a market comprised of n firms can be specified by the formula

$$p_i^* = [1/\det(\underline{C})] \sum_{j=1}^n b_{ij} (tX_{j+1} - tX_{j-1} + \beta k_j) \quad (34)$$

where $X_a = X_{n+a}$ ($a=0,1,\dots$). Given the recursive

properties of $\underline{B}$, a reduced form version of equation (34)

can be generated for an odd number of firms using the logic employed by Mulligan and Fik (1989), namely

$$p_i^* = [1/\det(\underline{C})] \left[\sum_{j=1}^{(n-1)/2} d_{(n+1-2j)/2}^n y_i^n (tx_{i+j} - tx_{i-j}) + \right. \\ \left. \beta u \left\{ \tau_{(n+1)/2}^n k_i + \sum_{j=1}^{(n-1)/2} \tau_{(n+1-2j)/2}^n (k_{i+j} + k_{i-j}) \right\} \right] \quad (35)$$

where $d_1 = 1$, $d_2 = 5$, $y^3 = 10$, $y^5 = 38$, $u^3 = 5$, $u^5 = 13$,

$\tau_1 = 1$, $\tau_2 = 3$, and the following set of relationships

hold:

$$y^n = \alpha y^{n-2} - y^{n-4} \quad \text{for } n \geq 7 \text{ and odd,}$$

$$\tau_j = \alpha \tau_{j-1} - \tau_{j-2} \quad \text{for } j \geq 3;$$

and $X_{-a} = X_{n-a}$ and $k_{-a} = k_{n-a}$.

Likewise when n is even, the equilibrium price for an i th interior firm can be written as

$$\begin{aligned}
 p_i^* &= [1/\det(\underline{C})] \left[\sum_{j=1}^{(n-2)/2} y^{(n-2j)/2} (tX_{i+j} - tX_{i-j}) + \right. \\
 &\quad \left. \beta v \left\{ \sigma_{(n+2)/2, i} k_1 + \sigma_1 k_{(n+2)/2} \right\} + \right. \\
 &\quad \left. \sum_{j=1}^{(n-2)/2} \sigma_{(n+2-2j)/2} (k_{i+j} + k_{i-j}) \right], \quad (36)
 \end{aligned}$$

where $y_1 = 1$, $y_2 = 4$, $y^2 = 12$, $y^4 = 48$, $v^2 = 2$, $v^4 = 8$,

$\sigma_2 = 2$, $\sigma_3 = 7$, which are regulated by the following

relationships:

$$y^n = \alpha y^{n-2} - y^{n-4} \quad \text{for } n \geq 6 \text{ and even,}$$

and

$$\sigma_j = \alpha \sigma_{j-1} - \sigma_{j-2} \quad \text{for } j \geq 3.$$

See Mulligan and Fik (1989) for some numerical examples.

From the above formulas it is possible to construct equilibrium price levels p_i^* (for an i th firm, $i=1, \dots, n$) as a function of two groups of numbers (for any circular market situation): one group representing firms' locational components and the other representing firms' marginal cost components. For example, the effects of rivals' location, own marginal cost, and rivals' marginal

cost on the equilibrium price p_1^* of firm 1 in a market containing $n=5$ firms (under GO pricing behavior, $\phi=-1$) can be computed as

$$p_1^* = .17073(tX_2 - tX_5) + .02439(tX_3 - tX_4) + .70731(k_1) + .12194(k_2 + k_5) + .02438(k_3 + k_4). \quad (37)$$

Equation (37) shows, in order, the effects of 1st-nearest neighbors' locations, 2nd-nearest neighbors' locations, own marginal cost, 1st-nearest neighbors' marginal costs, and 2nd-nearest neighbors' marginal costs. The weights attached to these effects display an interesting distance-decay property as the pricing conjecture changes from the near Löschian value of $\phi=.999$ to the Greenhut-Ohta strategy where $\phi=-1$. In Table 5, ratios of distance-decay effects are tabulated for these location and cost components. Note that the rate of distance-decay is greatest under Greenhut-Ohta pricing behavior. This indicates that as the price conjecture coefficient rises (falls), distant competitors have a relatively greater (smaller) influence in a firm's own equilibrium price. This trend is true for both location and marginal cost effects; with the firm's own marginal cost being relatively unimportant (important) when the pricing conjecture increases (decreases), i.e., when

ϕ approaches 1 (-1). When the pricing behavior of firms tend toward the Löschian extremity the marginal cost effects tend to dissolve, with the location effects of proximate rivals becoming more pronounced. Under Löschian behavior, all firms' marginal cost structures tend to have an equal effect on each firm's equilibrium price despite their different locations.

These distance-decay properties represent the space-echoing effects of pricing behavior. A similar exercise can be undergone for intermediate cases as well (i.e., for pricing conjecture which lie between the cases presented above). It follows, therefore, that unique distance-decay properties exist for each value of ϕ . Thus, as an extension of these numerical relationships, unique distance-decay relationships exist for asymmetrically distributed conjectures as well (although the identification of such properties is problematic given the infinitely large number of possibilities which exist).

Table 5

Component Ratios of Firm 1's Price in a Circular Market
for Various Consistent Pricing Conjectures

$\phi = .999$	n=5 firms			$.999$	n=7 firms		
	0	-1			0	-1	
<hr/>							
Ratios of Location Effects on Price							
3:1 (tX ₂ - tX ₅)/(tX ₃ - tX ₄)	5:1 (tX ₂ - tX ₃)/(tX ₅ - tX ₄)	7:1 (tX ₂ - tX ₄)/(tX ₃ - tX ₅)	1.668:1 (tX ₂ - tX ₇)/(tX ₃ - tX ₆)	3.8:1 (tX ₂ - tX ₇)/(tX ₄ - tX ₆)	5.858:1 (tX ₂ - tX ₇)/(tX ₄ - tX ₅)		
				<hr/>			
				5:1 (tX ₂ - tX ₇)/(tX ₄ - tX ₅)	19:1 (tX ₂ - tX ₇)/(tX ₄ - tX ₅)	41:1 (tX ₂ - tX ₇)/(tX ₄ - tX ₅)	
<hr/>							
Ratios of Marginal Cost Effects on Price							
1:1 (k ₁)/(k ₂ + k ₅)	3.666:1 (k ₁)/(k ₂ + k ₅)	5.8:1 (k ₁)/(k ₃ + k ₄)	1:1 (k ₁)/(k ₂ + k ₇)	3.727:1 (k ₁)/(k ₂ + k ₇)	5.827:1 (k ₁)/(k ₂ + k ₇)		
1:1 (k ₁)/(k ₃ + k ₄)	11:1 (k ₁)/(k ₃ + k ₄)	29.001:1 (k ₁)/(k ₃ + k ₄)	1:1 (k ₁)/(k ₃ + k ₆)	13.667:1 (k ₁)/(k ₃ + k ₆)	33.8:1 (k ₁)/(k ₃ + k ₆)		
				1.012:1 (k ₁)/(k ₄ + k ₅)	41.012:1 (k ₁)/(k ₄ + k ₅)	169.165:1 (k ₁)/(k ₄ + k ₅)	
Own Marginal Cost Effect (k ₁)							
0.200	0.578	0.707	0.144	0.577	0.707		

Note: Ratios computed from Mulligan and Fik (1988),
Table 1.

Linear Spatial Market

Suppose that a linear market of length A exists with 2 exterior or peripheral firms and $n-2$ interior firms ($i=1, n$). Equation (17), therefore, must be modified to include the boundary effects imposed on firms 1 and n which yield the following price relations:

$$p_1(2 - \phi) = p_2 + tX_1 + tX_2 + (1 - \phi)k_1, \quad (38)$$

$$p_n(2 - \phi) = p_{n-1} + 2tA - tX_{n-1} - tX_n + (1 - \phi)k_n, \quad (39)$$

which describe the direct effects of competition and physical market structure on exterior firms' prices. Again, the second-order condition is satisfied when individual price conjectural variation ϕ is less than unity. Note that the service areas on the bounded side of both exterior firms are implicitly accounted for in the pricing arrangements shown in equations (38) and (39) above. This information will affect the specification of elements in the 1st and n th row of matrices $\underline{C}$ and $\underline{X}$ in equation (21) and, therefore, all subsequent transformations. Under the bounded market description, the new matrix relations for firms operating with internally and externally symmetrical conjectures is formulated as

$$\begin{bmatrix} \mu & -1 & 0 & 0 & 0 \\ -1 & \alpha & -1 & 0 & 0 \\ 0 & -1 & \alpha & -1 & 0 \\ 0 & 0 & -1 & \alpha & -1 \\ 0 & 0 & 0 & -1 & \mu \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \end{bmatrix} = \begin{bmatrix} tX_1 + tX_2 + \Phi k_1 \\ tX_3 - tX_1 + \beta k_2 \\ tX_4 - tX_2 + \beta k_3 \\ tX_5 - tX_3 + \beta k_4 \\ 2tA - tX_4 - tX_5 + \Phi k_5 \end{bmatrix} \quad (40)$$

or

$$\underline{C}^* \underline{p} = \underline{X}^*,$$

where $\mu = (1/2)\alpha$, and $\Phi = (1/2)\beta$. The equilibrium price vector $\underline{p}^{**}$ is computed from the equation

$$\underline{p}^{**} = \underline{C}^{*-1} \underline{X}^*, \quad (41)$$

and restated as a function on n firms by

$$\begin{aligned} \underline{p}^{**} &= (\underline{C}^*)^{-1} \underline{X}^* \\ &= [1/\det(\underline{C}^*)] \underline{B}^* \underline{X}^*, \end{aligned} \quad (42)$$

with $\det(\underline{C}^*)$ representing the determinant of $\underline{C}^*$ (for a linear market composed of n firms) and $\underline{B}^*$ is the adjoint matrix of $\underline{C}^*$.

As before, the existence of similar sequential properties in matrix relations can be defined through the

following series of equations (note the boundary effect in comparison to (24)):

$$\det(\underline{C}^*)^3 = 2\mu^3 - 2\mu$$

$$\det(\underline{C}^*)^4 = 4\mu^4 - 5\mu^2 + 1$$

$$\det(\underline{C}^*)^5 = 8\mu^5 - 12\mu^3 + 4\mu$$

forming the general expression for successive determinants

$$\det(\underline{C}^*)^n = 2\mu \det(\underline{C}^*)^{n-1} - \det(\underline{C}^*)^{n-2} \quad (43)$$

for $n \geq 5$. As in the circular market case, once the 1st row elements of the adjoint matrix $\underline{B}^*$ are derived we have full knowledge of all elements $(b^*_{i,j})$ in $\underline{B}^*$. However,

certain properties need to be elaborated on, (i.e., those properties which differentiate the numerical relationships in the linear market from that of the circular market).

First, the underlying (nth order) adjoint matrix $\underline{B}^*$ can be generated for $n=3$ firms from

$$\underline{B}^*^3 = \begin{bmatrix} 2\mu^2 - 1 & \mu & 1 \\ \mu & \mu^2 & \mu \\ 1 & \mu & 2\mu^2 - 1 \end{bmatrix} \quad (44)$$

It is now possible to construct all the more complicated versions of $\underline{B}^*$ for higher orders ($n=4,5,\dots$) from $\underline{B}^*$. For the general $n \times n$ case the following identities can be noted:

$$\begin{aligned}
 \text{i.} \quad & b_{1n}^* = 1 ; \\
 \text{ii.} \quad & b_{1,n-1}^* = \mu ; \\
 \text{iii.} \quad & b_{1,n-2}^* = 2\mu^2 - 1 ; \\
 \text{iv.} \quad & b_{2j}^* = \mu b_{1j}^* \quad (\text{for } 2 \leq j \leq n) ;
 \end{aligned}$$

with all remaining 1st row elements derived by

$$b_{1,n-j}^* = 2\mu b_{1,n-j+2}^* \quad (45)$$

for $2 \leq j \leq (n-1)$. Given the symmetrical nature of $\underline{B}^*$ and identity (iv.) above (which yields all 2nd row elements of the adjoint matrix with the exception of the 1st column), a general property of adjoint matrix elements can be expressed through

$$b_{ij}^* = 2\mu b_{i-1,j}^* - b_{i-2,j}^* \quad (46)$$

for $i \geq 3$ and $i \leq j \leq n$, where all elements in the upper right-hand portion of $\underline{B}^*$ (including the main diagonal)

are therefore known. All equilibrium price solutions (for n firms in a linear market) are thus provided by manipulation of equations (43) through (46).

Remarks

As in the case of the circular market, the above arguments can be generalized to specify the equilibrium price p_i^* of an i th firm in a linear market having n firms by

$$\begin{aligned}
 p_i^* = & [1/\det(\underline{C}^*)] [2b_{in}^* t_A + (b_{i1}^* - b_{i2}^*) tX_1 + \\
 & \sum_{j=2}^{n-1} (b_{i,j-1}^* - b_{i,j+1}^*) tX_j + (b_{1,n-1}^* - b_{1n}^*) tX_n + \\
 & \phi b_{i1}^* k_1 + \beta \sum_{j=2}^{n-1} b_{ij}^* k_j + \phi b_{1n}^* k_n] . \quad (47)
 \end{aligned}$$

Notice that in equations (34) and (47), a firm's equilibrium price depends directly and indirectly upon the transportation rate, the location (and distribution) of other firms, and the marginal cost structure of all firms. However, in a bounded market, a firm's price also depends upon its own location (except for the case of the median firm when n is odd) and the length of the spatial market weighted by the transportation rate (t_A). When the market is bounded, firms' locations and marginal costs are

"weighted asymmetrically in space, except ... for the $[(n+1)/2]$ th firm when n is odd" (Mulligan and Fik, 1989).

Simulation results for the component ratios of a median firm's price in the linear market are charted in Table 6 (for $n = 5$ and 7 respectively). Note the inclusion of the weighted market length component (tA). As n increases and/or ϕ approaches -1 (the GO pricing conjecture) tA becomes more influential in the determination of equilibrium price (notice how the market-length effect drops off dramatically as ϕ moves downward from the near-Löschian conjectural value of $.999$). As before, there is a similarity in the behavior of distance-decay rates in both location and marginal cost effects, where distance-decay is lowest (highest) when pricing conjecture is highest (lowest).

A comparison of the results given in Tables 5 and 6 directly disclose the impacts of market boundaries on spatial pricing. It is immediately apparent that the rate of distance-decay is greater in the bounded market. In particular, it is evident that peripheral firms in the bounded market have less influence in the determination of equilibrium price levels than those firms classified as fully interior (all firms in the circular market) or those classified as partially interior (centralized firms in the linear market).

Table 6

Component Ratios of Median Firm's Price in a Linear
Market for Various Consistent Pricing Conjectures

n=5 firms (median=3)			n=7 firms (median=4)		
$\phi = .999$	0	-1	.999	0	-1
<hr/>					
Ratios of Location Effects on Price					
$\frac{4:1}{(tX_4 - tX_2)/(tX_5 - tX_1)}$			$\frac{2:1}{(tX_5 - tX_3)/(tX_6 - tX_2)}$		
			<hr/>		
			$\frac{8:1}{(tX_5 - tX_3)/(tX_7 - tX_1)}$		
<hr/>					
Ratios of Marginal Cost Effects on Price					
$\frac{1:1}{(k_3)/(k_2 + k_4)}$			$\frac{1:1}{(k_4)/(k_3 + k_5)}$		
$\frac{2:1}{(k_3)/(k_1 + k_5)}$			$\frac{1:1}{(k_4)/(k_2 + k_6)}$		
			$\frac{2:1}{(k_4)/(k_1 + k_7)}$		
<hr/>					
Own Marginal Cost Effect on Price					
0.250	0.583	0.708	0.167	0.577	0.707
<hr/>					
Market Length Effect on Price (tA)					
249.6140	0.0833	0.0283	166.1500	0.0022	0.0003

Note: Ratios computed from Mulligan and Fik (1988),
Table 2.

The results presented above are consistent with the findings presented in chapter three, where spatial isolation was associated with lower rates of competitive interdependence, as end-firms directly and indirectly influence the chain-like structure of price dependence through the limiting effects of boundaries, yielding strong "nearness" effects in (individual and average) equilibrium mill price. Yet, these patterns clearly indicate that there are multiple price truncating effects since prices and spatial price disparities have a tendency to be influenced not only by market density (the number of competing firms) and the concentration of those firms in space (the length of individual firm's geographic market segments or market shares) but also through the behavioral characteristics of individual firms, as well as, interdependent and exogenous market boundaries. This implies that the difference in distance-decay related price components in Tables 5 and 6 represent the distorting effects of geographic boundaries. If isolated competitors are less significant in the overall determination of price levels, then it is not intuitively obvious that price distortions caused by boundary effects necessarily imply a potential for peripheral firms to exploit their position or their bounded service

areas/segments through higher prices, given that the equilibrium price of any one firm is ultimately linked to all other firms in the market. This can be best illustrated by the components of price for an end firm ($i=1$) in a bounded market (listed in Tables 7 and 8).

Under near-Löschian behavior ($\phi = .999$), both own marginal cost of production and location of an end firm are less influential in the construction of its equilibrium price. It is easily recognizable that the distance-decay relations for marginal cost and location components show that the end firm's price is most dependent upon the cost and locational characteristics of its closest rival. In fact, the component weight attached to the firm's second closest rival is also more influential in the determination of its price than the firm's own location or marginal cost structure. Given such clear-cut interdependence in pricing behavior, it is hard to conceptualize a peripheral firm (even if it is moderately isolated) as having the capabilities of extracting monopolistic type rents when indeed the market is categorized as a competitive and linked oligopoly.

Table 7

Components of Equilibrium Price of 1st Firm
in a Bounded Market with n=5 Firms

Component	$\phi = .999$	$\phi = 0$	$\phi = -1$
Algebraic Components			
⁵ det($\underline{C}^*$)	0.00805	168.0	1632.0
b*	15691.5900	0.00343	0.00021
¹¹ b*	15583.0559	0.00092	0.00003
¹² b*	15505.6894	0.00024	6.3E-06
¹³ b*	15459.3291	0.000007	1.1E-06
¹⁴ b*	15443.8882	0.000003	3.7E-07
¹⁵			
Market Length Component			
tA	248.646	0.0119	0.0012
Marginal Cost Component			
k (own)	0.1263	0.5773	0.7070
¹ k	0.2508	0.3095	0.2426
² k	0.2496	0.0833	0.0401
³ k	0.2488	0.0238	0.0073
⁴ k	0.1243	0.0059	0.0012
⁵ k			

Table 7--Continued

Components of Equilibrium Price of 1st Firm
in a Bounded Market with n=5 Firms

Component	$\phi = .999$	$\phi = 0$	$\phi = -1$
Location Components			
tX ₁	0.8738	0.4226	0.2928
tX ₂	1.4965	0.5357	0.3430
tX ₃	0.9960	0.1428	0.0588
tX ₄	0.4975	0.0297	0.0098
tX ₅	0.1243	0.0059	0.0012

Table 8

Components of Equilibrium Price of 1st Firm
in a Bounded Market with $n=7$ Firms

Component	$\phi = .999$	$\phi = 0$	$\phi = -1$
Algebraic Components			
⁷ det($\underline{C}^*$)	0.01216	2340.0	55440.0
b*	7016.009	0.00024	6.3E-06
¹¹ b*	6940.787	0.00006	1.1E-06
¹² b*	6879.447	1.7E-05	1.8E-07
¹³ b*	6831.864	4.7E-06	3.2E-08
¹⁴ b*	6797.944	1.2E-06	5.0E-09
¹⁵ b*	6777.620	3.6E-07	9.7E-10
¹⁶ b*	6770.849	1.8E-07	3.2E-10
¹⁷			
Market Length Component			
tA	164.667	0.0008	3.0E-05

Table 8--Continued

Components of Equilibrium Price of 1st Firm
in a Bounded Market with n=7 Firms

Component	$\phi = .999$	$\phi = 0$	$\phi = -1$
Marginal Cost Component			
k ₁ (own)	0.0853	0.5773	0.7071
k ₂	0.1687	0.3094	0.2426
k ₃	0.1673	0.0829	0.0416
k ₄	0.1661	0.0222	0.0071
k ₅	0.1653	0.0059	0.0012
k ₆	0.1648	0.0017	0.0002
k ₇	0.0823	0.0008	7.0E-05
Location Components			
tX ₁	0.9147	0.4226	0.2928
tX ₂	1.6607	0.5358	0.3431
tX ₃	1.3245	0.1517	0.0588
tX ₄	0.9910	0.0384	0.0101
tX ₅	0.6596	0.0102	0.0017
tX ₆	0.3294	0.0025	0.0002
tX ₇	0.0823	0.0004	3.6E-05

As the market becomes saturated with competitors (i.e., as n increases) differentiation of the distance and conjectural components of price for nearest, next-nearest, etc., rivals becomes increasingly less important, as the effects of their marginal cost components become more evenly spread out (compare Tables 7 and 8). Notice the stability in the marginal cost and location weights under lower pricing conjectures. No doubt this variation is attributable to the underlying assumptions of the conjectures themselves. Since the Löschian conjecture initializes expected price response as instantaneous and equivalent, it is logical that price components of competitors be more important in the equilibration of a firm's mill price relative to a Löschian pricer's own marginal cost. Whereas the alternative conjectural modes of Hotelling-Smithies and Greenhut-Ohta possess an innate pricing expectation that is more neutral in its definition, one where anticipated rival response is either non-existent or reciprocal. Therefore, one would presume that such competitive or ultracompetitive conjectures would be associated with weights which emphasize the own-cost features of the firm itself to a higher degree in comparison to the Löschian case (as shown numerically).

It is interesting to note that the Löschian framework presents a somewhat contradictory pricing arrangement given that it is associated with the highest average mill price (in comparison to HS and GO behavior), yet it is the conjecture that is most dependent upon the relative locations of competitors. This emphasizes the importance of competing firms' behavioral parameters. As the pricing conjecture ϕ decreases in value, so does the intensity of competitive interdependence between proximate rivals. For HS behavior ($\phi = 0$), own marginal cost of production and the location of the nearest neighboring firm dominate as price components, with the influence of more distant competitors falling off quickly. As ϕ approaches -1 (the GO conjecture), this property becomes even more pronounced, as the peripheral firm's pricing behavior is most heavily weighted as a function of its own marginal cost. As previously implied, the interesting pattern in the equilibrium component weighting scheme reveals a noticeable dependence of the peripheral firm's price on the location of its nearest competitor (especially when the market has the greatest potential for higher prices, as ϕ increases). Thus, it has been demonstrated that both physical market structure (in terms of boundary effects and location) and the behavioral strategies employed by rival firms produce a variety of simultaneously

competitive influences on equilibrium price levels/patterns when the actors in a market are viewed as spatially interdependent.

Market Segment and Equilibrium Price

Equilibrium price levels are shown to exhibit a distinctive property for spatial markets classified as perfectly inelastic. The following relationship was obtained through empirical observation:

$$p_i^* = [1/(1-\phi_i)]a_i + k_i, \quad (48)$$

where price of an i -th interior firm in a circular market is a function of the behavioral parameter ϕ_i , the length of market segment a_i , and own marginal cost component k_i . Through simple manipulation of equation (48), we can solve for length of market segment as a function of price by

$$\begin{aligned} a_i &= (1-\phi_i)(p_i - k_i) \\ &= (\beta/2)(p_i - k_i), \end{aligned} \quad (49)$$

where $\beta = (2-2\phi)$ for a firm that exhibits internal symmetry in its pricing conjecture.

In the linear market, the above condition is satisfied by the imposition of the boundary restriction for

peripheral firms (i.e., for the $i=1$ or $i=n$ firm), where the following relationship is empirically obtained:

$$a_i = (\beta/4) (p_i - k_i) . \quad (50)$$

In matrix notation, it has already been established that $P^* = C^{-1} X$ (the optimal price vector for the industry at large). Return per unit of the commodity in question can therefore be represented as G , an $(n \times 1)$ vector which portrays equilibrium price less own marginal cost k , where

$$G = C^{-1} X - k . \quad (51)$$

Subsequently, an $(n \times 1)$ vector of equilibrium market lengths Ω can be constructed from the general matrix formulation:

$$\Omega = \underline{\Sigma} \underline{i} I G , \quad (52)$$

where $\underline{\Sigma}$ is an $(n \times 1)$ vector housing the appropriate values for the deflated β values with respect to market description, $\underline{i}$ is a balancing identity vector (where each element is equal to 1), and I is an $(n \times n)$ identity matrix (a matrix whose diagonal elements are unity and off-diagonal elements are equal to zero). Hence, given information on the marginal cost of production, the behavioral tendencies of price reaction, and the location of firms in space, it is possible to predict all firms'

equilibrium geographic market lengths as a function of equilibrium price. This can be demonstrated in the numerical example given below.

Consider a circular market of length $A=80$ and $n=3$ firms. Assume perfectly inelastic consumer demand and a transportation rate $t=1.0$. Furthermore, suppose that all firms were Greenhut-Ohta pricers (i.e., $\phi=-1$ for all firms). Therefore, since $\beta/2=[(2-2\phi)/2]=2$, equation (52) can be written in its extended notation as a function of C^{-1}
 $C^{-1} X = P^* = 16.333$ (for firms located at 0, 26.666, and 53.333, who operate under a constant marginal cost of production of $k=3$), as

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} = \begin{bmatrix} 2 \\ 2 \\ 2 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 16.333 & -3 \\ 16.333 & -3 \\ 16.333 & -3 \end{bmatrix}$$

$$= \begin{bmatrix} 26.666 \\ 26.666 \\ 26.666 \end{bmatrix} .$$

A similar procedure will hold for any mix of price conjectures, and produce a vector of geographic market share when each entry of Ω is divided by the length of the market itself. This property is convenient in the sense

that only information on firm location and cost structures are needed in order to solve for firms' equilibrium market segments.

Summary

This chapter concerns the identification of firms' equilibrium price levels and components (in both bounded and unbounded one-dimensional markets) under inelastic demand for three commonly referenced pricing conjectures. The theory on competitive pricing for spatial oligopolies has been reinforced, where price behavior has been shown as not just directly dependent upon the attributes of nearest competitors, but also indirectly linked to the attributes of all other spatially competitive rivals in the market. This is due to the chain-like nature of competition over adjacent geographic market segments through the transmitted price reactions of contiguous spatial rivals. Equilibrium prices are dissected into various components (of variable influence), which weight the effects of firms' marginal costs, locations, and the extent of market length; and reveal the distance-decay effects in relation to a symmetrical pricing conjecture. These distance-decay qualities are shown to be highly sensitive not only to price conjectural variation, but are

also sensitive to the designation of geographic boundary. Moreover, equilibrium geographic market share has been simultaneously linked to the economic and behavioral attributes of the market (i.e., price and conjecture). The next chapter explores the issues of market segmentation, price and profit levels, transportation rate parameters, market length, and the impact of mixed or asymmetrical (as opposed to symmetrical) pricing conjectures for the simple case of spatial duopoly in the context of elastic consumer demand.

CHAPTER 5

PRICE REACTION AND SPATIAL DUOPOLY

The Case of Elastic Demand

Spatial duopoly is the rudimentary case or limiting form of spatial oligopoly. By definition, it represents competition among $n = 2$ firms (as opposed to competition among few firms, $n > 2$) that are aware of each other, act and react in accordance with this awareness (and within the bounds of their expectations), and realize their price interdependence. Hence, firms can be construed as location-conscious entities since they understand that their service areas (market segments) are geographic in nature. In the short run, where locations are fixed, price competition becomes the critical decision-making process by which these service areas are determined. Chapter four has already explored the features of price competition under the assumption of consistent conjectural pricing. In this chapter, discussion turns toward the study of spatial markets with mixed or asymmetrical conjectures (i.e., when firms behave under different expectations). First, however, the analytics of spatial duopoly under symmetrical conjectures are introduced -- a framework

which serve as the building block for a more generalized model.

The Analytics

Consider the case of a one-dimensional linear (bounded) spatial market of length A , with two firms (duopolists) located at either end (i.e., $X_1 = 0$; $X_2 = A$). Benson and Faminow (1985) present an analogous market description for spatial duopoly. In this restricted case, each firm concerns itself strictly with the service area 0 to A (or A to 0) in the hope of capturing as large a market segment as possible away from its competitor, and thereby maximizing the extent of its own service area. Assume that this is attainable through consumers' responsiveness to price changes, where consumers are evenly distributed over this bounded market and possess identical linear demand curves (for a single homogeneous commodity) of the form $q = a - bp^d$, where p^d is the delivery price schedule, q is the quantity demanded at that delivered price, and a and b are known demand parameters ($a, b > 0$). Also, assume that over the period in question, firms' pricing policies are stable (i.e., they do not switch their price conjectures). In this way, a firm's equilibrium market area is a function of the behavioral parameters of rivals interacting in the market. Thus, firm

1's market area lies completely to the right and firm 2's market area lies completely to the left, where delivery price schedules intersect at a common boundary ($B_{1R} = B_{2L}$, at some location X_{12} where $p_1^d = p_2^d$). Since each delivery price schedule is made up of a firm's mill price p plus transportation expenditures incurred by the consumers, the setting of mill prices are crucial in the delineation of this common market boundary. If firms operate under the criterion of profit maximization, it is obvious that their expectations or conjectural properties in regards to a price reaction of a rival may well influence the designation of that boundary. But other forces are also prevalent (e.g., consumer preference as indicated by the demand parameters, a and b , consumption-related transportation expenditures as a function of t , and the length of the market and/or separation of existing retail outlets). Simulation experiments will be performed in an attempt to test specifically the potency of each of these market forces for firms that have adopted a certain short-run pricing policy (which are exogenously imposed for the sake of comparing the resulting equilibrium conditions). Benson and Faminow (1988) have studied the effects of endogenously determined pricing conjectures for experimental duopoly markets and the important role of

price reaction experience in the evolution of pricing behavior. Using probit analysis, these authors have convincingly showed a significant relationship between experience and equilibrium conditions that are predicted under tacit collusion (the Löschian conjecture). The purpose of this experiment differs in two ways: (1) firms do not switch or evolve their pricing behavior, so the equilibrium conditions under consistency in conjecture can be contrasted to both the Löschian benchmark ($\phi=1$) and intermediate conjectures (e.g., $\phi=0$ or $\phi=.5$); and (2) the importance of market attributes are considered for a variety of market conditions to assess the impacts of consumer-related parameters.

For the sake of being complete, it must be stated at the outset that the model can be developed for the case of $i=1, \dots, n$ firms, where $n > 2$, to derive the appropriate equations in relation to an interior firm facing elastic demand for either a bounded or unbounded market. However, to simplify the analysis the derivation is restricted to the case of spatial duopoly where firms are located at either end of a bounded market. Since the prominence of boundary effects have already been established, the focus here is on equilibrium price and profit as a function of market composition. Analysis proceeds from the market level (with the examination of average mill price

and profit) to the individual firm level (with the comparison of price ratios, market boundary, and percentage of the geographic market at equilibrium).

Duopoly and Symmetrical Conjectures

We can begin by describing a spatial duopoly where $n=2$ firms have like conjectures (i.e., $\phi_{12} = \phi_{21} = \phi$). If firms are located at the endpoints of a linear market of length A , and have equal marginal cost structure ($k_1 = k_3 = k$), each faces an aggregate market demand function of the form

$$\begin{aligned} Q' &= \int_0^{A'} [a - b(p' + tX)] dx \\ &= (1/2t)(a - bp')(D) - (b/8t)(D)^2, \end{aligned} \quad (36)$$

where $D = tA = (tX_2 - tX_1)$, $A' = (1/2)A$, and p' is equal

to a common price charged by the like reacting firms.

Solving for $\delta Q'/\delta p' = 0$, it can be shown that

$$\delta Q'/\delta p' = -(b/4t)[-2p + 2a/b + D + \phi(2p - 2a/b + D)]. \quad (37)$$

Substituting equation (37) into equation (15) and solving reveals the following quadratic:

$$p'^2 (4 - 4\phi) - p' \{4a/b + 6A + 4k + 2\phi(-2a/b + A - 3k)\} + 4a/b(A + k) + 2kA - A^2 + 2k\phi(-2a/b + A) = 0. \quad (38)$$

Note that as a/b , A , and k interact in equation (38) the price conjecture ϕ varies in its effect. This implies that there exists various parameter sets $S : a \in S_j, b \in S_j, k \in S_j$, and $A \in S_j$, $j = 1, \dots, f$, where the value of ϕ has little or no bearing on the equilibrium price level if conjectural neutralizing sets of parameters which work to offset the interacting coefficients in the above quadratic). This hypothesis is tested in forthcoming simulations.

Duopoly and Asymmetrical Conjectures

Assume an end firm (i.e., a firm with only one neighbor at the other side of the market) who wishes to set a mill price p_i such that profits will be maximized. The aggregate demand under this limiting case can be broken down into a right-side demand component Q_{iR} for firm 1 located at 0 and left-side demand component Q_{iL} for firm 2 located at A , where the following aggregate demand

components (Q_1 and Q_2) can be written (through the integration of equations (12) and (13), and by their summation (14)) as

$$Q_1 = Q_{iR} = \int_0^{B - 0} [a - b(p_1 + tX)] dx \quad (39)$$

$$= (1/2t)(a - bp_1)(p_2 - p_1 + D) - (b/8t)(p_2 - p_1)^2;$$

and

$$Q_2 = Q_{iL} = \int_0^{A - B} [a - b(p_2 + tX)] dx \quad (40)$$

$$= (1/2t)(a - bp_2)(p_1 - p_2 + D) - (b/8t)(p_1 - p_2)^2;$$

where $D = tA = (-tX_1 + tX_2)$. Solving the first-order

condition of equation (15) $\delta Q_i / \delta p_i = 0$, aggregate market demand as a function of mill price can be established for firms 1 and 2 from the integrated equations (39) and (40) respectively, as

$$\delta Q_1 / \delta p_1 = -(b/4t)[p_2 - 3p_1 + 2a/b + D +$$

$$\phi_{12}(p_1 + p_2 - 2a/b + D)]; \quad (41)$$

and

$$\frac{\delta Q}{\delta p_2} = -(b/4t) [p_1 - 3p_2 + 2a/b + D + \phi_{21} (p_2 + p_1 - 2a/b + D)] ; \quad (42)$$

where $\phi_{12} = \delta p_2 / \delta p_1$ and $\phi_{21} = \delta p_1 / \delta p_2$, indicating how firms 1 and 2 conjecture about their rival's behavior, respectively. Substituting equations (39) or (40) and (41) or (42) into equation (15), firm 1's or firm 2's reaction function can be solved for directly, yielding the respective quadratic equations for firm 1 or firm 2 as a function of price, marginal cost, market length, and conjecture. The quadratic equation for firm 1 is found to be

$$\begin{aligned} (9 - 2\phi_{12})p_1^2 - p_1 [4p_2 + 8a/b + 4D + 6k_1 + 2\phi_{12}(p_2 - 2a/b + D - k_1)] + 4a/b(p_2 + D + k_1) + 2k_1(p_2 + D) - \\ (p_2 + D)^2 + 2k_1\phi_{12}(p_2 - 2a/b + D) = 0 ; \end{aligned} \quad (43)$$

and the quadratic equation for firm 2 (as a mirror image to equation (42)) can be written as

$$\begin{aligned}
& (9 - 2\phi_{21})p_2^2 - p_2 [4p_1 + 8a/b + 4D + 6k_2 + 2\phi_{21}(p_1 - \\
& 2a/b + D - k_2)] + 4a/b(p_1 + D + k_2) + 2k_2(p_2 + D) - \\
& (p_1 + D)^2 + 2k_2\phi_{21}(p_1 - 2a/b + D) = 0. \quad (44)
\end{aligned}$$

For equations (43) and (44), the second-order conditions are satisfied when $\phi_{12}, \phi_{21} \leq 1$ as before. The above equations are presented by Mulligan (1988) in an overview of the effects of asymmetrical pricing conjectures. A much more in-depth analysis of spatial duopoly under mixed price conjectures is developed here.

The Simulation

Mulligan (1988) has reported on the need to examine the above model of price competition for spatial duopoly characterized by mixed conjectures, i.e., where ϕ_{12} does not equal ϕ_{21} . This methodology can obviously be extended for markets containing $n > 2$ firms, yet due to the indefinite number of possible cases that are associated with spatial oligopoly under asymmetrical pricing behavior this chapter restricts itself to the simpler versions of the two-competitor model in the interest of clarifying

some fundamental properties. Thus, the focus of the remaining sections of this chapter is on analysis of a simulated spatial duopoly, beginning with a description of average equilibrium price and profit (at the aggregate market level) for various combinations of pricing conjectures, market lengths, demand intensities, and transportation rates, and ending with a discussion of contrasting price/profit differentials at the individual firm level. Each market parameter is varied individually (with the remaining parameters held constant). Unless specified otherwise, the following constant parameter values are utilized throughout this experiment: $a=15$; $t=1.0$; $b=.75$; $k_1 = k_2 = 3.0$; and $A=20$.

Analysis at the Market Level

In the mechanics of price geography, the adage that "space matters" is quite visible in the sensitivity analysis of varying market length A (where $A: 5 \leq A \leq 40$) and its effect on equilibrium price and profit shown in Figures 19 and 20. It is evident that both the behavioral aspects of competitors and the combined expectations in rival's price response are extremely important in the determination of average mill price and profit. As the

Figure 19.

The Effects of Market Length and Asymmetric Conjectures on Equilibrium Mill Price.

Note: Convergence Price = 8.6667

Figure 20.

The Effects of Market Length and Asymmetric Conjectures on Average Equilibrium Profit.

length of the market is stretched (i.e., as A becomes large), it is apparent that mixed conjectural influences become less significant as the market length approaches some limiting value at around 22.667 units of distance (in conjunction with the other parameters used in this example).

This convergence point identifies the market length and price at which the firm behaves as though a monopolist. The monopoly radius $R(m)$ can be written as

$$R(m) = (2/3) [(a-kt)/bt] = 11.333,$$

and adjusted (multiplied by a factor of 2) to account for the limiting conditions of a bounded market composed of duopolists at each endpoint. The monopoly price $p(m)$ can be written as

$$p(m) = (1/3)(a/b) + (2/3)k = 8.6667.$$

Beyond that range, the dominance of conjectural mix reverses itself (i.e., higher prices are associated with Löschian behavior for market size below the limiting value and lower prices beyond). The converging behavior of average mill price and profit (to a uniquely identifiable pivoting value) seems to confirm the existence of a conjecture neutralizing set of market parameters as hypothesized above.

The average market profit functions tends to behave correspondingly to price levels (as would be expected in this simple competitive model), where profit is positively correlated with price. Notice, however, that prices are generally driven downwards as the degree of separation between these peripheral firms increases, whereas profit levels are increasing with a tendency to flatten out (compare Figures 19 and 20). Monopoly profits are shown to be approximately 1091.7778, or 2 times the monopoly profit for the unbounded market $G(m)$; where

$$G(m) = \{4(a-bk)^3\} / \{27(b)^2 t\} = 545.888.$$

Thus, as the extent of the geographic market increases higher equilibrium prices and profits are associated with GO pricing behavior (lower price conjectures). This is a direct contradiction to the properties of a market under Löschian pricing, and is most likely attributable to the perversities associated with transportation cost, and a critical market length where firms begin to act as monopolists over their respective market segments.

Price performance and conjectural mix produce radically different functions, with Löschian-type mixes behaving more linearly and downward as opposed to the curvilinear properties of Greenhut-Ohta-type reaction (where prices increase at a decreasing rate up to the limiting value and

begin to decline). As the breadth of the market expands, so too do HS-related conjectural mixtures reveal higher profits (this again is in direct contrast to the notion of Löschian competition yielding the highest profits). This suggests that transportation cost considerations are an important component in demand decisions when consumer demand is price elastic.

The identification of threshold values (as in the limiting size of market) where conjectural mix has no bearing on equilibrium schedules is not restricted to market size alone. Examination of the effects of varying transportation rates produce similar patterns in average equilibrium market conditions (Figures 21 and 22). In this case, a transportation rate threshold exists at approximately \$1.15 per unit commodity/per unit distance. As consumers' average transportation expenditures rise price and profit schedules show reversals in terms of the dominant conjectural mix. A second distinct convergence point is identified as transport rate begins to exceed the marginal cost of production for the commodity in question. One interesting feature is exposed here, namely the disparities in average profit as t increases between thresholds. Again, we see a tendency for GO-type strategies yielding higher relative price and profit levels for the market as a whole.

Figure 21.

The Effects of Transportation Rate t
on Equilibrium Mill Price.

Figure 22.

The Effects of Transportation Rate t
on Average Equilibrium Profit Level.

The impact of changing delivery price elasticities of demand is less crucial than that of the geographic variables of market size and the friction of distance parameter t (in terms of acquisition cost) (Figures 23 and 24). Inspection of average price and profit gradients show the greatest distinguishing characteristics when demand is relatively inelastic. A discontinuity seems to occur between the average conjecture when b is less than .75 (i.e., the asymmetrical conjectural sets of $\{\phi_{12}=1, \phi_{21}=-1\}$ and $\{\phi_{12}=0, \phi_{21}=0\}$ do not produce equivalent outcomes). This is a prevailing characteristic of all the relationships discussed previously in Figures 19 through 22 as well, but is most prominently demonstrated in the average profit level as b approaches zero (Figure 24). Note that as demand becomes extremely inelastic, the combined price reactions containing at least one Löschian component reveal drastically different (and higher) profit schedules. In fact, the greatest profit potential is associated with diametrically opposed pricing conjectures, that is, when $\phi_{12} = 1$ and $\phi_{21} = -1$ (and would obviously hold true for the converse of this case given the symmetrical properties of this market analysis). In addition, there exists a range of elasticity values where conjectural frameworks are virtually non-influential in the

Figure 23.

The Effects of Demand Intensity Parameter b
on Average Equilibrium Mill Price.

Figure 24.

The Effects of Demand Intensity Parameter b
on Average Equilibrium Profit Level.

equilibration of profit maximizing mill prices (e.g., when $b: \approx .75 \leq b \leq \approx 2.0$).

Interpretation of these simulation results can be alternatively illustrated by graphing the relationship between average equilibrium profits and price (Figures 25 through 27). The main advantage of this comparison lies in its ability to exploit the uncertain correspondencies between high prices and high profits. In other words, in the environment of spatially competitive duopoly, one must understand the nature of firms' behavioral tendencies in price reaction, as well as the geographical and demand side parameters, before a clear picture of market level price-profit configurations can be drawn. Therefore, in the evaluation of competitive oligopoly (as a generalization), price and profit schedules may provide misleading information as to the nature and intensity of competition without a priori knowledge of the behavioral tendencies of competitors and consumers.

Figure 25.

A Comparison of Average Equilibrium
Mill Price and Profit for Similar Values of b .

$b=1.25; .75; \text{ and } .25$

Figure 26.

A Comparison of Average Equilibrium
Mill Price and Profit for Similar Values of t .

Figure 27.

A Comparison of Average Equilibrium
Mill Price and Profit for Similar Values of A.

Remarks

The idiosyncracies presented above suggest a greater need to explore the various spatial implications which arise under geographically distributed competitors and their respective conjectural responses. Such an exercise is beneficial since it may reduce indeterminacy through the identification of plausible and/or rational firm behavior as determined by the prevailing conditions in the market. For more complex or realistic distributions of firms in space, the associated price conjectural range must be unique for every geographic location since the relative location, and subsequent distance-decay properties, of spatially dependent rivals and/or local market conditions will vary widely. It is apparent that aggregate level market area analyses are incapable of teasing out these localized competitive effects.

Thus, the ability of spaceless models of price competition to assess the structure-conduct-performance of markets must be questioned. Such models may be deemed appropriate when either the scale of analysis is relatively large and/or all relevant components of these models are simultaneously operative at thresholds where behavioral properties at the individual firm level are unimportant (i.e., if the spatial market is such that conjectural mixtures are equally influential (converged)

in the determination of prices given the underlying system parameters). This situation seems highly unlikely given the complexities, instabilities, and uncertainties which accompany the wide variety of behaviorally and spatially covarying chained price reactions which are possible. Such an improbability is exacerbated by the acceptance of market disequilibria (the existence of "steady-states"). In summarizing the average equilibrium conditions of the above simulated market, it is readily apparent that proper S-C-P market area research jointly consider the linkage of spatial and behavioral variables, something which has been historically overlooked by many practitioners of industrial organization. This section has reinforced the concerns and sentiments of geographers, regional scientists, and spatial economists as to the importance of space and location in market area analysis. The next section emphasizes micro- (or firm-) level price and profit comparisons and the effects of variable system parameters and mixed conjectures.

Discussion will now turn to a more detailed version of price competition under spatial duopoly with attention paid to the equilibrium conditions at the individual firm level. This will set the stage for the micro-level approach to simulated markets used in the remainder of this dissertation.

Analysis at the Firm Level

Individual equilibrium price, profit, and market boundaries are tabulated at the firm level for rivals operating in a mixed conjectural mode to assess their sensitivity to market length A , transportation rate structure t , and demand intensity b (See Tables 9 through 11). These results reveal marked differences in micro-level price trajectory paths and associated market boundaries as a function of system parameters. The effects of each of the three parameters listed above are examined in turn and their idiosyncracies discussed for three sets of conjectures in a spatial duopoly:

$$[\{\phi_{12} = 0; \phi_{21} = -1\}, \{\phi_{12} = 1; \phi_{21} = 0\}, \{\phi_{12} = 1; \phi_{21} = -1\}].$$

Note that these three special cases exhaust all possible pairings of Löschian, Hotelling-Smithies, and Greenhut-Ohta behavior which are asymmetrical and not obtainable by reflection or rotation (for spatial duopolists located on the endpoints on a one-dimensional linear market).

The Effects of Market Length

Figures 28 through 30 illustrate the impact of market length on the equilibrium mill-price trajectories under various conjectural frameworks. Price levels conform to

Figure 28. The Effects of Mixed Conjectures and Market Length on Equilibrium Price in a Bounded Spatial Duopoly (HS vs. GO).

Figure 29. The Effects of Mixed Conjectures and Market Length on Equilibrium Price in a Bounded Spatial Duopoly (L vs. HS).

Figure 30. The Effects of Mixed Conjectures and Market Length on Equilibrium Price in a Bounded Spatial Duopoly (L vs. GO).

the industry convergence property and converge at approximately $A = 22.5$. Note, however, that the place of convergence is quite different for each of the three cases examined. For instance, mixed conjectures which are comprised of a Löschian contingent (as in Figures 29 and 30) are more apt to produce higher individual mill-price schedules. Yet, at all market lengths, the spatial disparities in equilibrated price levels are subject to the underlying behavioral tendencies of the competitors. As the firm price levels converge, the individual shares of the spatial market become equally divided. At the point where market shares are equivalent, mixed conjectural set price differences can be seen, purely, as non-behaviorally linked outcomes (as the effects of market length negate the influence of price reaction and expectations). Prices are shown to converge at around \$8.68 per unit no matter what pricing strategy is employed at the firm level. For market lengths less than 22.5, the degree of price disparity varies widely. As average price conjectures are low, prices are shown to be an increasing function of market length (at a decreasing rate). The peak of these interactive functions are highly dependent upon the average industry conjectural parameter and the absolute quality of the individual firm level conjectural strategies.

Table 9

Equilibrium Mill Prices and Boundaries in a
Spatially Linked Duopoly as a Function of Market Length

Market Length A	Firm 1 $p^*(\phi=0)$ 1	Firm2 $p^*(\phi=-1)$ 2	p^*/p^* 2 1	B ,B 1R 2L	(B /A)x100% 1R
5	6.3739	5.5982	0.878	2.1121	42.2
10	8.2669	7.2997	0.883	4.5164	45.1
15	8.8985	8.2278	0.924	7.1646	47.7
20	8.4005	8.6194	1.026	9.8896	49.4
25	8.4685	8.6342	1.019	12.5828	50.3
30	7.9548	8.3789	1.053	15.2120	50.7
<hr/>					
	($\phi=1$)	($\phi=0$)			
5	11.2770	8.0610	0.714	0.8920	17.8
10	10.4691	8.7159	0.832	4.1234	41.2
15	9.7242	8.9300	0.918	7.1029	47.3
20	9.0258	8.8189	0.977	9.8965	49.4
25	8.3579	8.4943	1.016	12.5682	50.2
30	7.7094	8.0341	1.042	15.1624	50.5
<hr/>					
	($\phi=1$)	($\phi=-1$)			
5	11.4426	6.9017	0.603	0.2295	4.5
10	10.6079	7.7441	0.730	3.5680	35.6
15	9.8099	8.3306	0.849	6.7603	45.1
20	9.0532	8.6272	0.952	9.7869	48.9
25	8.3374	8.6380	1.036	12.6503	50.6
30	7.6567	8.4028	1.097	15.3730	51.2

System Parameters Used: $b=.75$, $a=15$, $t=1.0$, $k_1 = k_2 = 3$.

Price Convergence Factor: .0001

Table 10

Equilibrium Mill Prices and Boundaries in a
Spatially Linked Duopoly as a Function of Transport Rate

Transport Rate t	Firm1 $p^*(\phi=0)$ 1	Firm2 $p^*(\phi=-1)$ 2	p^*/p^* 2 1	B ,B 1R 2L	(B /A)x100% 1R
0.5	8.2669	7.2997	0.883	9.0328	45.1
1.0	8.8400	8.6194	0.975	9.8896	49.4
1.5	7.9548	8.3789	1.053	10.1413	50.7
2.0	6.7499	7.3554	1.089	10.1513	50.8
2.5	5.4459	5.9510	1.092	10.1010	50.5
3.0	4.0973	4.3547	1.068	10.0429	50.2
<hr/>					
	($\phi=1$)	($\phi=0$)			
0.5	10.4691	8.7159	0.832	8.2468	41.2
1.0	9.0258	8.8189	0.977	9.8965	49.4
1.5	7.7094	8.0341	1.042	10.1082	50.5
2.0	6.4455	6.8813	1.067	10.1089	50.5
2.5	5.2053	5.5627	1.068	10.0714	50.3
3.0	3.9772	4.1590	1.045	10.0302	50.1
<hr/>					
	($\phi=1$)	($\phi=-1$)			
0.5	10.6079	7.7441	0.730	7.1361	35.6
1.0	9.0532	8.6272	0.952	9.7869	48.9
1.5	7.6567	8.4028	1.097	10.2487	51.2
2.0	6.3100	7.4098	1.163	10.2599	51.5
2.5	5.1422	6.0041	1.167	10.1723	50.8
3.0	3.9451	4.3839	1.111	10.0731	50.3

System Parameters Used: $b=.75$, $a=15$, $A=20$, $k_1 = k_2 = 3$.

Price Convergence Factor: .0001

Table 11

Equilibrium Mill Prices and Boundaries in a Spatially
Linked Duopoly as a Function of Demand Intensity

Demand Intensity b	Firm1 $p^*(\phi=0)$ 1	Firm2 $p^*(\phi=-1)$ 2	P^*/P^* 2 1	B , B 1R 2L	(B /A)x100% 1R
0.4	13.6189	11.6504	0.855	9.0159	45.1
0.8	8.3225	8.2430	0.990	9.9602	49.8
1.2	5.3891	5.7100	1.059	10.1604	50.8
1.6	3.7500	3.9129	1.043	10.0814	50.4
+ 2.0	2.7229	2.6507	1.027	9.9638	49.8
+ 2.4	2.0200	1.7402	0.861	9.8601	49.3
<hr/>					
	($\phi=1$)	($\phi=0$)			
0.4	18.2035	14.5750	0.801	8.1857	40.9
0.8	8.3838	8.3129	1.008	9.9645	49.8
1.2	5.2206	5.4557	1.045	10.1175	50.5
1.6	3.6731	3.7882	1.031	10.0575	50.2
+ 2.0	2.7564	2.7051	0.981	9.9745	49.8
+ 2.4	2.1501	1.9489	0.906	9.8994	49.5
<hr/>					
	($\phi=1$)	($\phi=-1$)			
0.4	18.4878	12.5851	0.680	7.0486	35.2
0.8	8.3937	8.2440	0.982	9.9251	49.6
1.2	5.1806	5.7354	1.107	10.2774	51.3
1.6	3.6527	3.9306	1.076	10.1389	50.6
+ 2.0	2.7654	2.6419	0.955	9.9382	49.6
+ 2.4	2.1850	1.7048	0.780	9.7598	48.7

System Parameters Used: $a=15$, $t=1$, $A=20$, $k_1 = k_2 = 3$.

Price Convergence Factor: .0001

+ Indicates An Equilibrium Price Which Is Below Marginal
Cost (Implying Negative Profit Levels).

This implies that, even though the market as a whole may be operating under an average conjectural value, of say zero, there are many mixed conjectured sets which can yield a market average of zero and at the same time produce equilibrium mill prices that vary according with those unique sets. For example, consider the case of equal average conjectural values:

$$\text{Set 1: } \{\phi_{12} = 0; \phi_{21} = 0\}; \text{ and Set 2: } \{\phi_{12} = 1; \phi_{21} = -1\},$$

where for the case of spatial duopoly, have an average underlying price conjecture of zero. Simulation results are obtained for two market lengths below and above the convergent length of 22.5 (i.e, for $A=10,15$ and $A=25,30$), and are listed in Table 12. These results reinforce the belief that price levels are dually affected by spatial variables as well as the underlying reactionary traits of adjacent competitors at the micro-level (where competition is most intense). As the number of firms increase, as to allow both direct and indirect price reaction, it potentially becomes more difficult to unmesh the explanatory importance of chained price response and exogenous influences (like market length and composition). This is especially true when demand is elastic. Thus, as n increases, so does the likelihood of indeterminacies associated with the probable combinations of behavioral

and spatial factors which can produce a specific price distribution. As emphasized before, without knowledge of individual firms' pricing policies it becomes increasingly more difficult to speculate on the competitiveness of that market.

Table 12

Equilibrium Prices and Boundary for an Average Market
Conjecture of $\phi' = 0$ in a Bounded Spatial Duopoly:

Set	A	Mkt. Boundary	p^*_1	p^*_2	Average p^*
1	10	5.0000	8.4643	8.4643	8.4643
1	15	7.5000	8.9182	8.9182	8.9182
1	25	12.5000	8.4827	8.4827	8.4827
1	30	15.0000	8.0000	8.0000	8.0000
2	10	3.5680	10.6079	7.7441	8.7659
2	15	6.7603	9.8099	8.3306	8.9973
2	25	12.6503	8.3374	8.6380	8.4859
2	30	15.3730	7.6567	8.4028	8.0205

The Effects of Transportation Costs

Utilizing the information found in Table 9, mill price schedules are plotted against the transportation rate for a mixed conjectured spatial duopoly (Figures 31 through 33). Again, it is evident that price reaction is a key element in the determination of price paths as t (and

Figure 31. The Effects of Mixed Conjectures and Transport Rate on Equilibrium Price in a Bounded Spatial Duopoly (HS vs. GO).

Figure 32. The Effects of Mixed Conjectures and Transport Rate on Equilibrium Price in a Bounded Spatial Duopoly (L vs. HS).

Figure 33. The Effects of Mixed Conjectures and Transport Rate on Equilibrium Price in a Bounded Spatial Duopoly (L vs. GO).

ultimately delivery expenditure) varies. Notice that for rates less than 1.1, firms operating as Löschian competitors tend to display equilibrium price paths which are strictly decreasing as opposed to those firms which compete under GO or HS behavior (where equilibrium mill price rises to some convergence point as t approaches a value of 1.1 and then drops off more gently than its Löschian counterpart).

Duopolist's with GO behavioral tendencies exhibit price paths which produce the largest divergence from their competitor's price paths above and below that convergence rate. As t increases beyond 2.5 (i.e., as transportation costs begin to approach the marginal cost of production) prices begin to reconverge. As in the case of varying market length, price paths show wide variability in mill price levels at such convergence points (compare mill prices at the intersection of price paths shown previously in Figures 21 and 22). Although the inherent behavioral characteristics of firms may cancel out to yield congruent equilibrium mill prices for convergent parameters, the actual mix of pricing conjectures are solely responsible for the relative disparities in comparative price schedules.

The Effects of Demand Intensity

The price paths associated with varying demand intensity parameters are listed numerically in Table 11. For the three combinations of mixed conjectured duopoly, price paths are shown to behave as a function which decreases at an decreasing rate. Given the explicit cost features of the market in this example, price levels are consistent with prior findings. As demand becomes more elastic (i.e., as b rises) equilibrium mill prices are driven down toward the marginal cost of production. As the demand intensity parameter approaches a value of 2, firm level profits plunge to zero (i.e., firms' ability to exploit monopoly type rents are reduced as consumers become less resilient to changes in delivered price schedules or more price elastic). Note that firms operating in lower conjectures have prices which are higher than their competitors for $2.0 < b < 0.8$. Hence we find higher prices associated with the more competitive pricing strategies over a range of elasticities, where the Löschian pricer demonstrates greater sensitivity to highly responsive and price elastic demand conditions through lower equilibrium prices.

Summary

The modeling of spatial price competition under asymmetrical conjectures provides an enormous challenge in the evaluation of market pricing for which there exists an wide array of equilibrium conditions under varied system parameters. The implications for price and profit variations and their indeterminacies are clear. What must now be addressed is the issue of competitive performance for equilibrated markets comprised of mixed pricing behavior.

In the next chapter, competitive equilibrium conditions are examined for the case of spatial sextopoly (a market with $n=6$ firms) to compare and contrast various measures of market power which are commonly used in the industrial organization literature. Since price and profit schedules are inextricably tied to behavioral underpinnings, the foundations of market concentration as an indicator of market power must also be evaluated in terms of spatially linked behavior/conduct in the assessment of market performance. In the forthcoming simulation analyses, the equilibrium conditions and geographic market shares are identified for equally spaced competitors with mixed pricing policies.

The objective of the approach utilized in the next chapter is twofold. First, market equilibrium conditions are examined to search for a connection between market concentration and the spatial distribution and/or relative positioning of price conjectures. Firms are constrained to be equally spaced so that equilibrium price and profit are not distorted by market compactness (the effects due to clustering). This restriction is then relaxed in order to measure the impacts of firms' relative proximity on price. Secondly, it will be shown that traditional measurements of market concentration are both inadequate and unacceptable as indicators of market power in spatially competitive systems since they contain no information on the distributional characteristics of firms and their behavioral orientation.

CHAPTER 6

PRICE COMPETITION, MARKET CONCENTRATION, AND SPATIAL
OLIGOPOLY: THE CASE OF INELASTIC DEMAND

In theory, market structure can be trisected into the elements of: (1) market share or the specific conditions which define and/or delimit the market in terms of its product, potential substitutes or cross markets, and the geographic extent of its service area; (2) concentration among leading firms who are cognizant of their mutual interdependence in pricing and market share; and (3) the existence of barriers to entry within the industry (Bain, 1965; Shepherd, 1975, 1979). These structuralist approaches are well defined within the S-C-P paradigm (Bain, 1959; Stigler, 1968), and represent the basis for controversy within a spatial microeconomic framework (Benson, 1979). This chapter is primarily concerned with the first two elements which are viewed as inseparable in short-run spatially competitive oligopolies, since geographic market share is a the function of market density and the intertwining nature of price reaction. The emphasis here is on the inspection of competing firms' geographic markets at the market equilibrium and their associated profit shares for a spatial sextopoly

(competition among six firms for a share of a geographic market) with mixed conjectural pricing.

The purpose of this analysis is to verify Benson's conceptual model on the implications of spatial competition and the use of concentration ratios as an index for monopoly power (Benson, 1979). A series of simulations are run in order to refute the proposition that a causal relationship exists between concentration (via market share) and higher profits (via higher prices) in the spatial model. Many have argued that such causal relations stem from the improved production/internal efficiency as a function of scale (Demsetz, 1973; Peltzman, 1977; Shepherd, 1979). This argument will not be explored since the focus of this chapter is on examining the validity of concentration measures as adequate measures of leading firms' abilities to extract monopoly rents in a spatially competitive market where marginal cost of production among those firms are equal. The assumption here is that firms operate under similar cost structures, where the marginal cost curve is of a functional form which assures constancy over a wide range of output. Some criticism of this assumption is warranted (Benson, Faminow and Fik, 1989), yet to simplify matters a constant marginal cost parameter will be implemented.

Although the findings of this chapter are based on a highly concentrated geographic market composed of $n=6$ firms (a relatively small sample size), the argument presented here can be extended to hold for markets with $n>6$ firms (which are classified as geographically competitive oligopolies). In short, since the focus of this dissertation is on spatial competition "among the few", and since firms are not able to adjust their locations (within a finite geographic market) in the short run, the results presented for $n=6$ firms can be interpreted as representative for oligopolies composed of $n>6$ firms (that compete for a share of a finite market). It is questionable whether the simulation results are indicative of the long-run model were firms are able to enter, exit and relocate in the market. However, addressing this issue is beyond the scope of this work.

Background Information

Benson (1979) has logically defended the anti-structuralist assertion by citing the case of Löschian competition as a behavioral framework which produces the largest industry profits and yet has the lowest level of concentration (of any symmetrical conjecture in the long-run) as measured by concentration ratios. However, little has been published on the effects of asymmetrical

distributions of price conjectures and how they affect levels of market concentration. Moreover, there is the issue of boundary conditions, and how they influence the equilibrium properties of the price-profit correspondence. To assess the effects of asymmetrical price conjectural variation, the next section presents the problem in the context of simulated markets where consumer demand is relatively inelastic.

Price Patterns and Profits Under Mixed Conjectures

A total of twenty-six simulation exercises were run, contrasting various spatial distributions of mixed price conjectures for a competitive oligopoly of $n=6$ firms. These simulations were composed of the thirteen unique spatial arrangements of equally spaced rivals (as enumerated in Table 13) and run for both the linear and circular market descriptions. Four general spatial distributions of pricing behavior are considered, the first three being asymmetrical and the last being symmetrical - the benchmark cases examined by Benson (1979); namely,

- (1) alternating conjectures - a distribution of regularly opposing or alternating conjectures over space;

- (2) clustered conjectures - the tendency for like conjectures to agglomerate in space;
- (3) scattered conjectures - comprising irregular or pseudo-random geographic distributions of behavioral pricing strategies; and
- (4) the commonly used case of symmetrical conjectures.

The following system parameters were utilized to derive the equilibrium solutions: market length $A = 80$; transportation rate $t = 1.0$; and consistent marginal cost $k = 3.0$ (for all firms), where consumer demand is classified as inelastic. The objective of this analysis is to contrast price, profit, market share, and concentration in relation to market description and the distribution of directly interacting adjacent conjectures at equilibrium. The results are compiled in Tables 14 through 18, and the implications of this output discussed at length. Although the observation of firm-level profit is a somewhat unrealistic assumption (since it is rarely observed in the real world), it is nonetheless utilized in the construction of traditional S-C-P measures (to enhance the realization that such measures inadequately capture the essence of spatial price competition).

Table 13
Spatial Distribution of Simulated
Conjectural Arrangements

Firm Position and Conjecture:

Case #	1	2	3	4	5	6
<hr/>						
Alternating Conjectures:						
1	0.0	-1.0	0.0	-1.0	0.0	-1.0
2	0.0	+1.0	0.0	+1.0	0.0	+1.0
3	-1.0	+1.0	-1.0	+1.0	-1.0	+1.0
Clustering Conjectures:						
4	+1.0	+1.0	-1.0	-1.0	-1.0	+1.0
5	0.0	0.0	-1.0	-1.0	-1.0	0.0
6	0.0	0.0	+1.0	+1.0	+1.0	0.0
Scattered Conjectures:						
7	-1.0	0.0	+1.0	+1.0	-1.0	0.0
8	-1.0	+1.0	0.0	0.0	-1.0	+1.0
9	-1.0	-1.0	0.0	+1.0	+1.0	0.0
10	-1.0	+1.0	0.0	-1.0	+1.0	0.0
Symmetrical Conjectures:						
11	+0.999	+0.999	+0.999	+0.999	+0.999	+0.999
12	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
13	0.0	0.0	0.0	0.0	0.0	0.0
<hr/>						

Note: Case 11 represents a "near-Löschian" pricing system.

The Preliminaries

In order to proceed with the analysis of spatial competition and market concentration some fundamental concepts and techniques need to be reviewed. Firstly, some descriptive statistics of the market will be employed. These statistics are necessary to describe the overall characteristics of the market in terms of the behavioral and spatial properties of price reaction, and include the following measures:

- 1) Average Pricing Conjecture { Avg ϕ }:

$$\text{Avg } \phi = [\sum_{i=1}^n \phi_i]/n ; \quad (45)$$

- 2) Average Equilibrium Mill Price { Avg p^* }:

$$\text{Avg } p^* = [\sum_{i=1}^n a_i p_i^*]/n , \quad (46)$$

where p^* is weighted by a_i , (the extent of a firm's equilibrium market segment);

- 3) Geary Ratio $GR(y)$ (Geary, 1954) (a measure of spatial dependence/covariation in a variable y based upon a paired comparison of mapped relations of that variable for juxtaposed values in space; commonly referred to as a index of spatial autocorrelation):

$$GR(y) = \frac{[(n-1) \sum_{i=1}^n \sum_{j=1}^n c_{ij} (y_i - y_j)^2]}{2 \left(\sum_{i=1}^n \sum_{j=1}^n c_{ij} \right) \sum_{i=1}^n (y_i - \bar{y})^2} \quad (47)$$

where $c_{ij} = 1$ if areal units i and j are adjacent, and 0 if otherwise (Griffith, 1987). The expected value of GR is unity.

Measuring Spatial Dependence

The Geary Ratio is a general measure of the level of spatial dependence (in an autoregressive sense) that exists in a geographic distribution of some mapped variable. Three situations are plausible: (1) the variable exhibits a tendency to cluster in space (i.e., like values tend to be located next to each other; high values next to high values and vice-versa); (2) the variable exhibits a tendency to alternate over space (i.e., dissimilar values, in terms of magnitude, tend to be juxtaposed); and (3) the variable exhibits no spatial dependence in its geographic distribution and can therefore be construed as randomly distributed (i.e., there are no regularities in contiguous or adjacent values over space (Odland, 1988). In the first case, a clustering of like values is known to be associated with a positive spatially autocorrelative pattern-- a static depiction of some potentially positive

spatially dependent process (if the realization of that distribution is representative). Such a pattern would be portrayed by a Geary Ratio that was significantly less than unity. The second case represents a negative spatially autocorrelative pattern (and perhaps, process) yielding a Geary ratio that was significantly greater than unity; and the third, an indicator of a pattern (or process) that is most likely stochastic or random. In the event the pattern is random, the Geary Ratio would not differ significantly different from unity.

Measures of spatial dependence and autocorrelation parameters can be useful in the description of price patterns amongst neighboring competitors distributed over a spatial market. Spatial autocorrelation techniques have already gained much use in the analysis of price competition for spatially interactive markets (Haining, 1984, 1986; Fik, 1988). These measures provide a powerful summary of price dependence, since they have the potential to describe the covariation of mill prices for adjacent market segments and/or rivals. The monitoring of such price distribution information can also provide insight (if applied over time) to the price reactive patterns of competitors (i.e., the pricing tendencies for spatially interdependent rivals in the short run). Spatial autocorrelation measures are useful to summarize the

general pattern of market price relations over space as prices tend toward equilibrium.

The next section discusses the connection between the spatial distribution of pricing conjecture and equilibrium price level for the thirteen simulated markets described above.

Spatial Dependence in Pricing Conjectures

Tables 14 and 15 list some descriptive statistics for the simulation discussed above (for the circular and linear markets respectively). The results indicate that a high positive correlation exists between those cases which have significant spatial dependencies in adjacent pricing conjectures and those showing significance in price patterns. This is more true for the circular market than for the bounded market description, however. As the average ϕ value tends to decline, so do the discrepancies between $GR(\phi)$ and $GR(p^*)$ (as in cases 4, 5, and 6). Another interesting feature can be noted for markets with equal average pricing conjectures and equal variance (e.g., cases 1 and 5; cases 2 and 6; cases 7 through 10); that is, relative positioning or location of firms is the force which drives and differentiates equilibrium price levels. In short, since price competition is occurring between neighboring rival firms (that operate under firm-specific

pricing strategies), it is the relative distribution of those firms (and conjectures) which ultimately determines prices at the equilibrium.

For the same distribution of firms in space, equilibrium prices in the linear/bounded market are shown to be more prone to cluster as demonstrated by the lower Geary Ratios for cases 4,6, and 9. This boundary effect is further exemplified by a comparison of cases 1,2, and 3 - the instances of alternating conjectures. Under the unbounded market description, spatial dependence in price follows a similar pattern to that of price conjectures (i.e., both $GR(\phi)$ and $GR(p^*)$ signify negative spatial dependence).

In the bounded market, prices equilibrate in a random fashion (i.e., the $GR(\phi)$ reveals negative spatial dependence (by design) and the $GR(p^*)$ is not significantly different from 1). As expected, for inelastic consumer demand, prices in the linear market tend to be greater than those in the circular market, with prices exploding under the symmetrical near-Löschian conjecture. Notice that in the circular market, case 3 produces a similar average equilibrium mill price to that of an HS symmetrical conjecture; yet, in the linear market this correspondence breaks down as case 3 actually produces a lower average mill price than its symmetrical HS

counterpart. Again, it must be stressed that, the relative positioning of pricing conjecture (or the behavioral properties of firms) and boundary distortions manufacture a wide variation in average equilibrium price levels, creating price patterns which are not directly traceable to their component parts (with, of course, the exception of the strict Löschian case). This leads one to believe that the indeterminacies associated with oligopolistic modeling are even more complex than realized, given that one must not only consider price conjectural variation but the spatial distribution and boundedness of that distribution!

Thus, the polemics of structure-conduct-performance testing must acknowledge the importance of space and location in the assessment of market competition. Market area analyses that do not incorporate geographical concerns must therefore be suspect if the spatial structure of a market proves to significantly influence the competitive pricing. Let us now compare and contrast industry profits under the same spatially diverse conjectural arrangements.

Table 14

Simulation Ouput: Spatial Sextopoly (Circular Mkt)

Case #	Avg. ϕ (var)	GR ϕ	Avg. p*	GR p*
1	-0.5 (.25)	1.6667*	12.0666	1.6667*
2	0.5 (.25)	1.6667*	29.6667	1.6667*
3	0.0 (1.00)	1.6667*	16.3333	1.6667*
4	0.0 (1.00)	0.5555*	16.8775	0.4486*
5	-0.5 (.25)	0.5555*	12.4297	0.4644*
6	0.5 (.25)	0.5555*	30.2000	0.4397*
7	0.0 (.66)	0.8333	17.2468	0.5285*
8	0.0 (.66)	1.4583	16.6672	1.1888
9	0.0 (.66)	0.4166*	18.5102	0.4588*
10	0.0 (.66)	1.2500	16.7024	1.2500
11	0.989 (0)	-	1336.3333	-
12	-1.0 (0)	-	9.6666	-
13	0.0 (0)	-	16.3333	-

* Level of spatial autocorrelation significant at 95% confidence level (see Odland, 1988 for z-test).

(var) stands for the variance in ϕ , shown in parentheses.

Table 15
Simulation Output: Spatial Sextopoly (Linear Mkt)

Case #	Avg. ϕ	(var)	GR ϕ	Avg. p*	GR p*
1	-0.5	(.25)	1.6667*	14.2743	0.8609
2	0.5	(.25)	1.6667*	35.2189	1.2150
3	0.0	(1.00)	1.6667*	19.1864	1.2133
4	0.0	(1.00)	0.6667*	17.2331	0.3349*
5	-0.5	(.25)	0.6667*	14.5359	0.5281*
6	0.5	(.25)	0.6667*	46.4811	0.4174*
7	0.0	(.66)	0.8750	21.2883	0.7583
8	0.0	(.66)	1.2500	19.4096	0.9403
9	0.0	(.66)	0.3750*	27.8779	0.3168*
10	0.0	(.66)	1.3750	22.4171	1.0786
11	0.989	(0)	-	1603.0020	-
12	-1.0	(0)	-	11.3680	-
13	0.0	(0)	-	19.4235	-

* Level of spatial autocorrelation significant at 95% confidence level.

(var) stands for the variance in ϕ , shown in parentheses.

Spatial Dependence in Profit Level

Short-run profits at the equilibrium, as shown in Table 16, demonstrate a wide variation in outcome. There are definite implications here to interpret conjectural mix as a barrier to entry (if medium-run decisions of entry and exit are enhanced by the spatial distribution of pricing behavior). If firms use profitability as a signal for entry, firms may conceive this profitability as a function of the competitiveness of the market and the locational attributes of those competitors who define that market. Without knowledge of the chaining of relative conjectural pricing amongst spatially linked competitors, firms may enter into a profitable or lucrative industry and find that they cannot maintain localized profitability as subject to the pricing policies of their nearest rivals (assuming rivals don't change). Hence, there are two issues to be dealt with if short-term profits are used as signals which stimulate entry and exiting: (1) are firms to expect that positive industry profits can be translated into actual post-entry profits as the market becomes saturated with competitors? ; and (2) how are those profits realized at a locally competitive scale, as defined by a potential entrant's or existing firm's nearest competitors (i.e., is the decision where to locate as important as whether or not to enter?)? Thus, it is the

medium-run question as to the viability of a firm with respect to both industry-wide competition and localizing agents (i.e., the pricing behavior of neighboring firms). It is obvious that the thirteen spatial distributions of firms' stimulated price reactions provide a large range of signals for potential entrants. It is conceivable to argue that four basic types of conjectures can arise in a spatially competitive situations over the long run:

- (i) price expectations (both immediate and higher order);
- (ii) location conjectures (with respect to either industry wide profit signals or localized profitability); (iii.) entry and/or exit conjectures (as a function of expected versus realized profitability or barriers to entry); and
- (iv) a mixture of (i) through (iii). Although beyond the scope of this dissertation, the implications are clear that short-run pricing behavior may be part of a long-run reaction strategy which encompasses the interplay of multiple conjectural variations (i.e., the short-run pricing policies of firms may be linked to a competitive outlook which exceeds the short run).

Table 16

Average and Total Industry Profit Levels:
Spatially Competitive Sextopoly

Case #	Market Description: (n=6 firms)			
	Circular		Linear	
	Avg Profit	Total Profit	Avg Profit	Total Profit
1	122.3111	725.3333	151.4598	901.9450
2	711.1110	2133.3333	894.3068	2577.5100
3	355.5556	1066.6666	446.6141	1294.9150
4	397.0197	1110.2045	429.5276	1138.6480
5	124.2415	754.3826	149.9963	922.8750
6	752.3555	2175.9999	1289.3910	3478.4950
7	305.3225	1139.7518	405.6693	1463.0670
8	286.2670	1096.3818	339.0083	1312.7750
9	316.3373	1240.8164	550.8858	1990.2360
10	274.5370	1096.1940	382.0060	1553.3680
11	1777.8100	10666.8000	22990.1300	138001.7500
12	88.8888	533.2800	110.5610	669.4426
13	177.7778	1066.6200	219.4295	1313.8810

Note: The existence of boundary effects are immediately evident in the consistently higher prices and profits associated with the linear market under inelastic demand.

Price Conjectures and Market Concentration

Concentration estimates are measures of the degree of combined market power or competitiveness of leading firms in a market. Concentration ratios are used in that evaluation of combined market share or power and are "a dilution of the simple effect that a single firm with the same market share would have" (Shepherd, 1979, p.180), where the degree of dilution is dependent upon many factors. Oligopoly and its indeterminacies produces varying degrees of competitiveness, ranging from "loose" to "tight" as seen in the hypothesized relationship between increasing rates of return (profit) and increasing combined market share of leading firms. The pitfalls surrounding this concept are numerous, given that the expected relationship stated previously is subject to qualification stemming from the logic that concentration does not distinguish between coordinated or independently competitive behavior (or combinations thereof) amongst those leading firms (i.e., there is no account for the degree or ferocity of price undercutting incentives or collusionary potential in competition). Furthermore, the problems of defining market concentration become more difficult when both the total number and spatial distribution of firms which compete in an industry are

highly variable. This condition is exacerbated when one also considers the indefinite number of reactionary outcomes as a function of spatially variant pricing conjectures and localized distance-decay properties which determine the strength of interdependent price linkages. In addition, such variables as internal cost structure, scale, output level, the stability of pricing behavior of individual firms and their neighboring competitors, the delineation of geographic service areas, and the complexities which arise from the combination of these factors, compound the problem. Nevertheless, concentration and market share measurements have remained as staples in the industrial organization literature.

In the forthcoming paragraphs, a selection of classical S-C-P measures of market power is reviewed along with the introduction of some geographically sensitized indices which measure simulated equilibrium profit shares and service areas. The intent of this comparison is to emphasize the point that existing procedures are insufficient in the detection of market power and must, therefore, be dismissed as relevant indicators of market power in the assessment of anti-competitive behavior.

Some Commonly Used Indices of Concentration

There are four widely used and accepted S-C-P indices which enumerate market concentration: (1) the standard four-firm concentration ratio CR₄; (2) the Herschman-Herfindahl index HH; (3) the Rosenbluth index R; and (4) the Entropy index E. A brief summary of these indicators is now given.

(1) CR₄ - The leading four-firm concentration ratio is simply constructed by summing the market shares (in terms of profit) of those four individual firms which hold the largest influence. It is denoted by the formula

$$CR_m = \sum_{i=1}^m s_i, \quad (48)$$

where $m=4$ and s_i is the market share of an i -th firm in an industry composed of n firms with market shares listed in descending order as $i=1, \dots, m, \dots, n$. CR_m has a minimum value of (m/n) and a maximum value of unity (where $m=n$). This conventional ratio is then used in the statistical comparison of combined market share and profitability, to test the hypothesis that large profit shares are a function of market share.

(2) HH - The Hirschman-Herfindahl index is similar in construction to that of CR_m , in that it sums the squares of all competing firms' market shares thereby weighting

the larger firms' shares relative to the smaller. It can be written as

$$HH = \frac{\sum_{i=1}^n s_i^2}{n}, \quad (49)$$

with a range of: $1/n \leq HH \leq 1$. The squaring of market share is used to exaggerate the potential market power holdings of firms with large market shares.

(3) R - The Rosenbluth index of concentration is the converse of HH, in that it attaches more weight to smaller or fringe firms in an industry. First, all firms within the industry are ranked by market share in descending order j : $j=1, 2, \dots, n$. Secondly, R is formulated as

$$R = 1 / \left(2 \sum_{j=1}^n \frac{s_j}{j} \right) - 1, \quad (50)$$

where $1/n \leq R \leq 1$.

(4) E - The entropy index of market concentration is an information theoretic approach which measures the degree of certainty or information content in a distribution of market share. It can be written in the following manner:

$$E = - \sum_{i=1}^n p_i \log p_i, \quad (51)$$

where E is inversely related to the degree of market power and ranges between a minimum value of zero (when 1 firm solely controls a market) to a value of $\log(n)$ (for an

equal distribution of market share among all n firms). For a more complete discussion of these four measures of concentration, see Marfels (1975).

Although the above techniques represent the most commonly used S-C-P methods for estimating concentration, some alternative methods which include geographic variables can be visualized. For instance, one may construct a measure of geographic market share or influence for the m leading firms in an industry by summing the extent of their dominant service areas. In the case of our one-dimensional simulated market, the extent of firm coverage is denoted by a_i - the delivery price determined market segment. Hence, $CR_m(a)$ (an index which measures concentration from the m leading firms' geographic market share) can be yield information on the areal domination of an industry in terms of coverage. In this way, concentration can be viewed simultaneously in terms of profit share (by $CR_m(Z)$) and geographic share (by $CR_m(a)$).

Following the logic of geographically sensitizing concentration ratios (i.e., the measurement of concentration in terms of geographic market share), other conceivably useful indices can be proposed. For example, a hybrid of the classical entropy statistic (E) introduced earlier can be restated by geographic market share.

Ranging from a minimum value of 0 and a maximum of unity, a relative entropy index of geographic market share

H_a (a function which is inversely related to market share) can be formulated as

$$H_a = \left[- \sum_{i=1}^n a_i \log(a_i) \right] / \log(n) , \quad (52)$$

where a_i is an i -th firm's service area defined by the equilibrium market segment and $\log(n)$ is the balancing factor which assures that the index ranges from 0 (the most concentrated distribution) and 1 (a perfectly even distribution). In order to filter out the importance of price in the equilibration of these market segments, a weighted entropy index can also be proposed and defined as

$$H_p = \left[- \sum_{i=1}^n (p_i a_i) \log(p_i a_i) \right] / \log(n) . \quad (53)$$

This index may be useful in assessing the influence of own price in the resolution of competitive market segments. A similar index could be conceptualized to weight the average price for an interior firm and its nearest neighbors (to its left and right), although interpretation of such an index may be difficult, and therefore will not be considered at this time.

Lastly, two experimental concentration indices are introduced, namely, MP1 and MP2-- market power indices 1 and 2. These measures are defined by the following functional relationships:

$$MP1 = [\text{Avg. } Z/Z(GO)]CR4(Z) , \quad (54)$$

with market power being a function of the average industry profit divided by the theoretical profit level that would exist if all competing firms were GO pricers (an ultracompetitive benchmark), times the four-firm market concentration ratio of profit share; and

$$MP2 = [\text{Avg. } Z/1]CR4(Z) , \quad (55)$$

where MP2 is a proxy of MP1 with 1 substituted for the GO pricer profit level constraint (since this may be largely unobservable or impossible to calculate). These measures of market power are intuitively appealing in that they overcome some of the basic limitations of simple concentration ratios which ignore the variance in industry profits under alternative behavioral conditions. An obvious deficiency of these indices lies in the fact that profits may not be directly observable. However, within the confines of this simulation experiment it will be assumed that profit levels are observable in order to demonstrate the variability in these alternative measures under radically different spatial distributions of pricing

conjectures. The following example will help to illuminate this point.

Simulation Results

Four-firm concentration ratios for profit share and market length were computed from the price and profit functions of the simulated spatially competitive sextopoly under the mixed conjectural formats listed above. The results of this simulation are tabulated in Tables 17 through 19 for both linear/bounded and circular/unbounded markets for the purpose of contrasting traditional S-C-P measures and the suggested theoretical alternatives.

Three prominent features of Table 17 need to be highlighted. First, there is noticeable correlation between those cases involving two or more Löschian pricers and concentration ratios which tend toward unity (regardless of boundedness) (e.g., cases 2,3,4,6,8, and 10), with the exception of the symmetrical Löschian case (#11). However, in cases involving only a limited number of Löschian pricers, the market concentration of profit shares is entirely made up of firms characterized by alternative conjectures (which have lower prices). In these cases, those firms are usually juxtaposed to higher conjectures and have the ability to undercut their Löschian competitors; once again supporting the adage that

"location matters". More importantly, this reinforces the belief that Löschian competitors actually may be a destabilizing force when surrounded by firms with lower pricing conjectures, thereby yielding Löschian profits which are minimal or zero (Coyte, et al., 1988). Thus, in a real short-run market setting, the existence of HS and GO pricers (or approximately close hybrids) reduces the likelihood of short term Löschian profitability. Such a situation is feasible when firms adopt a fixed conjectural pricing strategy. The Löschian competitor's market area will simply be eroded away as consumers rationally patronize its lower priced neighbors. This is consistent with the empirical evidence reported by Coyte et al., 1988. Therefore, the existence of rationally or irrationally defined price conjectural parameters must be defined in terms of relative location and the strategies employed by neighboring competitors.

In comparing cases 2 and 3, it is evident that distributions involving conjectures which alternate over space (one of which being Löschian) show increasing firm level profits as competitors' pricing conjectures rise. Hence, since the distribution of profit shares is highly sensitive to the distribution of conjectures, even the ultracompetitive case of GO pricing can yield market conditions of lower prevailing prices and a high

concentration of profits amongst the more competitive (lower price conjectured) firms. A second interesting feature can be identified here. Notice that consistent conjectures (cases 11,12, and 13) produce the lowest four-firm concentration ratios, as conceptually posited by Benson (1979). Moreover, it is impossible to deduce any information on the competitiveness of these markets simply by their CR4's, given that any symmetrical conjecture will delimit the lowest conceivable concentration ratio. This index approaches 1 (0) as the number of competitors (n) decreases (increases).

Thirdly, concentration ratios which reveal a dominant four-firm cluster (as $CR4=.9999$) show a marked difference in the actual level of total and average industry profits. This finding strengthens the argument that such measures are inappropriate indicators of market power. These issues are further confused by the implications of boundary. Bounded markets show a greater ability to produce higher industry and average profits as the average conjecture increases or conjectures become more symmetrical. There is a trend that is most apparent for markets housing lower pricing conjectures that vacillate over space (e.g. cases 1 and 5), where industry profits are higher for bounded versus unbounded markets as average profits increase; yet, maximized CR4 measures have remained stable (compare

Tables 16 and 17). Thus, in some instances (i.e., some distributions of pricing conjectures) boundary implications are negligible or nil, since CR4 ratios have already been maximized. This also demonstrates the insensitivity of concentration ratios to boundary effects for highly competitive asymmetrical conjectures.

Table 17

Concentration Ratios for the Four Leading Firms
by Profit (Z) and Geographic Service Area (a)

Case #	Circular		Linear	
	CR4 (Z)	CR4 (a)	CR4 (Z)	CR4 (a)
1	.6862	.7333	.7124	.7492
2	.9999	.9999	.9999	.9999
3	.9999	.9999	.9999	.9999
4	.9999	.9999	.9999	.9999
5	.7203	.7079	.7516	.7636
6	.9999	.9999	.9999	.9999
7	.9999	.9999	.9999	.9999
8	.9999	.9999	.9999	.9999
9	.9999	.9999	.9999	.9999
10	.9999	.9999	.9999	.9999
11	.6666	.6666	.7973	.7985
12	.6666	.6666	.7213	.7154
13	.6666	.6666	.7001	.7368

Note the boundary effect for cases with low CR4 indices.

The inadequacies of classical S-C-P measures are further emphasized by the simulation results presented in Table 18. Alternative measures of market concentration (i.e., the spatial entropy and the other traditional S-C-P

indices) show little improvement in explaining the linkage between pricing conjecture and profit share or the relations of geographic distribution, boundedness, and price. On the other hand, the experimental market power indices show a significant sensitivity to leading firms' abilities to extract profits in relation to the competitive framework of a consistent GO conjecture. Both MP measures show little correlation with CR4 indices since they are constructed from profit variables. The range of these measures are as follows:

$$MP1 : m/n \leq MP1 \leq CR4(Z) (Avg. Z_L) ;$$

$$MP2 : (m/n) (Z_{GO}) \leq MP2 \leq CR4(Z) (Avg. Z_L) ;$$

where m equals the number of leading firms (usually 4), and Z_{GO} and Z_L are the profit levels for consistent GO and L behavior respectively. In reality, the MP2 measure can be computed if the number and location of competitors, the extent of the geographic market, the elasticity of demand (as a function of delivery price), industry profits, and the cost structures of firms are known.

As n becomes increasingly larger, the lower and upper ranges of this index compress at zero (the perfectly competitive setting). In the long run, a large and

stabilized MP2 index can also be viewed as an indicator of existing entry barriers (i.e., if excessively large profits stabilize over time in a competitively compressed industry (in terms of density) with little or no entry and/or exiting). For the unbounded competitive oligopoly simulated here, the MP2 index for the symmetrical Löschian, HS, and GO cases are approximately 1/9.0 of the total industry profit level. In the bounded market, the proportions of MP2 to total industry profits for consistent L, GO, and HS behaviors are 1/7.528, 1/8.394, and 1/8.552 respectively. The difference in these ratios can be construed as a pure boundary effect which is conjecture specific.

Notice that Löschian behavior is associated with market power indices which are a greater percentage of total industry profits when monopoly type boundaries exist (as does in the linear market case). There are obvious shortcomings to measures of this kind, since they operate under the assumption that positive MP values beyond the ultracompetitive GO behavioral base (or the HS level) imply some sort of market power. This statement is, of course, dependent upon the spatial distribution and relative positioning of firms' conjectures and the stability of excessively high MP values over time.

Although this approach ignores the internal efficiency aspects of firm size and output, as well as the process by which equilibrium is attained (something which may never be directly observable or attainable) these or similar type of approaches may show promise in dissecting the competitive properties of an industry on various theoretical ground. This is extremely apparent in the high correlations between the average market conjecture (the level of spatial covariation in distributed conjectures as a function of adjacency and boundedness), and the calculated MP values (compare MP indices to Tables 14 and 15). A quick scan of results for the bounded versus unbounded markets show a wide variation in the behavior of these market power indices.

Table 18

Alternative Measures of Market Concentration
for the Circular Market

#	Spatial Entropy Indices		E	Traditional S-C-P Indices		Experimental Indices	
	H a	H p		HH	R	MP1	MP2
1	.9887	.9975	.7770	.1671	.1167	0.944	83.929
2	.6131	.6131	.4770	.3332	.2307	7.999	711.039
3	.6131	.6131	.4771	.3332	.2307	3.999	355.520
4	.6011	.5788	.4450	.3765	.4016	4.466	396.979
5	.9966	.9971	.7725	.1701	.1823	0.795	70.730
6	.6073	.5941	.4607	.3563	.3835	8.463	752.280
7	.7543	.7380	.5687	.2865	.3152	3.434	305.291
8	.7563	.7584	.5894	.2639	.2867	3.220	287.266
9	.7730	.7376	.5632	.2929	.3156	3.558	316.305
10	.7649	.7332	.6019	.2498	.2513	3.088	274.509
11	1.0000	1.0000	.7781	.1666	.1666	133.320	11850.688
12	1.0000	1.0000	.7781	.1666	.1666	0.666	59.253
13	1.0000	1.0000	.7781	.1666	.1666	1.333	118.506

Table 19
Alternative Measures of Market Concentration
for the Linear Market

#	H a	H p	E	HH	R	MP1	MP2
1	.9834	.9961	.7747	.1685	.1784	0.975	107.899
2	.5975	.6029	.4692	.3449	.3712	8.088	894.217
3	.5992	.6040	.4702	.3431	.3679	4.039	446.569
4	.5945	.5540	.4218	.4192	.4562	3.884	429.484
5	.9855	.9929	.7670	.1744	.1905	1.019	112.737
6	.5842	.5490	.4240	.4081	.4493	11.661	1289.262
7	.7341	.7412	.5766	.2781	.3049	3.668	405.628
8	.7596	.7617	.5920	.2602	.2791	3.065	338.669
9	.7580	.6554	.4922	.3780	.4073	4.982	550.830
10	.7620	.7697	.5969	.2555	.2720	3.454	381.967
11	.9761	.9766	.7492	.1790	.1919	165.791	18330.030
12	.9965	.9980	.7738	.1688	.1796	0.721	79.747
13	.9930	.9985	.7764	.1675	.1740	1.389	153.622

Boundary Conditions

APPENDIX A lists a variety of descriptive statistics to illustrate the impacts of market boundedness. Linear markets can be portrayed as markets with "tighter" adjacent pricing behavior and wider variations in equilibrium price levels as seen in the comparison of c_1 and c_2 - the sum of differences squared for imposed conjectures and their corresponding equilibrium mill price. The pure geographical boundary effects are recognized in cases 5,6,11,12, and 13, where the summed values of conjectural differences squared remain equal while mill prices are forced to rise strictly as a function of the boundedness of the market. These marked changes are again visible in the positive change in the CR4 indices (with the exception of case 6). The minor change in price covariation and the zero change in market concentration is due to two factors: (a) interior and/or agglomerated Löschian pricers (which are surrounded by more competitive pricers-- lower pricing conjectures) have a large share of their market share eroded away given their tendency to charge significantly higher prices than their surrounding competitors; and (b) the dominance of HS pricers that have captured the entirety of that market on both sides of their Löschian rivals (with the unevenness in conjectural distribution accounting for the marginal

shift in covarying mill price for the circular market in contrast to the linear specification).

The smallest changes in price covariation are linked to the more highly competitive conjectures and/or conjectural distributions (cases 1,5, and 12). To summarize, the higher the average pricing conjecture and/or the smaller its spatial covariation, the larger is the impact of boundary on mill price and market concentration. As a corollary, one can conceivably reverse this argument for the positioning of conjectural pricing in space (i.e., the decisions on which conjectures are based, both perceptively/subjectively and geographically by the firm). In other words, price reaction is likely to be dependent upon, as Coyte et al (1988) suggest, "the relative proportion of their (firms) market perimeters formed by fixed boundaries, monopoly boundaries and fronts with neighboring firms". Thus, if peripherally located firms tend to exploit their geographic advantage by choosing to raise their pricing conjecture to some level where their service areas will not be competitively overlapped by more interior firms (who perhaps exhibit a more competitive pricing behavior) in order to reap larger individual profits, the degree of boundedness becomes critical in obtaining that end. The implications are clear; namely, (1) any attempt at analyzing market concentration must

weigh the geographic potential of isolated and/or peripherally located firms to impose Löschian-type behavior; and (2) such considerations must account for the overall distribution of conjectures and their direct and indirect influences (which may not be symmetrical.

Summary

In this chapter we have witnessed a wide variety of plausible conditions which produce similar market concentrations and largely diverse price patterns and profit levels. The interdependence of chained price reactions, boundary distortions, and asymmetrical distributions of pricing conjectures were discussed, and the implications noted for the spatial model of competitive oligopoly. In retrospect, traditional concentration measures were shown to be inadequate as indicators of market power, as they are incapable of providing insight into the finer resolving forces of a market's spatially competitive make-up. In reaction to those inadequacies, two alternative (experimental) measures of market power were presented as a function of price conjectural variations. Using the GO pricing case as a benchmark in which to compare competitive-profit levels, a direct correspondence was established between market

power, profit, and firms' price conjectural parameter.

In the chapter that follows, attention turns toward the importance of the geographic distribution (locational aspects) of firms and the effects of clustering, in the determination of equilibrium price. The aim of Chapter 7 is to explore the possibilities that competitive agglomerations and/or the spatial distribution of firms' pricing policies have limiting effects on the pricing behavior of interior firms. A brief analysis of marginal cost advantage is also presented.

CHAPTER 7

SPATIAL PRICE COMPETITION AND CLUSTERING

This chapter examines price patterns in simulated markets to assess the impacts of competitive clustering in space. It is posited that as agglomeration intensity increases (i.e., as firms become more clustered in the market) price differentials between firms will tend to decrease. In addition, the antithesis of this argument can be tested; namely, as firms or clusters of firms become isolated from other firms or clusters their associated price levels and differentials will tend to rise. These properties are tested by simulating the effects of spatially competitive clusterings of firms on equilibrium price and profit.

Simulating Agglomerative Structures

Consider a circular market with a circumference of 80 distance units composed of five firms and evenly distributed consumers of unit density. Assume that demand is relatively inelastic (as in the case of retail food

markets). A simulation experiment is performed for a series of four distinct market arrangements which display varying degrees of firm density (see Table 20 for the locations of firms under each of the four market descriptions). Equilibrium price and profit levels are obtained using the model of spatial price competition presented in Chapter 4.

Table 20

The Locations of Firms for Four Market Descriptions

Market	Locations of Firms 1,2,3,4,5	Equidistant to Nearest Neighbor
A	0,10,20,60,70 Slightly Compressed	Yes
B	0,5,10,70,75 Highly Compressed	Yes
C	0,5,20,60,75 Locally Compressed	No
D	0,5,35,45,75 Dually Compressed	Yes

System Parameters: $t=1.0$; $A=80$; $k_i = 3$ ($i=1, \dots, n$); $n=5$.

Simulation results are based on $n=5$ firms, but can be generalized to finite geographic submarkets where few firms compete for submarket shares under various densities. This is consistent with the locational patterns of firms observed in reality (a topic that will be addresssed in Chapter 9). The purpose of this exercise is to test the relationship between equilibrium price (and profit) and the degree of clustering exhibited in the market.

If price is directly related to distance between competitors, we should find lower equilibrium prices associated with highly clustered firms (particularly those which are central, as in the case of firm 1 in each of the four markets listed above). The simulation output is tallied in Tables 21 and 22. Two outstanding features necessitate acknowledgement when one compares the distribution of price and profit:

- (1) the greater the level of geographic concentration or market compression-- the lower the equilibrium mill price; and
- (2) the consistency of centrally clustered firms to have lower prices than their peripheral competitors (e.g., firm 1) is only attainable when either
 - (a) pricing conjectures are symmetrical, or

- (b) when that internalized firm adopts a lower pricing conjecture than its peripheral counterparts, *ceteris paribus*.

Given these results, several questions need to be raised; i.e., if firms are dispersed over space in such a manner that higher conjectures prove to be unprofitable in the short run, does the spatial structure then delimit plausible (rational) pricing behaviors given that a potential exists for firms to undercut the prices of their competitively clustered nearest neighbors, thereby reducing overall price levels to the point where entry (beyond the short-run) is discouraged? If this is the case, can any pricing strategy be purely seen as a short term decision/behavior, where firm's price expectations adapt to the physical structure of the market? Does not the initial location of the firm entertain some thought of a long run locational strategy, whereby pricing policy must later adhere to the bounds defined by the integrated nature of a spatially competitive market?

The output in Table 22 (for the dually compressed market) shows the ability of exterior firms (such as firms 2 and 5) to squeeze the profitability of their interior competitor (firm 1) in three ways. Firstly, if external firms adopt lower price conjectural parameters they have the ability to encroach on firm 1's market boundaries.

Secondly, the competitive effect can be viewed as purely geographical (as shown in Table 22) where profitability of an interior firm is eroded away as the locations of competitors compress in space. Again, as previously implied throughout this dissertation, it is the geographic context (the spacing or density of firms) which may influences the competitive behavior of spatial rivals. Indeed, their behavior (if restricted to some bounded rationality) can be seen as an outcome of both expectations and relative location. This property is not evident in the spaceless model of price competition as noted by Benson and Faminow (1986).

Obviously, a third effect can be seen as a combination of the first and second. It would be interesting to see how these effects measured up to one another in the context of the long run where price, location, and conjectural parameters are endogenized. Such a topic must be left to future research endeavors, however, since the focus of this work is mainly on the short run.

The arguments outlined above can also apply to a spatial marginal cost advantage, something which is explored in the next chapter. This presents a more realistic approach to spatial price competition: a topological or networked market where firms compete for the market segments which link them.

Table 21

The Effects of Market Compression on Equilibrium
Price and Profit Under Inelastic
Demand and Symmetrical Conjectures

Market	ϕ	Price (Profit)			Average Price/Profit
		1	Firm: 2	3	
A	0	14.5789	16.1574	24.0526	20.0844
		(134.072)	(173.130)	(443.213)	(309.626)
	.99	1591.190	15970.07	1614.835	1603.062
		(25223.76)	(25410.49)	(25980.12)	(25602.95)
	-1	8.3658	9.0975	14.2195	11.8727
		(57.584)	(74.360)	(251.754)	(171.624)
B	0	10.8947	13.7894	28.2631	22.6450
		(62.326)	(116.412)	(638.227)	(440.642)
	.99	1581.348	1592.131	1624.697	1603.207
		(24911.86)	(25253.45)	(26299.13)	(25609.90)
	-1	6.1707	7.5121	16.9024	13.9332
		(20.107)	(40.719)	(386.555)	(279.484)
C	0	11.9473	15.8947	25.6315	20.9622
		(80.055)	(166.274)	(512.188)	(352.346)
	.99	1585.269	1596.092	1618.776	1603.114
		(25035.76)	(25379.49)	(26107.35)	(25605.46)
	-1	6.6585	8.9756	15.1915	12.5560
		(26.769)	(71.415)	(297.442)	(205.153)
D	0	13.5263	19.0526	21.6842	19.5547
		(110.803)	(257.687)	(349.099)	(281.059)
	.99	1591.151	1602.032	1609.895	1603.031
		(25222.27)	(25569.10)	(25821.14)	(25601.44)
	-1	7.3902	11.1707	12.6341	11.4607
		(38.548)	(133.521)	(185.633)	(148.200)

Note: Firm pairs 2,5 and 3,4 have equivalent equilibrium prices and profits. All results are for the circular/unbounded market.

Table 22

Equilibrium Price and Profit Levels for Market D
Under Two Asymmetrical Pricing Conjectures

Conjectural Mix { ϕ }	Price (Profit) Firms:			Average Price (Profit)
	1	2	3	
<hr/>				
.99,0,0,0,0				
	27.6609 (6.081)	22.9075 (396.309)	22.9691 (398.767)	22.9529 (396.333)
<hr/>				
-1,0,0,0,0				
	9.6666 (88.888)	18.0000 (225.000)	21.3333 (336.111)	18.1388 (253.240)
<hr/>				

The implications of the results presented above are clear. If the profitability and/or market area of an interior firm is eroded away either through the effects of agglomeration or by exterior competitors entertaining lower pricing conjectures, the behavior of that interior firm may be restricted within some parameter range which can be viewed as "rational" given the spatial arrangement of competitors and the price reaction functions of adjacent rivals. Thus, rational pricing conjectural variations are delimited by both the geographic structure and the behavioral characteristics within spatially competitive markets.

Summary

It has been demonstrated that both the geographic and behavioral properties of price-interdependent firms are important in the determination of short-run spatial equilibrium conditions. This has notable implications on the assessment of the "structure-conduct-performance" relations of spatially linked oligopolists who price compete for a share of a geographic market (as noted conceptually by Benson, 1979). It has been suggested, by the findings presented here, that the distribution of competitors and their behavioral parameters may delimit a range of rational price conjectures which are inextricably tied to the relative locations of rivals, their pricing policies, and the direct and indirect price linkages in the market. Hence, both space (the relative locations of firms and market boundary conditions) and behavior (the pricing policies of spatially competitive firms) play an important role in the determination of price, profit, and geographic market share.

CHAPTER 8

A TOPOLOGICAL APPROACH TO SPATIAL COMPETITION

Up to now, this dissertation has focused entirely on modeling spatial oligopolies in two one-dimensional settings, with little attention being paid toward more complex market arrangements. As an extension of one-dimensional market area analysis, this chapter generalizes my analytical model of price competition (for inelastic consumer demand) using a topological approach. This allows me to examine interdependent network price reactions and multiple competitive market segments. In the initial stages of this chapter, a generalized framework for competitive networks of rival price reaction is developed and the implications of increasing connectivity/accessibility noted for two geographically distinct cases of spatial quintopoly in a bounded market setting (competition amongst $n=5$ mutually interdependent and topologically connected firms) (See Figures 34 and 35). The analysis progresses from a comparison of symmetrical pricing conjectures to that of diametrically opposing conjectures for internal (centralized) versus

external (peripheral) firms, and ends with a discussion on the boundary effects of centrally dense market structures and the algebraic properties of the connectivity matrices which describe firms' direct price reactions as a function of their topologically linked rivals.

Bounded Geographic Market Networks:

Figure 34
An Illustration of a Simple Linear
End-Bounded Market Network

Figure 35
An Illustration of a Centrally Dense
Tri-Bounded Market Network

Bounded Market Relations

A more general approach can be taken to model spatial price equilibrium for a bounded market comprised of a network of competing rivals such as in Figures 34 and 35.

Network linkages determine the number of nearest neighbors that firms perceive as being competitors. In this topological market description, firms have the potential to be directly connected to more than two adjacent rivals (as illustrated for firm 2 in Figure 35, that compete directly with firms 1,3, and 4). This simple network is used to develop an extended version of the matrix relations presented in Chapter 3. In order to accomplish this task, some modifications and notational changes must be made.

Consider a firm's price reaction parameter ϕ , a constant own-pricing expectation for all competitors which are directly linked (through first order connectivity). Let d_i equal the number of direct linkages to competitors from an i -th interior firm (where we do not consider the firm as being linked to itself). Assume that all firms are connected at some order v (which includes all direct and indirect linkages), i.e., there are no isolated firms. Given this information we can modify the expressions for α and β , and create new parameters α' and β' which incorporate the degree of connectivity d_i , where

$$\alpha' = 2(d_i) - d_i \phi = d_i (2 - \phi) ;$$

and

$$\beta' = d_i - d_i \phi = d_i (1 - \phi) .$$

Also, peripheral firm relations can be restated for the parameters μ and ϕ for bounded competitors ($i=1, i=n$) with only one direct market linkage ($d_1=1, d_n=1$ for Figure 34; $d_1=1, d_3=1$, and $d_n=1$ for Figure 35). It follows that

$$\mu' = 2 - \phi ;$$

and

$$\phi' = 1 - \phi .$$

A connectivity matrix C (with typical elements c_{ij} , $i=1, \dots, n$ and $j=1, \dots, n$) can be constructed from the following criterion:

the cell c_{ij} is a non-zero entry (i.e., equal to 1) iff

- (a) the i -th and the j -th firms are adjacent or first-order connected; or
- (b) the i -th/ j -th ($i=j$) firm is bounded or exterior.

Along with the redefinition of these conjectural parameters, the network linkages need to be introduced into the $\underline{C}^*$ (market connectivity) matrix as non-diagonal entries whose cells contain -1 if firms are directly connected and 0 if indirectly connected. Thus, the n -th order matrix $\underline{C}^*$ in equation (40) can be initialized for Figure 35 (with the number of direct linkages for any firm

j is equal to $\sum_{i=1}^n |c_{ij}|$, where c_{ij} is a typical element of the matrix $\underline{C}^*$ and $i \neq j$) as follows:

$$\underline{C}^* = \begin{bmatrix} \mu' & -1 & 0 & 0 & 0 \\ -1 & \alpha' & -1 & -1 & 0 \\ 0 & -1 & \alpha' & 0 & 0 \\ 0 & -1 & -1 & \alpha' & -1 \\ 0 & 0 & 0 & -1 & \mu' \end{bmatrix}. \quad (56)$$

To simplify matters, a distance matrix D (which contains information on the physical distance which separates competitors) will not be specified. In this simulation exercise all firms are defined as equidistant to their nearest competitor (i.e., all network vertices are standardized to an equal length). Nevertheless, for exterior or bounded firms, a separate boundary condition needs to be imposed; namely, any bounded firm (like firms 1, 3, and 5 in Figure 35) is enumerated as being located at twice the distance to its market edge (or itself). Note, in this case, firm 3's distance to itself is still zero, while the peripheral firms' (firm 1 and 5) distance to itself is some positive amount (the distance between itself and its boundary (times 2)). In addition, the total extent of the market A (or the summation of all individual market segments) will be held constant ($A=80$ units of

distance). Distances to second-nearest competitors will not be considered. Hence, all non-zero d_{ij}^* entries will exactly correspond to the non-zero values of off-diagonal c_{ij} entries. This assumption can be relaxed without loss of generality in the model. For the sake of brevity, a full designation of the distance matrix will be foregone. Instead, all non-zero connectivity entries exactly determine distance entries $d_{ij} = 16$ units (and $d_{ij} = 2 \times 8$ or 16 units for i 's/ j 's which are bounded when $i=j$).

The own marginal cost entries in matrix $\underline{X}^*$ (of equation 40) must also be aligned with their appropriate ϕ' and β' values in order to compute the equilibrium price vector (from equation 41). Similar modifications can be made for the circular market relations shown in equations (21) and (22). Note however, since all firms are viewed as interior, boundary conditions are not necessarily specified as in the linear market case above. As the boundary implications have already been established, the cases involving circular market descriptions will be ignored for the present. The main concern here is on comparing the effects of multiple boundaries to see how price patterns are altered (or boundary effects are enhanced) as interaction or competitive interdependence increases due to a centrally dense market arrangement (where interior firms price react with respect to more

than two competitors). Theoretically, as the market becomes fully connected the matrix $\underline{C}^*$ is composed of all non-zero entries for non-diagonal positions (i.e., all non-diagonal cells contain -1's). Furthermore, if firms are unevenly dispersed each element of D (the distance between any one firm and any other) must be separately and individually identified. This model can also be extended to examine the location of firms within a larger geographic market as represented in two-dimensional (Euclidean) space. Since this is beyond the scope of this project, the above example will suffice in the examination of multiple boundary effects.

Topologically Defined Market Segments

Individual firm-level market segments can now be derived and written as a function of networked price relations, where

$$a_i = (1/2)t \left[\sum_{k=1}^{m-1} c_{ik} p_k - \left(\sum_{k=1}^{m-1} c_{ik} \right) p_i + t \left(\sum_{j=1}^m c_{ij} d_{ij}^* \right) \right], \quad (57)$$

where $k \neq i$. The summation of only $m-1$ entries prevents the inclusion of redundant own price information from entering into the price relations formula when equilibrium mill prices are computed.

Subsequently, the location matrix $\underline{X}^*$ can be specified according to the connective properties of the market as

$$\underline{X}^* = \begin{bmatrix} t \left(\sum_{j=1}^m c_{1j} d_{1j}^* \right) + \phi_k & 1 \\ \vdots & + \beta_k \\ \vdots & 2 \\ \vdots & \vdots \\ \vdots & + \beta_k \\ & n-1 \\ t \left(\sum_{j=1}^m c_{nj} d_{nj}^* \right) + \phi_k & n \end{bmatrix} . \quad (58)$$

The number of competitors d_i which are directly linked to a firm i and the degree of separation amongst i 's competitors are imposed through the matrices $\underline{C}^*$ and $\underline{X}^*$ (through the elements c_{ij} , c_{ij} , and d_{ij}^*), where the network equilibrium price vector $\underline{p}^{**}$ can be expressed as

$$\underline{p}^{**} = \underline{C}^*{}^{-1} \underline{X}^* . \quad (59)$$

Equilibrium price levels of the spatially competitive quintopoly for the two markets networks described above were computed for the following distributions of price conjectures listed in Table 23.

The numerical results (equilibrium prices) for the fifteen simulated markets illustrated in Figures 34 and 35 (and Table 23) are compiled in Tables 24 and 25 respectively. Analysis of the data follows.

Table 23
 Geographic Distribution of Pricing
 Conjectures for a Spatially Linked Quintopoly
 for Fifteen Simulated Markets

Setting	Firms:				
	1	2	3	4	5
1	HS	HS	HS	HS	HS
2	NL	NL	NL	NL	NL
3	GO	GO	GO	GO	GO
4	NL	NL	HS	NL	NL
5	GO	GO	HS	GO	GO
6	HS	HS	NL	HS	HS
7	GO	GO	NL	GO	GO
8	HS	HS	GO	HS	HS
9	NL	NL	GO	GO	GO
10	NL	HS	HS	NL	NL
11	GO	HS	HS	GO	GO
12	HS	NL	NL	HS	HS
13	GO	NL	NL	GO	GO
14	HS	GO	GO	HS	HS
15	NL	GO	GO	NL	NL

Note: NL = near Löschian behavior; HS = Hotelling-Smithies behavior; GO = Greenhut-Ohta competition.

Table 24

Equilibrium Prices for the Linear Market (n=5 firms)
Depicted in Figure 34

#	p* 1	p* 2	p* 3	p* 4	p* 5	1-GR(p*)	c2
1	28.33	21.66	20.33	21.66	28.33	.252	184.88
2	2012.91	2001.01	1997.10	2001.01	2012.91	.285	628.63
3	16.66	12.00	11.33	12.00	16.66	.233	88.88
4	168.62	138.27	78.63	138.27	168.62	.336	17909.87
5	16.93	12.80	15.90	12.80	16.93	-.190	106.55
6	31.71	28.43	44.02	28.43	31.71	-.220	1015.24
7	17.83	15.51	31.22	15.51	17.83	-.154	1009.82
8	27.42	19.84	13.94	19.84	27.42	.443	368.75
9	132.78	102.08	41.36	102.08	132.78	.335	18518.43
10	69.65	38.32	45.64	106.23	136.89	.674	11294.63
11	18.85	18.55	17.40	13.07	17.02	.332	71.70
12	50.41	81.82	74.80	37.23	36.11	.543	4021.01
13	32.34	59.02	54.83	19.67	19.22	.454	3931.89
14	24.25	13.51	12.84	19.52	27.26	.459	440.80
15	51.62	20.11	25.06	86.25	117.11	.665	11429.06

Note: the symbol {-} means symmetrical price relation among mirror-imaged firms (i.e., firms 1 and 5; and firms 2 and 4).

Table 25

Equilibrium Prices for the Network
Market (n=5 firms) Depicted in Figure 35

#	p* 1	p* 2	p* 3	p* 4	p* 5	1-GR(p*)	c2
1	25.90	16.81	17.90	16.09	25.54	.330	347.50
2	1614.91	1599.03	1599.07	1599.00	1614.88	.392	1008.84
3	15.82	9.46	10.48	8.84	15.61	.311	175.37
4	240.00	210.37	114.68	250.65	279.88	.717	25021.41
5	15.97	9.93	14.65	8.92	15.64	.146	206.41
6	27.63	20.27	35.94	17.07	26.03	.331	780.53
7	16.47	11.42	27.18	9.19	15.73	.393	643.07
8	25.40	15.80	12.60	15.80	25.40	.506	389.11
9	189.89	159.76	60.58	201.51	231.22	.717	26739.37
10	67.69	36.33	27.66	81.66	112.57	.689	8136.26
11	17.36	14.09	16.54	9.66	15.88	.274	150.16
12	48.09	61.19	76.45	28.76	31.88	.668	2931.04
13	27.43	44.31	59.74	14.99	17.66	.647	2779.16
14	24.25	13.51	12.52	19.52	27.26	.459	440.80
15	51.70	20.19	14.06	65.99	97.05	.680	8185.88

A comparison of the output in Tables 24 and 25 for a restricted market length of $A=80$ (i.e., where the summation of individual market segments equals 80 units) exemplifies the effects of geographically compressing a market and increasing the number of first order neighboring competitors (as the radial or spoked market increases the overall connectivity of adjacent firms from 7 to 8 joins). Holding system parameters constant, equilibrium mill price levels demonstrate a tendency to decline under the spatially concentrated network market. Irregularly spaced firms with mixed conjectures tend to bring about the most dramatic price changes (reductions) for firms which are either highly connected (or most accessible) or internalized and adjacent to the accessible firms. Even though more external firms have been simulated by the centrally dense market (firms 1,3, and 5), internalized firms (firms 2 and 4) lower the potential for higher prices at peripheral locations. However, the spatial distribution of prices becomes more variable as the squared differences in neighboring rival price schedules rise (i.e., c_2 behaves rather erratically). This further emphasizes the need to review price competition as both a function of relative positioning (and separation) and the behavioral aspects of networked pricers.

Another interesting feature is evident in the juxtaposition or spatial covariance of equilibrium prices. Note that the spatial autocorrelation index ($1-GR(p^*)$) retains its sign for identical simulated conjecture sets under both market structures. The most volatile cases involve combinations of near-Löschian competitors and lower conjectured pricers (e.g., compare settings 4,9 and 10). More subtle alterations in price patterns are associated with conjecture sets which are lower in their average, like the ultracompetitive cases involving GO and HS competitors (e.g., compare settings 5,8 and 11). In fact, in one situation (case 14), the connectivity of the market is shown to be irrelevant in defining the equilibrium condition. This implies that as competitors approach the ultracompetitive extreme of GO pricing, connectivity becomes less influential in the price convergence process (i.e., as more competitors take on reciprocal pricing strategies the physical layout of the market becomes less of a factor in the chained response of rivals).

In order to more closely examine the impacts of connectivity and market structure on equilibrium price levels, a second series of simulations were run for the market networks illustrated by Figures 36 and 37. To assist in the description of price conjectural

Figure 36. Network I

Figure 37. Network II

distribution, it is assumed that 2 rival chains (as opposed to n individual firms) compete for market segments as represented by the links of the network. Chain A has five firms located at nodes 1,3,5,7, and 9; and chain B has four firms located at the remaining nodes. Market network I - Figure 36 (II - Figure 37) allows for complete first-order connectivity between all firms of chain B (A). This is done to test the price competitiveness of highly connected networks in terms of absolute and relative location (i.e., to monitor the effects of highly versus lowly connected firms). The purpose of this exercise is to expose the nature of price reaction for market networks having varying degrees of central density. Notice that firm 5 (on average) has fewer direct linkages to other firms (be they of the same chain or not) in network I than in network II. It is hypothesized that this connectivity differential will have a marked effect on equilibrium prices.

For simplicity, it will be assumed that firms of like chains operate/conjecture under internal symmetry. Simulation results are presented in Tables 26 and 27. A brief discussion of the general price patterns follow. This approach may be viewed as beneficial in discerning the equilibrium conditions as an outcome of behavior for networks or markets which are centrally focused as opposed

to those which are peripheral in their orientation (i.e., in terms of connectivity).

Under symmetrical pricing behavior, differences in network connectivity are shown to produce widely varying price patterns. For instance, in the peripherally emphasized network (Network I) there is an inherent symmetry in chain-level equilibrium mill price (Table 26). This is most likely caused by the evenness in the number of linkages which extend from each of the interior nodes/firms (with the exception of firms located at the corners of the market). Notice also, that as conjectures decline from Löschian to Greenhut-Ohta competition, mill price and spatially connected price differentials tend to be less pronounced.

The symmetrical distribution of equilibrium mill prices also hold for the asymmetrically defined chain-level conjectures with similar properties. For example, as the average chain-level conjecture decreases so do the spatial equilibrium price differentials in the market network. However, it is apparent that the relative location of those conjectures is extremely important in determining relative mill price schedules.

Note the consistency in the spatial autocorrelation index. In each case, a substantial amount of negative spatial dependence is present. When chain-level

conjectures are switched, the corresponding chain price ratios exhibit a greater disparity in the ratio of larger to smaller equilibrium price levels (or price conjectures). This is easily seen in the sequence of price ratios for pricing scenarios 4 through 9. Note that the sequence constructed from Table 26 reads: 1.484; 1.845; 1.193; 1.599; 2.145; 1.333. These conditions are easily attributable to three factors: (1) the behavioral aspects of jointly competitive agents; (2) the relative positioning of firms as a function of separation and linkage; and (3) the number of pricers associated with internalized versus externalized (those operating from corners or edges) market locations (i.e., the degree of connectivity). The third condition also includes the effects of longer market segments which are more or less entirely controlled by chain 2, i.e., the stretches of the network which exist between firms (2,4; 2,6; 4,8; and 6,8). These factors account for the price irregularities over space which are not due to the behavior of the firm.

A comparison of the equilibrium properties for the exercise above unearths another interesting finding, that is, the inability of the underlying average conjecture to influence the relative correspondence of chain-level price. In most cases, even as the average conjecture was

Table 26

Equilibrium Prices for Simulated Market
with Two Chains: Network I (Figure 36)

Conjectures Chain 1,2	p* 1	p* 2	p* 5	1-GR(p*)	c2
(.99,.99)	1105.909	1106.938	1105.909	n.a.	25.41
(0,0)	13.637	14.274	13.637	-.3502	9.74
(-1,-1)	8.230	8.690	8.230	-.3496	5.08
(1,0)	30.656	20.656	*	-.3500	2400.00
(1,-1)	21.828	11.828	*	-.3499	2400.00
(0,-1)	11.186	9.372	*	-.3499	78.95
(0,1)	32.428	51.856	*	-.3499	9058.82
(-1,1)	17.314	37.142	*	-.3499	9058.81
(-1,0)	9.584	12.754	*	-.3499	241.16

Note: * means symmetrical price relation between p* and
p* .
5 1

Table 27

Equilibrium Prices for Simulated Market
with Two Chains: Network II (Figure 37)

Conjectures Chain 1,2	p* 1	p* 2	p* 5	1-GR(p*)	c2
(.99,.99)	1106.711	1105.887	1107.327	-.2690	30.46
(0,0)	14.146	13.628	14.479	-.6170	10.96
(-1,-1)	8.602	8.225	8.828	-.6001	5.58
(1,0)	50.913	32.428	53.741	-.4093	9165.48
(1,-1)	36.199	17.714	39.027	-.5093	9165.48
(0,-1)	12.560	9.576	13.070	-.4165	242.16
(0,1)	20.820	30.684	20.411	-.3652	2402.22
(-1,1)	11.943	21.847	11.655	-.3606	2401.10
(-1,0)	9.327	11.182	9.442	-.3286	79.41

varied markedly, little or no change in the spatial autocorrelation measure was detected. Hence, the speculation that alternating pricers may be indicative of alternating conjectures (Fik, 1988) may be unwarranted, although this property is still not inconsistent with the idea of switching conjectures at the chain level. For cases involving asymmetrical chain-level conjectures, it has been demonstrated that higher (lower) chain-level equilibrium prices are associated with higher (lower) conjectures.

A look at network II (one which is more centrally or radially concentrated around firm 5) reveals a much different pattern in equilibrium prices (Table 27). Although the general finding of higher conjectures, higher prices is still intact (no doubt a function of isolated market segments between firms of chain 1), an asymmetry in prices arises. Here we find inconsistencies between equilibrium price levels for like chains; specifically associated with firm 5 of chain 1. This condition must be construed as a byproduct of the hyper-connectivity of that node in relation to all other nodes. In other words, given that each node in the system is directly linked to firm 5 and its degree of connectivity is more than two times that of any other node, firm 5 (although symmetrical in terms of its chain-level conjecture) operates in an independent

pricing fashion. This again emphasizes the importance of location and spatial organization in the resolution of prices (or more realistically the tendency toward price equilibrium). This is not to say that similar situations cannot arise due to the inconsistencies of individual conjectural activity of firms within a chain. Certainly, the spatial identity or locational circumstance can also force a deviation from chain-level symmetry in the trade-off between maximizing profits at the firm versus chain level; especially for circumstance involving either highly dense/clustered or highly isolated market segments or sub-networks (something which will not be explored in this work).

The simulation results for network II are not as easy to analyze in terms of spatial price covariation. Note that as average conjecture declines, so to does the chain-specific discrepancy in equilibrium prices. This, however, only arise when the average conjecture drops below .111 (compare cases {1,0} and {1,-1}) or when the dominant chain (the chain with a greater number of firms and the most centrally located firm - chain 1) exhibits a lower pricing conjecture. In general, when the dominant chain exhibits a higher or equivalent pricing conjecture, the centralized firm (firm 5) displays a significantly higher mill price. This reaffirms the possibility of higher

connectivity and/or competitive linkages being associated with higher prices (as discussed in chapters 2 and 3). The reverse is true only for cases $\{0,1\}$ and $\{-1,1\}$ where the dominant chain portrays a more competitive or lower conjecture. Yet, this property will not hold for the ultracompetitive case of $\{-1,0\}$, where the price of firm 5 rises marginally above that of its exterior counterparts. This idiosyncrasy negates the identity of GO pricing as a well-behaved and ultra-competitive conjecture in that it shows minor deviations in form which are no doubt a byproduct of the spatial influences discussed throughout this dissertation. Hence, the characteristics of the network are as important in delimiting the range of equilibrium prices as are the behavioral aspects of the market agents. Once again, the theme which underscores this argument, the notion that "space matters", is unequivocally established; thus adding to the array of potential indeterminacies which surround the concept of spatial price competition under inelastic consumer demand.

The Implications of Cost Efficiency

Assume that all $n=9$ firms (found in Network II in Figure 37) behave symmetrically in their pricing behavior. To simplify matters, the three most commonly used pricing

conjectures will be used (i.e., NL, HS, and GO behavior). Furthermore, suppose that the most accessible firm (firm 5) operates at such a scale that it incurs a cost savings or a reduction in its marginal cost of production. A simulation analysis is performed to compare two different marginal cost structures for firm 5, where k_5 equals 1.5 and .3 (or one-half and one-tenth the marginal cost of all other firms in the market, as $k_i = 3$ for all other i firms, $i \neq 5$). The simulation results are presented in Table (28). Attention is paid to the new equilibrium price schedules (in comparison to those derived under constant marginal cost parameters), relative price changes, and the percentage of that cost savings which is realized through lower prices, differentiated by conjecture.

Two striking features are noteworthy when one compares the percentage of cost savings passed on in the form of lower prices (Table 29). First, the lower the underlying price conjecture, the greater the realized price reduction by the cost-efficient firm. However, the aggregate effect (in terms of the overall price reduction) is the most pronounced under higher conjectures. Even though this is true on an absolute basis, it turns out to be only a small percentage of the equilibrium price level of firm 5.

Table 28

Simulation Results for an Accessible and
Cost-Efficient Firm (Firm 5) for Network II

Cost Efficiencies

50%					90%		
ϕ	Firm	k	p*	change	k	p*	change
NL	1	3	1106.339	-.372	3	1106.041	-.670
	2	3	1105.515	-.374	3	1105.217	-.670
	5	1.5	1106.943	-.384	0.3	1106.637	-.690
HS	1	3	13.932	-.214	3	13.760	-.385
	2	3	13.414	-.214	3	13.243	-.385
	5	1.5	13.622	-.857	0.3	12.936	-1.543
GO	1	3	8.452	-.159	3	8.332	-.270
	2	3	8.076	-.150	3	7.956	-.270
	5	1.5	7.778	-1.050	0.3	6.938	-1.890

Note: Firms 3,7,9 (4,6,8) behave identically to firm 1 (2).

All changes in equilibrium prices are with respect to price under constant marginal cost structures.

The distance between firms 1 and 2, and firms 2 and 5 is equal to 10 units, and $t = 1.0$.

Secondly, in reviewing the output presented in Tables 28 and 29, it is readily apparent that all firms adjust to the cost-efficiency of their competitor (owing to the chain-like price reactive structuring of firms). Yet, the most dramatic disparities in equilibrium mill prices (at the chain level) are associated with lower pricing conjectures. In other words, a production cost savings which filters through a market in terms of lower prices has its greatest impact when firms are pricing or conjecturing more competitively (lower). Thus, there is great variability in the implications which surround the concept of firm-level cost-efficiency, since it is not at all clear that cost savings get passed on to the consumer in terms of lower prices. Unless the behavioral tendencies of the firm are known, as well as the connective structure of the market (including the behavioral parameters of competitors within that network), little can be said regarding the benefits and/or spatial welfare implications of cost efficiencies.

Table 29

Overall Equilibrium Price Reductions and Price
Changes as a Percentage of Firm 5's Equilibrium Price

ϕ	Price Reaction (Market)	% of Firm 5's p^*
<hr/>		
50% Cost-Efficiency		
.99	-3.376	0.30
0	-2.569	18.86
-1	-2.250	29.92
<hr/>		
90% Cost Efficiency		
.99	-6.050	0.54
0	-4.622	35.73
-1	-4.050	58.37
<hr/>		

Note: % cost efficiency refers to a firm's marginal
cost of production advantage over its competitors.

Summary

This chapter has developed a topological approach to spatial price competition, where firms in a network compete for market segments on the basis of connectivity. It has been demonstrated that both the geographic characteristics of a market and the behavioral attributes of competitors within that market are important in the determination of equilibrium price schedules. Such an approach can be seen as a more realistic description of geographically competitive markets than those proposed by economists (Ohta, 1988). This model is easily adaptable to applications involving directional flows of consumers and multipurpose/multistop and/or comparison shopping, as well as, more complex retail systems which offer a central place type division of establishments and retail clusters (to examine the effects of agglomeration economies). Further expansion of the model must involve competition for a two-dimensional market.

Attention now turns to a descriptive account of a real competitive market in order to examine the validity of distance-decay relations in price dependence through an empirical examination of price competition between major retail chains which are geographically distributed over a

metropolitan area. The study of relative chain-level price schedules is the focus of Chapter 9. The analysis proceeds from a descriptive manner to that of the statistical investigation of price-distance relations to uncover regularities which may exist at the macro-level (i.e., for the market as a whole). Given that pricing conjectures are not observable, no conclusions will be made as to the nature of firm or chain-level expectations. The objective of the following chapter is to ascertain statistically the relationship between contiguous price schedules and the relative locations of chain-specific firms to validate the salience of space.

CHAPTER 9

PRICE COMPETITION: AN EMPIRICAL ANALYSIS

A Synopsis

This chapter examines the geography of competition and price amongst five major retail food chains in the metropolitan Tucson area (Table 30). Descriptive statistics on the relative location and mapped point pattern of individual stores are compiled to test whether or not the observed distribution of competing chains (made up of many spatially distributed establishments) by location can be linked to a realization of a random process. Although the sample is restricted to omit at least one other major chain competitor and several independents and convenience-store retailers, it represents a substantial proportion of the large-scale operators which compete for surrounding geographic markets. This sample was chosen on the basis of the availability of price information via a consumer-oriented television cable reporting system.

This chapter also examines the statistical correspondence between firm location and price. Descriptive statistics are computed for a given

distribution of chain-store market areas delineated by Thiessen polygons, services offered at those locations (by proxy variables), and reported chain-level price information, in the search for geographic order in observed price levels (e.g., price-distance relations and distance-decay effects). In addition, the empirical procedures employed in this chapter will investigate the relationships between the relative location of firms (distances to nearest competitors) and the geography of price. Methods include such procedures as spatial autocorrelative indexing (as a general measure of spatial dependence), point pattern analysis, and estimated generalized least squares regression modeling (a modified ordinary least squares approach which accounts for spatial dependence in error). The objective of this approach is to substantiate the importance of space (and relative location) by looking at price patterns which conceivably underlie a competitive pricing process.

The Data

Weekly price reporting was assembled by an independent agency for randomly selected outlets for the following chains: ABCO, FRY'S, SAFEWAY, LUCKY, and SMITH'S. The cable-based comparison shopping guide is assumed to contain price information which is representative for the

chain as a whole. These reported prices do not, of course, contain information on localized specials (i.e., discounted items at the individual store level). However, most advertised specials (printed in newspapers) suggest that discounted items are priced and honored at the chain level, implying that the reported data are strongly representative for the chain as a whole. It is therefore assumed that intra-chain pricing will vary slightly, with the independent pricing effects evening out over space.

A previous attempt at studying price competition amongst Tucson retail food chains have uncovered two regularities in spatial price patterns: (1) an direct and statistically significant relationship between the spacing of competitive chains and their reported price levels; and (2) in general, a trend for price levels to be higher for firms which are isolated or peripherally located in the market (Fik, 1988). The approach taken in this chapter differs from the previous study in four ways. First, market areas for individual outlets will be determined on the basis of distance minimization (through the construction of Thiesen nets); as opposed to the census tract definition of market areas used previously. Secondly, a point pattern analysis of chain outlets will be undergone to assess the relative locations of competitors for the market as a whole. Thirdly, distance-

decay properties in reported price levels are tested against the distance to nearest and next-nearest rival chains. Lastly, the emphasis here will be on verification of the findings reported by Fik (1988).

An example of comparative price levels by chain is given in Table 31 for a six-week period. Note that there are 47 retail outlets in all, comprising five competing chains. Store locations are obtained from street addresses published in the local phone directory and coded by the appropriate census tract (Table 30).

The Cable Reporting System

The Cooke Cable Comparison Shopping Guide is a retail food-price reporting system which provides the consumer with information (as a public service) on chain-level prices for a comparable market basket. Survey data are obtained by trained professionals who monitor least-cost store brand items and/or specific national brands, and compile a shopping list which is composed of selected food and kindred products under the headings of meats, groceries, produce, and sundries. Price levels do not reflect such intangibles as convenience, store size, shopping environment, and/or quality components related to the products and

Table 30
Location of Retail Outlets
by Street Address and Census Division

#	Chain	Code	Location	Census Tract
1	ABCO	#101	4625 E. Speedway Blvd.	31.01
2	"	#102	7125 E. Speedway Blvd.	40.01
3	"	#103	428 W. Valencia Rd.	37.03
4	"	#104	6310 N. Oracle Rd.	47.03
5	"	#105	2140 W. Grant Rd.	45.04
6	"	#106	5555 E. River Rd.	47.05
7	FRY'S	#201	7050 E. Golf Links Rd.	40.09
8	"	#202	555 E. Grant Rd.	14
9	"	#203	3910 E. Grant Rd.	29.01
10	"	#204	3770 W. Ina Rd.	46.06
11	"	#205	7850 E. Speedway Blvd.	40.14
12	"	#206	3640 S. 16th Ave.	25.01
13	"	#207	4150 E. 22nd St.	35.01
14	"	#208	7951 N. Oracle Rd.	46.03
15	"	#209	9401 E. 22nd. St.	40.21
16	SAFEWAY	#301	1940 E. Broadway Blvd.	7
17	"	#302	6230 E. Broadway Blvd.	33.01
18	"	#303	7125 E. Golf Links Rd.	40.11
19	"	#304	885 E. Grant Rd.	14
20	"	#305	8740 E. Broadway Blvd.	40.21
21	"	#306	3749 W. Ina Rd.	46.05
22	"	#307	4070 N. Oracle Rd.	45.09
23	"	#308	5548 E. Grant Rd.	30.01
24	"	#309	1551 W. St. Mary's Rd.	11
25	"	#310	7820 E. Wrightstown Rd.	40.20
26	"	#311	4752 E. Sunrise Rd.	47.05
27	"	#312	7900 N. Oracle Rd.	47.06
28	"	#313	1767 E. Prince Rd.	27
29	"	#314	2940 W. Valencia Rd.	41.02

Note: Table continued on next page.

Table 30--Continued
 Location of Retail Outlets
 by Street Address and Census Division

30	LUCKY	#401	1740 W. Ajo Way	25.02
31	"	#402	3900 W. Ina Rd.	46.06
32	"	#403	7877 E. Broadway Blvd.	40.14
33	"	#404	719 E. Fort Lowell Rd.	26.02
34	"	#405	4722 E. Broadway Blvd.	34
35	"	#406	5540 E. 22nd St.	35.03
36	"	#407	3356 S. 6th Ave.	24
37	"	#408	3925 E. Grant Rd.	29.01
38	"	#409	5667 E. Speedway Blvd.	30.02
39	"	#410	8975 E. Tanque Verde Rd.	40.16
40	"	#411	6488 N. Oracle Rd.	47.06
41	"	#412	2520 S. Harrison Rd.	40.18
42	"	#413	2000 E. Irvington Rd.	41.03
43	"	#414	4751 E. Sunrise Dr.	47.05
44	SMITH'S	#501	4036 N. 1st Ave.	46.09
45	"	#502	2480 N. Swan Rd.	29.04
46	"	#503	7050 E. 22nd St.	40.11
47	"	#504	2950 W. Ina Rd.	46.05

Note: The information contained in this table is used to locate firms and their market areas as defined by Thiessen nets. Street addresses are converted into map coordinates and market areas delimited by distance minimization. Census tract information is used in describing the general characteristics of consumers within the constructed Thiessen nets for tracts contained within those nets (market areas).

Table 31

Comparison Shopping Guide Total List Prices for
Competing Metro-Tucson Retail Food Chains
(Markets Surveyed Weekly from 7/27 through 8/21, 1988)

Time Period	Retail Food Chain				
	ABCO	FRY'S	LUCKY	SAFEWAY	SMITH'S
Week 1 - 7/27/88					
1	179.30 (4)	171.30 (2)	172.51 (3)	183.35 (5)	165.72 (1)
Week 2 - 8/3/88					
2	179.35 (5)	175.72 (3)	168.83 (2)	176.56 (4)	163.46 (1)
Week 3 - 8/10/88					
3	181.78 (5)	181.05 (4)	174.21 (2)	180.91 (3)	165.77 (1)
Week 4 - 8/17/88					
4	167.26 (5)	164.10 (4)	165.43 (4)	164.82 (3)	157.03 (1)
Week 5 - 8/24/88					
5	177.21 (4)	173.85 (3)	168.79 (2)	179.26 (5)	165.80 (1)
Week 6 - 8/31/88					
6	183.01 (4)	180.42 (3)	172.29 (2)	183.38 (5)	168.74 (1)

Note: Store rankings (from low to high) are shown in parentheses below the reported total price schedules. Data taken from consumer cable reports.

services offered or the shopping experience. Hence, no judgments are made as to the competitiveness of store chains based on product quality components and/or store environment. The cable price report focuses specifically on prices for comparable items of a fixed market basket. For example, no allowances are made on comparative cost structures (on a chain or individual store basis) and their effect on general price levels.

Information is, however, available on those stores which offer such services as a bakery-deli and/or a pharmacy which are listed under separate phone numbers by store address. Although it is impossible to observe cost functions for individual stores, information on internalized services may be helpful in understanding the general spatial distribution of competing chains and services offered and how that relates to the geography of store location and price. A complete listing of stores which house such services is given in Table 32 (by store code). The presence or absence of such services will be used at a later time in a dummy variable context to test the importance of these services and how they correspond to the intensity of competition as a function of rival proximity and the degree to which competitors cluster in space (i.e., do rivals have a tendency to offer more internalized services as either spatial market density of

competitors increases or as distance between nearest-neighboring rivals decreases?).

The interjection of the service variable provides the flexibility to compare chain-level price with distance to nearest competing chain while adjusting for any potential agglomeration economies which may exist at the individual firm level. Categorically, these services are broken down into two separate and unique classes since their threshold sizes may differ. It is posited that the availability of in-store services may be tied to store chains which charge higher prices. Of course, the reverse may be true if those stores are operating at larger scales which are obtaining size-related efficiencies (as shown in the previous chapter). This problem will not be addressed here since no information is available on the cost-efficiency of those operations.

A Point Pattern Analysis

A point pattern distribution of the 47 retail outlets is constructed using street addresses superimposed on a 1980 census tract map for the metro-Tucson area. X,Y - coordinates are charted for a rectangular region delineated by the four most extreme points in terms of direction (i.e., the furthestmost retail outlets to the

north, south, east, and west). These points will serve as a basis for defining the spatial market. Given the observed point pattern, it is easily seen that this market boundaries (as defined by the exterior points) form a rectangular market. The sides of the rectangle, which encompasses the study area, are restricted to bound these peripheral points by a fixed distance of .125 inches (where 1 inch equals 2.666 miles). It is assumed that this rectangle covers a significant portion of the outer range for exterior establishments. All X,Y - coordinates are measured in relation to the southwest corner (where $X=0$, $Y=0$), and are listed in Table 33. A coordinate system is applied in order to carry out a "point pattern analysis" on the location of firms (See Figure 38). The length of the study region (X-axis) is approximately 15.32 miles, and the width (Y-axis) is approximately 13.99 miles. Total areal-coverage is approximately 214.54 square miles. Some inherent distortions may exist in the plotted data (as great as plus or minus 10% for each axis). These distortions are due to rounding errors, resolutional considerations, and/or minor inaccuracies in the search algorithm which maps the spheres of influence for each firm. The meaning of these geographic sub-markets is discussed in subsequent paragraphs.

Table 32

A Listing Of Stores with Separate Phone Numbers
for Bakery-Deli and/or Pharmacy Services

Store Chain	Code #	Deli-Bakery	Pharmacy
ABCO	#101	Yes	Yes
"	#102	Yes	Yes
"	#103	Yes	Yes
"	#104	Yes	No
"	#105	Yes	No
"	#106	Yes	No
FRY'S	#201	No	Yes
"	#202	No	Yes
"	#203	No	Yes
"	#204	No	Yes
"	#205	No	Yes
"	#206	No	Yes
"	#208	No	Yes
"	#209	No	Yes
SAFEWAY	#302	Yes	No
"	#303	Yes	No
"	#306	Yes	No
"	#308	Yes	No
"	#309	Yes	No
"	#311	Yes	No
"	#313	Yes	No
"	#314	Yes	No
LUCKY	#414	Yes	No
SMITH'S*	#501	No	Yes
"	#502	No	Yes
"	#503	No	Yes
"	#504	No	Yes

Note: Only those stores which have separate telephone lines for services are listed.

*Smith's does not have a separate phone line for its Bakery-Deli department (although contact can be made through the main switchboard). In order to maintain consistency in the approach outline in this chapter it will be treated as having no separate service-line connection.

Table 33

X,Y Coordinates for Retail Outlets by Code

	Store	x	y		Store	x	y
1	#204	.125	4.875	25	#314	2.500	.125
2	#402	.250	4.875	26	#103	1.718	.156
3	#306	.687	5.000	27	#203	3.000	2.812
4	#504	.718	4.875	28	#408	3.031	2.937
5	#208	1.593	5.125	29	#502	3.296	2.812
6	#312	1.926	5.125	30	#308	3.718	2.812
7	#412	1.926	4.687	31	#101	3.187	2.562
8	#104	1.926	4.406	32	#409	3.750	2.531
9	#415	3.531	4.218	33	#302	3.875	2.250
10	#311	3.531	4.093	34	#405	3.312	2.156
11	#106	3.750	3.562	35	#206	3.062	1.812
12	#307	1.656	3.531	36	#406	3.656	1.812
13	#501	2.078	3.593	37	#201	4.218	1.421
14	#313	2.218	3.281	38	#303	4.343	1.500
15	#404	2.000	3.187	39	#503	4.125	1.812
16	#304	2.046	2.937	40	#403	4.562	2.187
17	#202	2.031	2.937	41	#205	4.562	2.375
18	#104	1.406	2.968	42	#102	4.265	2.484
19	#309	1.343	2.468	43	#310	4.781	2.781
20	#301	2.343	2.125	44	#410	4.937	3.015
21	#206	1.468	1.437	45	#305	5.031	2.250
22	#410	1.218	1.125	46	#209	5.156	1.812
23	#407	1.812	1.250	47	#413	5.500	1.531
24	#414	2.375	.812

Figure 38.
 Point Pattern Distribution and Equally Weighted
 Thiessen Polygons for Tucson Metropolitan
 Retail Food Outlets.

The geographic pattern of retail food outlets displays a density of .219 points/establishments per square mile with a mean first (second) nearest-neighbor distance of .814 (1.253) miles. Mean and median geographic centers are formed by the coordinates ($X=2.843$, $Y=2.775$; and $X=3.015$, $Y=2.734$) respectively. Both indicators of spatial centrality are proximate to store #203 and the highest market density which contains stores for four of the five rival chains within an area of 1.166 sq. miles. The pooled standard distance of point spread by coordinates is found to be 1.761 inches as determined by the standard distance of the X-axis (Y-axis) of 1.229 (1.261).

A quadrat analysis composed of 77 rectangular areal divisions (each covering approximately 2.786 square miles) reveals a mean quadrat count of .597 points per areal unit and a variance of .980, or a variance-mean ratio of 1.641 (with a standard error of .1622). The associated t-test for the variance-mean ratio is calculated to be 3.952, which exceeds the critical value for t with 76 degrees of freedom at the 95% confidence level. Hence, the null hypothesis of a randomly distributed point pattern is rejected (i.e., there is statistical evidence that the distribution of retail outlets has a tendency to cluster in space). This property is reinforced by the binomial and poisson probabilities as measured by chi-square statistics

of 20.855 and 17.864 respectively (exceeding the critical chi-square value of 7.815 with 3 degrees of freedom at the .05 significance level). Moreover, the point pattern is described by a nearest-neighbor index of .762 with a z-test value of -3.120 under a null hypothesis that mean distance between points is identical.

Given the evidence present above, it is reasonable to infer that the locational pattern of competing retail food chains exhibits a marked tendency for clustering (i.e., the pattern is unlikely to have been generated by a random and independent process). On an individual basis, the distribution of intra-chain firms shows a regular and even distribution over space. With this in mind, it is clear that rival chains limit the extent of their duplication in the competition over fixed geographic sub-systems of the market by simultaneously locating relatively far apart at the intra-chain scale and relatively near at the inter-chain scale. This is readily apparent in their tendency to form several competitive clusters which can be identified within the study region. The bounds of these competitive enclaves are somewhat fuzzy; thus, a market area delineation will be performed at the individual firm level to analyze the extent of a firms' market influence on the basis of relative location.

Equally weighted Thiessen polygons are constructed to form a unique partitioning of the study region into individual market areas which delineate submarkets that are closest to each outlet or points (Figure 38). By definition, Thiessen polygons or nets are drawn to satisfy the condition that "any location on the map associated with a point is closer to that point than to any other point on the map" (Barber, 1988). The illustration provided is a computer mapped version of a Thiessen net program (for an algorithm which): (1) joins each point on the map to all neighboring points; (2) bisects these joining lines; and (3) converts bisected lines to polygons through a search method which uniquely recognizes the vertices where bisectors converge. Thus, each Thiessen net represents a unique region of influence for individual retail outlets which are equally weighted.

A weighted (nxn) joins matrix W (with typical elements w_{ij}) is identified for polygons which are contiguous (by the use of binary weights: 1 if contiguous, 0 if non-contiguous) (Cliff and Ord, 1973), and outlets which are less than or equal to two standard distances away. Spatial dependence statistics are then measured for the cable price data under the assumption that the reported prices are representative of the chain's average price levels. This proposition can be defended on two grounds: (a) the

price surveys are conducted at randomly selected firms in the metro area; and (b) given that the price survey controls for a common market basket and includes lowest priced items, it seems highly unlikely to generate such stability in the rankings of chain price if indeed the price levels were uncharacteristic of a chain's pricing policy.

Since the cable price reporting system is observable by both consumers and/or retail competitors it can be thought of as a vehicle by which pricing strategies can be implemented. This may explain the small variation of price leadership by rank. To examine the price dependency in space, a measure of spatial autocorrelation will be estimated; namely, THE MORAN COEFFICIENT (see APPENDIX B for a detailed discussion on the calculation and interpretation of this index). The results of this test for spatial price dependence in weekly price reported data are given in Table 34. This table lists the Moran Coefficient, its variance, and the associated Z-score tested for significance at the 95% confidence level under the hypothesis of zero spatial autocorrelation in chain price.

Table 34

Moran Coefficients and Z-test Scores for Weekly
Cable Price Data (6 Consecutive Weeks):

Week	MC	VAR(MC)	Z	Range Of Prices
1	-.2356	.010748	-2.0636*	17.63
2	-.2459	.010733	-2.1643*	15.89
3	-.2000	.010712	-1.7309	16.01
4	-.1212	.010681	-0.9625	10.23
5	-.2612	.010751	-2.3095*	13.46
6	-.2564	.010751	-2.2644*	14.64

* Significant at the 95% confidence level.

The Results

In four of the six time periods tested above, chain-level price data showed a significant amount of negative spatial dependence. In other words, the reported price schedule for firms associated with the geographic market areas defined by the Thiessen nets (as a function of distance) shows a regular pattern whereby prices alternate over space (or between abutted Thiessen nets).

Furthermore, the distribution of additional in-store services as denoted by extra telephone service lines produces a similar negatively spatially autocorrelated

pattern. Binary data for the inclusion (1) or exclusion (0) of this variable was tested under the assumption of randomness, yielding a binary $Z(1,0)$ of 2.374 (Barber, 1988), a value which is statistically significant at the 95% confidence level. However, given the fact that telephone-service lines may be weak measures of the actual in-store services being offered (as in the case of Smith's, where separate phone-line for Deli/Bakery do not exist, but the service does), the results presented on the spatial dependence of in-stores services may be disputed due to a spurious correlation. However, since Smith's only represents four observations among forty-seven it can be argued that the statistically significant binary spatial autocorrelation index is representative of a competitive pattern for the market at large.

Given the results above, it is evident that regularities in spatial pattern exist in both the relative distributions of chain price (in four out of six weeks) and the presence or absence of additional in-store services as proxied by available telephone lines. The next logical step in this overall market area analysis is to test the relationship between reported price levels and distance to nearest and next-nearest neighboring chain. It is hypothesized that a positive relationship exists between general price levels and distance to nearest

competitor. This correspondence is evident in the average ranked distance by chain to its nearest neighbor and average chain-level price ranking over the time periods investigated (Table 35). Using the comparison of distance rank to overall price rank, a Spearman Rank correlation coefficient of .8 is produced, with a t of 2.3094 (significant at the 90% confidence level). This statistic, however, is grossly insensitive to the geographic qualities of chain separation. Yet, there is modest evidence that a positive numerical relationship does exist between chain price and the degree of separation on average. In other words, for the grouped data (by chain), chains which are farther apart from one another on average (by rank) tend to have higher reported price levels.

Table 35

Ranked and Average Distance to Chain's Nearest Neighbor (NN) and Ranked Chain Price Data for the Six-Week Period

Chain	Average Distance NN (in miles)	Distance Rank	Average Rank Chain Price over six weeks	Overall Price Rank
ABCO	1.1520	(5)	4.500	(5)
FRY'S	0.6104	(1)	2.833	(3)
SAFEWAY	0.8029	(4)	4.166	(4)
LUCKY	0.7910	(3)	2.500	(2)
SMITH'S	0.7851	(2)	1.000	(1)

Note: Ranking is from low (1) to high (5). Distance Rank is based on an average distance to nearest rival chain.

A Regression Approach

In order to examine properly this distance-price phenomenon, an estimated generalized least-squares (EGLS) procedure is employed (Griffith, 1988). In the handling of spatial data, where spatial dependence in regression error is suspected, a spatial operator is imposed to correct this dependence. This transformation is accomplished by adjusting for the maximum likelihood estimate of spatial autocorrelation (MLESA). For a more detailed discussion of this approach and the transformation of spatially dependent data, see Griffith (1988).

The regression model can be stated as

$$\text{TPTGL} = \beta_0 + \beta_1 \text{DISTNEAR} + \beta_2 \text{DISTNEXTNEAR}, \quad (61)$$

where TPTGL = total chain-specific price for total grocery list, DISTNEAR = distance to nearest competitor in miles, DISTNEXTNEAR = distance to next-nearest competitor. The model is calibrated for each period and the output listed in Table 36. Table 36 contains the parameter estimates under MLESA estimation and their respective t-values, the adjusted coefficient of determination, and the maximum likelihood spatial autocorrelation parameter used control for spatial dependence in error.

Table 36

Estimated Generalized Least-Squares Regression
Output for Price-Distance Relationship

Week	β_0	β_1	β_2	$\bar{R}^2$	F	MLESA
1	97.889 (28.82)*	17.251 (2.180)*	10.131 (1.559)	.317	15.097*	-.585
2	93.640 (22.07)*	17.620 (2.197)*	9.133 (1.396)	.351	13.974	-.659
3	97.384 (22.32)*	16.983 (2.069)*	9.192 (1.371)	.329	12.804	-.643
4	98.001 (28.33)*	12.987 (2.096)*	8.509 (1.662)	.372	15.151	-.512
5	94.800 (24.27)*	19.642 (2.665)*	9.363 (1.557)	.437	19.357	-.650
6	95.140 (21.81)*	18.940 (2.287)*	9.346 (1.385)	.363	14.608	-.675

Note: t-statistics in parentheses. *Significant at 95% confidence level.

Critical t (44 degrees of freedom, 95%) = 2.015

Critical t (44 degrees of freedom, 90%) = 1.678

Critical F (2,44 d.f. at 95%) is approx. 4.00

MLESA is the maximum likelihood estimate of spatial autocorrelation present in LS error terms.

The regression results confirm the importance of distance to nearest competitor as a factor which influences competitive price levels. In each of the six weeks inspected, the intercept and DISTNEAR coefficient prove to be both positive and significant at a 95% confidence check. Note that in each case the DISTNEXTNEAR coefficient was estimated as insignificant, yet retained a positive sign and a magnitude which on average is approximately half the value of the DISTNEAR coefficient. Nevertheless the DISTNEXTNEAR coefficients indicate the presence of a distance-decay relationship between relative chain prices and the separation of outlets (given that each estimated coefficient is statistically significant at the 80% confidence level). Obviously, the distance-decay properties obtained in the simulated markets have been replicated for spatially competitive chain outlets. These results support previous findings for the same market composed of a different mix of competing chains (Fik, 1988).

Two implications are clear:

- (i) the closer a chain is on average to a competing chain the lower the price differential between them; and
- (ii) the more isolated firms (chains) tend to be associated with higher prices.

These properties are consistent with results obtained in simulated markets shown previously in Chapter 4! This implies that if one were to have knowledge of firms' marginal cost structures, relative locations, and consumer related transportation costs, one could approximate firms' pricing behavior by comparing the observed pattern to that of one generated by simulation. This may be the key to lessening the indeterminacies associated with price competition in spatial oligopoly. Of course, analysis of pricing behavior without knowledge of firms' cost structures and internal efficiencies must remain purely speculative. No attempt will be made here to elaborate on this issue, since it is beyond the scope of this dissertation.

A Question of In-Store Services

We now turn to the question of in-store services for the Tucson retail food market, to explore whether or not a correlation exists between the geographic distribution of internalized services and price. Since the distribution of additional phone-lines or departmentalized services is negatively autocorrelated over space it can be assumed that the predominant vehicle for competition among firms is price. This, however, can only be logically asserted

for the short-run where firms' locations are fixed. Clearly, locational considerations can be viewed as a form of competitive action as firms (and in the aggregate, chains) compete for positioning and/or share of a geographic market in relation to competitors with fixed locations. In addition to competitive location, firms and/or chains may also compete by way of offering more services to attract customers. Implications which surround trade-offs between scale (operational efficiency), potential benefits of agglomeration economies (from both the perspectives of producers' and consumers' welfare), and increasing cost structures associated with supplementary services will not be debated here. For the sake of argument, it is hypothesized that increased in-store services are associated with a higher marginal cost of production - a cost that will ultimately be transferred over to the consumer in terms of higher prices. In order to test the correspondence of price and additional in-store service offerings, the following regression model was calibrated using the estimated generalized least-squares procedure:

$$TPTGL = \beta_3 + \beta_4 DISTNEAR + \beta_5 D1 + \beta_6 D2 , \quad (62)$$

where D1 and D2 are binary dummy variables which indicate the presence (1) or absence (0) of separate phone-lines

for the in-store services of Deli/Bakery and Pharmacy respectively. The output is shown in Table 37 below. Again, cautioned must be exercised in interpreting these results given the problems discussed earlier in regards to the appropriateness of the service-line variable as a measure of the existence of in-store services. Nonetheless, the results presented in Table 37 show some interesting statistical properties.

Table 37

Estimated Generalized Least-Squares Regression
Output for Price-Distance-Service Relationships

Week	β_3	β_4	β_5	β_6	$\bar{R}^2$	F	MLESA
1	118.31 (41.54)*	13.954 (3.62)*	14.793 (4.43)*	-5.926 (-1.79)	.538	19.231*	-.399
2	110.05 (36.02)*	15.134 (3.58)*	14.533 (4.03)*	0.803 (0.22)	.473	15.102*	-.365
3	112.18 (34.63)*	15.242 (3.38)*	14.274 (3.73)*	0.806 (0.21)	.436	13.195*	-.376
4	103.33 (36.05)*	16.199 (4.06)*	9.008 (4.05)*	-1.874 (-0.55)	.418	12.364*	-.487
5	108.94 (35.98)*	16.541 (3.92)*	13.827 (3.86)*	-1.768 (-0.50)	.492	16.207*	-.387
6	111.15 (35.41)*	16.584 (3.79)*	15.320 (4.13)*	0.124 (0.03)	.496	16.426*	-.287

* Significant at 95% confidence level.

The above regression format has slightly increased the amount of explained variation in chain price. The results demonstrate that a strong and positive statistical relationship exists between the offering of Bakery/Deli services and price as noted by the t-tests on the D1 coefficient. There are, however, conflicting results for the estimated coefficient of D2. In fact, during the first week, there is evidence (at the 80% confidence level) of a negative statistical association between price and Pharmacy services. This is probably tied to the availability of such services at Smith's - the lowest priced competitor throughout the six-week period (with an average least/most price ratio of .9184 for the period in question). Smith's price schedule (in price ratio form) is .9237, .9427, and .9652 to that of ABCO, Fry's, and Lucky respectively. Alternatively, this situation can be viewed as a sign of operational efficiency (lower marginal cost of production) and/or lower pricing conjectures (given that Smith's advertises its superstore/supersize status and is positioned third closest to its nearest neighboring chain). In order to defend this assertion, a simulation was run for the previously described market in the last chapter.

Smith's, the lowest priced store throughout the study period, continually monitors prices among the major food chains in Tucson (for a fixed market basket, on a weekly basis), and has consistently reproduced and advertised similar results to that of the consumer cable reports (i.e., that they are approximately 10% lower in price than Safeway, and at least 5% cheaper than their other rivals throughout the greater Tucson area). Although its advertising strategy revolves around mega-size (economies of scale) and multiple in-store service offerings, we cannot be certain whether this pricing advantage is due to its scale of operation or its pricing policies, or a combination of both.

Additional Consumer Benefits And Services

In order to fully evaluate the potential savings from multipurpose shopping activities a comprehensive study must be done on the site attributes of each outlet, and how that outlet is located relative to other retail anchors which may attract additional volume of consumer-oriented traffic (e.g., an attached shopping complex, a community or neighborhood center, or a detached and proximit nucleus of ancillary tertiary activities). The site can also be assessed in terms of service types and a

representative price vector for a fixed bundle of consumer goods and services from a designated node/outlet. This should include the market area which contains the closest establishments which supply those itemized goods and services. Other consumer-related benefits which are chain or store specific can be introduced, such as internalized banking and double coupons. For example, in the metropolitan Tucson area two chains offer the double coupon option (Fry's and Safeway, the third and first highest priced store chains over that six-week period). Binary spatial autocorrelation indices suggest that the geographic pattern of those stores which offer this savings option in comparison to those that do not is not random.

Specifically, the Z-test associated with the test for spatial covariation of Thiessen market nets which have double coupon savings ($Z(1,1)=-3.4658$) signifies that the market areas of those store chains (Fry's and Safeway) tend to cluster in space (i.e., the coupon option seems to be positively spatially autocorrelated). Such indirect pricing policies may also be conceptualized as chain-level decisions which can affect expectations on rival pricing behavior (and can be viewed as conjectural modifiers!). These modifiers will surely alter the trajectory of price (or even output) reaction functions. Subsequently, the

notion of price leadership and spatial competition must move beyond the evaluation of mill price and price expectation to incorporate the notion of service conjectures.

This thinking may expand the pool of indeterminacy which surrounds price theory in spatial oligopolies. The more correct approach may involve the simultaneous assessment of geographically bundled competitive oligopolies who are jointly substitutable (i.e., those competitors who sell comparable or interchangeable commodities or services), complementary (i.e., those oligopolists who offer related consumer products, like food stores, department stores, and pharmacies), and independent (i.e., those firms offering dissimilar or unrelated consumer products, like food stores and optometry services). Recognition of an intertwined competitive fabric is necessary in coming to grips with more complex price-reaction functions which are built on the premises of multipurpose shopping advantage and the spatial layout of rivals within these three competitive groupings. Additional considerations for shopping environment and the shopping experience (i.e., behavioral perspectives) may also prove to offer some useful information in the explanation of price setting and conjecture. Hence, the relative attractiveness of firms

(in terms of price, available services, and the shopping experience) must not be seen as separate or isolated from integrated network of its spatially linked rivals, clustered non-rivals, and overall site characteristics which delimit the potential for multipurpose shopping. This framework may also be extended to embody the effects of multi-stop activities in the delivery cost - mill price trade-off.

Consumer Attributes and Market Areas

Spatial price differentials may also arise in response the attributes of consumers who are contained within the geographic markets of rival outlets. To test for this possibility, bivariate regressions were run for the models listed below (Table 38), contrasting aggregate chain-level prices for the six-week period (ATPTGL) with the average socio-economic characteristics of the population and housing attributes contained within the generated Thiessen nets using census tract data.

The following criterion is used to assign census tracts to the market nets:

- (1) a market area or polygon is said to be encapsulate a census tract if it covers more than 33% of its surface;

- (2) census tracts cannot be assigned to more than two polygons if one of the polygons covers more than two-thirds of its area; and
- (3) census tracts which contain the outlet are always utilized (even if they conflict with (1) and/or (2)).

These rules were administered to limit the smoothing effects of spatial averaging and to lessen the severity of the already existing distortions in the Thiessen plot. The main objective of this approach is identify rough estimates of the average sub-market profile, with the intent of testing the possibility of short-run price discrimination (at the chain level). This "quick and dirty" approach can obviously be refined through the use of block-group data or surveying at the neighborhood level. However, such procedures are outside the time framework and scope of this dissertation; and therefore will not be employed. It will be assumed that census-tract information is representative (on average) for tracts contained within the outlined market areas.

Table 38

Bivariate Regression Models Estimated
Using Dependent Variable ATPTGL

Independent Variable (IV)	Verbal Description Of IV
TPOP	Total Population
PERHIGH	Percent (25yrs. old+) High School Graduate
NUMHH	Number Of Households
MDINCOME	Median Income
MEDHV	Median Housing Value
MEDCR	Median Contract Rent
TOTHU	Total Number Of Housing Units
VACHU	Overall Vacancy Of Housing Units*
PCINCOME	Per Capita Income
MFINCOME	Mean Family Income
PERFAMBEL	Percent Of Families Below Poverty Level**

* Vacancy Statistics Count Those Dwellings Which Are For Sale, For Rent, Awaiting Occupancy, Occasional Use, Seasonal, And Boarded Up (usually less than 2%).

** Poverty Threshold Is Defined As \$7,142 For An Average Size Family.

Data taken from 1980 Census of Population and Housing, Tucson, Arizona, U.S. Department of Commerce, Bureau of the Census.

Only one of the eleven bivariate (EGLS) regression models calibrated produced a statistically significant result (Table 39). This regression model indicates that market areas (as designated by averaged census tract data for the least distance Thiessen nets) with higher percentages of families below the poverty threshold exhibit a tendency to pay more for the same bundle of goods on average than do market areas with lower percentages of impoverished families. Given that this study involves the use of aggregate chain-level data, the statistical properties are most likely explained by the lack of competitive clustering or the isolation of individual outlets for areas deemed as relatively more impoverished (i.e., there is less agglomeration or more distance between chains for sub-markets classified as relatively poor).

Table 39

EGLS Regression Output for Significant Model

$$\text{ATPTGL} = 645.860 + 9.3770 \text{ PERFAMBEL}$$

$$(32.5817) \quad (3.9695)$$

$$\text{MLESA} = -.559 \quad \bar{R}^2 = .2302 \quad F = 15.7589$$

Note: t-statistics in parentheses.

In any event, this result is consistent with the concerns voiced in a recent United States House Select Committee report on hunger which emphasized the disproportionate burden on low-income families in food-related expenditures, in terms of both higher store prices and greater percentages of income (Christian Science Monitor, May 2, 1988). The study showed that the poor tend to spend as much as 61% of their disposable income on food, in comparison to the 15% for the average consumer. The reasons for these disparities are numerous, including such factors as (i) the exodus of supermarkets to more land-extensive suburban locations (out from the poorer inner-city sites); (2) the higher transportation costs associated with acquisition of necessity items as a function of limited access to private transportation modes and the scarcity of inner-city sites; (3) the higher insurance rates (due to the incidence of crime), employment instability, and security expenses in depressed areas; (4) the reliance on independent and higher cost food chains (although not applicable here); (5) the temporal disagreement of discounted or affordable food with the distribution of food support programs (i.e., the lack of sale-priced items during the issuance of food stamps and welfare payments); the inability of the poor to obtain adequate consumer price information through

newspaper subscription or televised cable reports; (7) the lack of an inner-city tax advantage for newly locating store chains; and (8) the outmoded nature of existing inner-city grocery outlets which are small in size and less cost-efficient (Christian Science Monitor, May 2, 1988). Other empirical work has also supported these claims (Caplovitz, 1967; Alcaly and Klevorick, 1971; Alcaly, 1976; Hall, 1983), citing the importance of such factors as consumption choice (as a function of selection and quality), store size, chain affiliation, neighborhood attributes, and the characteristics of the localized population cohorts. In addition to these components, it is also plausible to contend that higher prices, for those firms which are less threatened by proximate rivals (e.g., isolated inner-city outlets), are associated with higher pricing conjectures. This can be especially true if suppliers consider the monthly cycle of low-income purchasing as a function of welfare related transfers.

It has already been established, through simulation, that higher conjectures tend to be destabilizing in a competitive cluster (i.e., when a firm is surrounded by competitors operating under lower conjectural parameters). This argument can be expanded to incorporate variable or cyclical price-elasticities of demand (given the transient nature and availability of the poors' monthly disposable

income). Hence, the notion of price competition conjures up a spatio-temporal-site-situation (STSS) framework from which the S-C-P must be carried out.

The concept of conjectural variation can also be broken down by stratifying food types and their demand sensitivity (i.e., pricing policies on those goods which have a lesser propensity to sell versus those that are fast movers regardless of price, or the converse; or those which are more price or cross-price elastic), thereby limiting the degree of pricing effects to those products which are drawing cards or relatively expensive food items (e.g., sale priced items or meats) - an STSS+ framework. The aggregate nature of the data presented here, however, does not allow for the examination of such price discriminatory practices. It is obvious that a much more detailed account of both the supply and demand side of the problem must be undertaken before an accurate account of comparative price scheduling be made.

Alternatively, the methodology employed in the delineation of Thiessen type market areas can easily be modified by the use of unequally weighted Thiessen polygons which are based on the probabilities of shopping the various centers as a function of distance, the number of services being offered, and size (as a function of floor space) (Huff, 1963). Lakshmanan and Hansen (1965)

have proposed the use a weighted index L_{ij} of zonal attraction A_{ij} and separation d_{ij} , as defined by

$$L_{ij} = [A_{ij}^{\alpha} / d_{ij}^{\beta}] / [\sum_{j=1}^n A_j^{\alpha} / d_{ij}^{\beta}] , \quad (63)$$

where α and β represent the promotional and inhibiting weights which are associated with attractiveness and distance respectively. This, however, presents the additional problems of dealing with overlapping trade areas, the formulation of an attractiveness variable which can be receptive to a combination of magnetic forces (such as size, the number of in-store services being offered, potential agglomeration economies, the quality of the shopping environment, etc.), and appropriate weights to attach to these considerations. Even if probability contours of shopping behavior could be drawn for each establishment, they would tend to exclude many other factors which may equally come into play; namely, behavioral or sociopsychological concerns such as "content imagery" (the consumers' perceptions of the value of those service outlets) and "movement imagery" (the images consumers have as to the ease of movement to and from those outlets or their perceptions of outlet accessibility), the information consumers may have regarding price and product information within their

behavior space, and the uncertainties which surround consumption decisions which vary in terms of purchase intensity (expenditures), market knowledge as function of experience, order of the goods in question, and habit formations (Yeates and Garner, 1976). Attractiveness and distance relations are also subject to the criticism that they ignore complications which arise in the comparison of trip types and trip utility, i.e., there is no distinction between single-purpose trips (where a convenience trip is made to a store destination and back to the given origin), multiple-purpose trips (which describe shopping trips made at more than one establishment where a variety of goods may be purchased), and combined-purpose trips (which include shopping and non-shopping related stop overs, like journey-to-work/journey-to-shop travel patterns), or the relative worth of these trips (Yeates and Garner, 1976). Moreover, no account is made of the propensity of coupon-related savings, variations in price elasticity of demand as a function of disposable income, or the effects of store and/or brand loyalties. Many complications can also arise from a producers' perception of his/her market and patronage. These components, many obviously intangible, represent just the tip of the iceberg! One could speculate further on the diverse set of synchronic outcomes which may vary profusely over space and time. It is posited that

separation breeds uncertainty, the concept and usage of the phrase "conjectural variation" can take on a myriad of meanings.

Price Patterns And Chain Takeover

Shortly after the last cable report in August, Lucky supermarkets of Arizona was sold to the Phoenix-based ABCO chain, thereby concentrating the control of the Tucson market. Cable price data were then collected for three time periods (for weeks beginning November 2, 9, and 16) and the procedures above were repeated. During this time no significant levels of spatial autocorrelation in the raw data was uncovered. The source of this reduced price variability is most likely due to two contributing factors: (1) the reduction in both the number of competitive chains and the probability of there being price regularities as this number increases; and (2) the contiguity relationships in an overall pattern that is largely composed of smaller competitive enclaves/clusters (thus evening out the negative covariation amongst contiguous Thiessen nets). The regression output showed the same, although less severe, significant correspondence between the more spatially solidified price patterns and the independent variable PERFAMBEL (Table 40). The remainder of the models tested again showed no statistical

relationship between the other socio-economic variables and chain-level price schedules.

Table 40

Regression Results for the Post-Buyout Time Period
for Chain Price as a Function of Percentage of
Families Classified as Below the Poverty Threshold

$$\text{ATPTGL} = 382.515 + 2.5842 \text{ PERFAMBEL}$$

$$(54.788) \quad (3.3428)$$

$$\text{MLESA} = -.309 \quad \bar{R}^2 = .1662 \quad F = 11.1735$$

Note: All parameter estimates are statistically significant at the 95% confidence level.

Similar mergers and takeovers have been occurring throughout the nation over the past year, producing dramatic changes in the geography of price competition on both local and regional scales. These takeovers come in the wake of a post-industrializing economy that is becoming more responsive to sectoral shifts, corporate leverage, recapitalization and investment patterns, in the progression, evolution, and resolution of a service-based economy (Business Week, November 7, 1988). The recession-resistant nature and strong cash flow properties of food chains are being given as the reasons for the sudden

acquisition activities of expanding chains (Arizona Daily Star, August 28, 1988).

The apparent concentration of the market may be misleading, however, as supermarkets combat the competitive influences of (1) discount retailers and drug stores who are experimenting with grocery departments (the so-called "hypermarkets"); (2) proliferating convenience stores and food and beverage gas stations; (3) entering and restructuring large-scaled operations that are constantly reorienting themselves toward a particular target group; and (4) heightened competition of supermarkets to provide "high-margin amenities" (e.g., video rental, pharmacies, automotive supplies, a larger line of housewares, health and beauty aids, toys, separate fresh meat and bakery departments, etc.) and pleasant shopping environments (Arizona Daily Star, August 28, 1988). Chains must commit to and deploy these service offerings lest they be perceived as less attractive or competitive by consumers. The decision to recapitalize can be thought of as a "service conjecture". This reaction curve should not be confused with an location/service reaction-- a long-run investment decision (as opposed to price reaction-- a short-run phenomenon, or output reaction, a medium-run phenomenon).

Service competition simultaneously incorporates price and output on a commodity specific basis (e.g., the decision to institutionalize an in-store service at given levels of output and competitive price). The inherently geographically competitive profit-maximizing (STSS+) service-price-output conjecture (SPOC) (a multifaceted decision-making process) and the resultant price schedule is, therefore, quite complex when taken with respect to the long run; and are further complicated for entry-level firms conjecturing on a viable location-- a long-run entry location conjecture (ELC). Existing firms may also consider the profitability associated with market exit and re-entry-- a re-entry location conjecture (RLC). A parallel line of reasoning on profitability can be made for the expectations which accompany a buyout. In short, the indeterminacies which abound in spatial price theory seem infinitely more complex than realized. Not only are SPOCs highly variable and too numerous to fathom, but so too are the possible STSS+ frameworks and LC's that initiate (and perhaps constrict) the underlying mix of SPOCs which are competitive or feasible. Location and/or relocation decisions can be used to reorganize spatial markets and intrinsically define some localized threshold, creating barriers to entry, with relational distance

serving as a protection device against the inclusion of further competitive agents (Ohta, 1988).

In sum, one can envisage a multidimensional conjectural matrix (CM) (containing many behavioral parameters) which varies in its component parts as a function of spatial and temporal constraints. Table 41 summarizes and defines the adjustment period for many of these components.

Table 41
Some Components of the Multidimensional
Conjectural Matrix (CM)

Acronym	Argument	Adjustment Status
PC	Pricing Conjectures	Short Run
OC	Output Conjectures	Medium Run
SC	Service Conjectures	Medium Run
ELC	Entry Location Conjectures	Long Run
RLC	Re-Entry Location Conjectures	Long Run
SPOC	Combined Service-Price-Output Conjecture, (STSS Specific)	Short-Medium Run
STSS	Spatio-Temporal-Site-Situation Framework	(n.a.)

Note: In no means do the above components of the conjectural matrix exhaust all possibilities. The above list only represents those components which are the most obvious.

Summary

The theme which abounds throughout this work is once again reinforced, and unequivocal; that is, any survey of price competitive markets must deliberate on the context, essence, and influence of spatial variables. Provisions must be made to assess the implications of geographic market density, clustering, and separation of market agents, as well as the distance-decay properties involved in price reaction and consumer response. Until a spatially and behaviorally sensitive framework is developed to evaluate competition, i.e., a structural-conduct-spatial-performance (S-C-S-P) paradigm which incorporates many of the concerns discussed above, the standing of the classical industrial organization literature will remain a subject of great debate (Benson, 1979; Ohta, 1988). The findings in this chapter point to the significance of the geographic relationships for chain-level price schedules in a retail food market over the short run. Computer simulations and empirical evidence all point to the multifaceted nature of spatial effects.

Future research in this area must address these effects and come to grips with the pressing issues of (1) how spatially separated rival oligopolists and the overall market arrangement and configuration effect the geography of price, and how this in turn determines the (a) ability

of those firms to extract monopolistic-type profits, and if indeed (b) there is some delimitation of viable location-specific conjectural behavior as a function of that market arrangement; (2) how the intensity and velocity of spatially linked price response is affected by the geographic layout of a market and its boundary conditions as conjectures and/or profits stabilize; (3) how the degree of connectivity affects competitively linked price levels; (4) how firms of a similar chain variate from a chain-pricing strategy (if one does exist); and (5) how to test the structural-conduct-spatial-performance of geographically competitive oligopolists given the variabilities, asymmetries, and indeterminacies which typify this problem. Without a doubt, this may be one of the greatest dilemmas to face the fields of geography, economics, and regional science to date. The evaluation of an imperfectly competitive market remains a paradox, caught in an unfavorable lair of recursion that goes something like this: ...in the equilibration of price, space and behavior matter, yet location-specific and spatially dependent behavior complicates and expectationally based behavior is unobservable and inseparable from spatially defined parameters,...which matter, and are key in the equilibration process. Add the intricacies discussed above, and the problem becomes

almost insoluble. It is now up to science to unlock or at least to condense the uncertainties which are embedded within this stalemate.

CHAPTER 10

IN SEARCH OF A HOLISTIC APPROACH TO PRICE
THEORY IN SPATIALLY COMPETITIVE MARKETS:
SOME FINAL COMMENTSDissertation Summary

This dissertation has focused on the importance of space and behavior in specifying equilibrium conditions for firms in price-linked competitive oligopolies. Several important findings are established in the dissertation, including the following: (a) the spatial distribution and pricing behavior of firms both have dramatic effects on the equilibrium conditions of geographically competitive markets; (b) structural-conduct-performance inquiries consolidate and consider spatial and behavioral elements in the contextual assessment of firm conduct, competition and market performance, given the inadequacies of the traditional spaceless/behaviorless S-C-P model; (c) boundary conditions have a marked impact on spatial firms' price and profit functions; (d) the spatial distribution of pricing conjectures may lead to a range of feasible conjectures for interior firms; and (e) empirical evidence support the existence of distance-decay effects

in reported prices (as uncovered for five competing chains in the Tucson metropolitan retail food market). An outline for future research has also been drafted in the discussion, stressing the complexities of spatially competitive markets.

A spatially sensitized approach to price competition must be taken if proper estimation and interpretation of market power, spatial price patterns, and consumer welfare issues are to be reckoned with. Simulation and experimental modeling is crucial to meeting this end, since it may serve as a benchmark for comparison and will help us understand the subtleties of competition in spatial oligopoly. Limitations notwithstanding, it is plausible to conceive of theory development as a way in which to shrink the domain of indeterminacies which accompany the modeling of spatial oligopoly. For example, firms' pricing behavior revealed distinct distance-decay properties in equilibrium price levels under the assumption of inelastic demand. Furthermore, there is empirical evidence that supports this deduction, at the chain-level, for a spatial distribution of retail food outlets (where the demand for food is known to be relatively inelastic). Thus, it is the refinement of a strong theoretical base and an empirical replication of the theoretically defined constructs that

is important in the establishment of axioms and explanation, and the implications which follow.

Economists have tended to ignore the importance of integrating the spatial and behavioral features of markets into the price reaction and adjustment process. It has been demonstrated that distance-decay components of price produce a highly variable equilibrium pattern, one which is extremely dependent upon the location and pricing conjectures of competitively linked firms. To ignore the implications of these geographic variables, and assume (as many economists do) that the market is malleable, adaptive, and conjecturally and locationally symmetrical is to exaggerate and oversimplify the workings of price competition in the real world.

This dissertation has provided an alternative to the oversimplified versions of price competition by examining the impacts of asymmetrical conjectures, location, connectivity, distance-decay, and geographic boundaries under various market descriptions. Even though the analyses were couched in terms of the short run, they will help provide a basis on which to develop a long-run model in which the path to equilibrium is hypothesized to be complex and highly variable. Given the vast array of asymmetrical behaviors, geographic distributions of market agents, and other competitive forces that exist in

spatially competitive markets (including the ability of firms to conjecture in price and location), the long-run model provides a challenge to the findings of economists who simply assume its equilibrium conditions as opposed to sequentially adjusting toward them. The modeling framework presented in this dissertation does not ignore the importance of space and behavior in the attainment of equilibrium, and therefore offers a more realistic foundation on which to expand and address the problem of modeling imperfect competition over the long run. Assuming away the very things which make the problem interesting and useful is to understate the true nature of the process itself. Economists must question and defend their positions on price adjustment models which are largely incapable of dealing with mixed conjectures, boundary effects, and non-malleable geographic markets, and their associated distance-decay properties which are inherently asymmetrical.

Major Themes Found In This Dissertation: A Recapitulation

This dissertation has identified five major factors which affect spatial price variation; namely, (1) geographic market boundaries; (2) market size and structure (the spacing, number (density), and relative

location of firms); (3) the degree of connectivity or competitive interaction; (4) distance-decay properties of symmetrical and asymmetrical pricing behaviors; and (5) conjectural variation. Let us review each of these factors in turn and thereby highlight some of the relevant findings of the dissertation.

Geographic Market Boundaries

Chapters three, four, sixth, and eight have shown the importance of geographic market boundaries. In the simulation experiments, which compared the circular (unbounded) market to the linear (bounded) market, it was demonstrated that geographic boundaries have a price-inflating effect on equilibrating prices of peripheral firms. These exterior firms exhibit monopoly-like control over the bounded side of their market segment (i.e., they are only partially price reactive to rival firms which are interior). This price-inflating effect destroys the possibilities of symmetrical equilibrium prices even if all firms behave symmetrically, and represents (for the case of symmetrical pricing conjectures) a purely geographic effect. Since real-world markets tend to show some degree of boundedness, this inherently geographic property must be taken into account if one is to gain an

accurate picture of spatial price competition in the short run. In sum, it was demonstrated that the existence of market boundaries has an important role in influencing the spatial distribution of equilibrium prices and profits.

Market Size and Structure

The geography of price has been shown to be sensitive to the size and configuration of the market. The simulations of spatially competitive markets composed of price elastic consumers (chapter five) have convincingly displayed how equilibrium price and profit levels respond to both market length and market density (number of firms). Therefore, a second geographical component is shown to be of importance in short-run price reaction. As market length increases and firms begin to amass some degree of "local" market power (i.e., where firms eventually act as spatial monopolists), equilibrium prices converge at a market length which is insensitive to the underlying pricing strategies of the firms themselves. As market length expands beyond the point of monopoly, the behavior-specific price equilibrium price trajectories reverse (an obvious perversity) -- this is a situation which will only be true over the short run. Nevertheless, the geographic implications of varying market length

(influence) are clear when one evaluates spatial price variation amongst competitors with varying degrees of market exposure. This is particularly true for rivals who are unevenly distributed over space as in real markets. Hence, geographic separation can play a major role in the determination of prices and, as speculated in chapter seven, can quite possibly have a limiting effect on the range of plausible pricing behaviors entertained by spatially-linked rivals.

Connectivity

Chapter eight focused on the development of a more realistic approach to spatial price competition by introducing a topologically oriented framework in which firms price react through the connective structure of the market. The designation of a geographic market as a network gives the researcher the ability to establish the intensity of direct and indirect price linkages in space on the basis of such connectivity. This model offers an extremely flexible approach in which to evaluate the impact of geographic order and competition from both the individual firm and firm chain perspective. It was demonstrated that mill price (on average) is inversely related to the number of connections or linkages in a

market. Therefore, the spatial distribution of prices at an equilibrium is affected by market boundary, market structure, and market connectivity (at both the firm and chain level). The geographic implications are clear, especially when one considers the realism of spatially competitive retail chains as shown by the empirical evidence presented in chapter nine.

Distance Decay

The simulations in chapter four has showed the existence of behaviorally oriented distance-decay properties in equilibrium price levels and various price components. Furthermore, the idea of distance decay in price relations has been substantiated by the empirical support disclosed in chapter nine. These findings are important, in a geographical sense, for two reasons: (1) there is a spatial impact in terms of direct and indirect price linkages which influence equilibrium price levels; and (2) the distribution of firms and their pricing policies can have dramatic effects on the realization of these distance-decay properties. In other words, the distance decay in rivals' price schedules/components is determined by the behavioral characteristics of rivals and their relative locations which can prove to influence both

the intensity and impact of distance decay effects as competitors price react/interact. Therefore, these conditions cannot be viewed as separate from the market size, structure, and connectivity variables identified above, which define the geographic configuration of a spatial market.

Conjectural Variation

Last, but by no means last, is the component which underlies a major portion of this dissertation, namely the idea of conjectural variation (revolving around the expectation of rival behavior). Chapters four through eight have demonstrated the relevance of "price conjectural variations" from a symmetrical and, more importantly, from an asymmetrical standpoint. The understanding of this behavioral component is both crucial and necessary for the proper evaluation of price reactions in spatially competitive markets. The spatial distribution of pricing conjectures has a marked impact on the resultant distribution of prices and profits for markets in the short run. Although the findings presented in this dissertation are for price behaviors which are exogenously imposed, the arguments can be applied to location and output conjectures as well. This implies that a need

exists to develop the "long-run model" of spatial price competition with the endogenization of conjectures within that model, as suggested in chapter nine. Thus, it is not only the geography of a market which matters, but also the spatial distribution of its agents and their pricing policies.

A Future Research Agenda

A need clearly exists for a long-run model of spatial markets that examines the locationally competitive features of retailing in order to bring about a better understanding of reality. Moreover, the advantages of endogenously imposing behavioral parameters within the mechanics of a long-run model (i.e., the incorporation of simultaneous price and location conjectures under some decision criterion) are many. An understanding of profit-maximization in a model which allows for both price and location adjustments can help explain how the patterns of competition (as witnessed by the locations and viability of firms) manifest themselves in space. This will bring us one step closer to the recognition of a multifaceted conjectural matrix which encompasses the considerations of space, time, site, situation, service mix, price, output, and related feedbacks. Then, and only then, can spatial

price theory evolve and produce a more representative picture of reality, one which is composed of inextricably linked market agents, each of which is affected by rivals' sizes, efficiency, separation, expectations, and actions.

This work actually implies the need to view the market process in a holistic sense. The inclusion of behavioral parameters has been shown to allow for a wide array of simulated price patterns given a variety of market conditions. Furthermore, equilibration of price and profit has been shown to be responsive to the demand intensity of consumers, market size, market density, connectivity, transportation costs, boundary effects, and the spatial arrangement of competing entities. With this in mind, it therefore seems apparent that any resultant distribution of price must be seen as an outgrowth of economic, behavioral, and geographical forces (see Figure 39). This statement inevitably supports the simple fact that geography has much to contribute in the way of building a price/location-theoretical base from which the foundations of welfare analysis can productively expand. The holistic approach to imperfect competition must include four distinctive forces: (1) economic variables such as market structure, conduct, and performance (i.e., concentration, efficiency, and integration); (2) geographic concerns such as the distribution and spacing

Figure 39.
Spatial Price Competition: A Holistic Approach

of firms (spatial market structure), size and delineation of market areas, and boundary conditions; (3) market parameters such as price elasticities, transport rates, and cost efficiencies; and (4) the behavioral elements which are defined through firms' pricing, output, and locational conjectures.

Coupling behavioral and spatial structure is paramount in achieving this end, and will assist in the dissection of causal linkages from a seemingly randomized process. Morrill (1988) has so aptly commented on the need to interpret long-term/macro-level geographic structures with the short-term/micro-level interplay between spatial variables and their constraining effect on the behavior/action of individuals. In a recent article on geographic themes and goals Morrill points out that:

"One of the more important research challenges will be how to understand uniqueness not as an inconvenient outcome of random forces but as the consequence of human intentions." (Morrill, 1988, p. 538).

This mindset has been applied in the simulation of short-run price patterns in spatial markets through the integration of conjectural forces and a static geographic structure. The next step is to add further realism into the model by imposing conjectural variations which influence price and location over the long-term (i.e., to

endogenize the location decision). Ohta (1988) has recognized the importance of spatial parameters in the optimal location of firms, and the implications for profit potential in imperfectly competitive systems. However, Ohta's approach does not deal directly with the geographic nature of price competition. This is contrary to the theme which underlies this dissertation, which suggests the need to reformulate such spatial price theory and its constructs by exploring spatial constraints and behavior. Once this is accomplished, it may provide a clearer understanding of spatial economic form and welfare related issues, and how that form relates to the human element, and its "space-defining" power.

Afterword: A Geographer's Perspective

New frontiers await the wakened and geographically conscious mind. It is only a matter of setting the alarm clock to the right time/place, be there to hear it go off, and getting out of bed. Sleep is essential, but it is time to wake, diverge, and advance. As social scientists, we must adhere to the rigor of our pressing agenda, while simultaneously rethinking and reshaping the foundations of downtrodden theory. Endeavors such as these are essential to the much-needed recasting and replacement of the pillars of existing knowledge. To ignore the prominence of space in social-science theory development is to build a superstructure which will inevitably crumble.

APPENDIX A
CONCENTRATION RATIOS AND BOUNDARY EFFECTS

#	(Market)				+CR4 (Z)	+CR4 (a)	+H a
	Circular c1	Circular c2	Linear c1	Linear c2			
1	12.0	85.33	10.0	201.52	+.0260	+.0159	-.0053
2	12.0	2133.33	10.0	2906.21	.0000	.0000	-.0156
3	48.0	2133.33	40.0	2870.90	.0000	.0000	-.0139
4	16.0	7241.72	16.0	8692.38	.0000	.0000	-.0066
5	4.0	72.34	4.0	319.13	+.0313	+.0557	-.0111
6	4.0	7367.11	4.0	7472.03	.0000	.0000	-.0231
7	16.0	3107.49	14.0	3016.02	.0000	.0000	-.0202
8	28.0	1482.93	20.0	2165.46	.0000	.0000	+.0033
9	8.0	3366.89	6.0	3532.52	.0000	.0000	-.0150
10	24.0	1555.09	22.0	1783.07	.0000	.0000	-.0029
11	0.0	0.00	0.0	555.51	+.1306	+.1318	-.0239
12	0.0	0.00	0.0	62.61	+.0547	+.0488	-.0035
13	0.0	0.00	0.0	133.95	+.0335	+.0702	-.0070

See Key on next page.

APPENDIX A -- Continued

Key: c1 = summed differences in adjacent conjectures squared, or

$$c1 = \sum_{ij}^{nn} c_{ij} (\phi_i - \phi_j)^2 ;$$

c2 = summed differences in adjacent equilibrium mill prices squared, or

$$c2 = \sum_{ij}^{nn} c_{ij} (p_i - p_j)^2 ;$$

+CR4(Z) = change in 4-firm profit share concentration ratio, defined as $[\text{CR4}(Z)_L - \text{CR4}(Z)_C]$; and

+CR4(a) = change in 4-firm geographic market share CR4, defined as $[\text{CR4}(a)_L - \text{CR4}(a)_C]$,

where subscripts L and C denote linear and circular markets respectively; and

+H = change in relative entropy index for geographic a market share (linear - circular).

Note: The elements c_{ij} are binary (i.e., either 1 or 0), and derived from the market specific connectivity or joins matrix C' of order n, where 1 denotes a join (adjacency) and a zero entry denotes a non-join (non-adjacency) between competitive rivals. Given the one-dimensional nature of the markets simulated, the rook's case definition of connectivity was utilized (Cliff and Ord, 1973).

APPENDIX B

THE MORAN COEFFICIENT

The Moran Coefficient (MC) (Moran, 1948) is defined as

$$MC = \left(\frac{n}{\sum_i \sum_j w_{ij}} \right) \left(\frac{\sum_i \sum_j w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2} \right), \quad (60)$$

$$E[MC] = -[1/n-1]$$

and

$$VAR[MC] = (v1 - [v2]v3)/v4,$$

where:

$$v1 = n[(n^2 - 3n + 3)S_1 - nS_2 + 3 \left(\sum_i \sum_j w_{ij} \right)^2],$$

$$v2 = [(1/n) \sum_i (x_i - \bar{x})^4] / [(1/n) \sum_i (x_i - \bar{x})^2]^2,$$

$$v3 = S_1^2 - 2nS_2 + 6 \left(\sum_i \sum_j w_{ij} \right)^2,$$

$$v4 = (n-1)(n-2)(n-3) \left(\sum_i \sum_j w_{ij} \right)^2,$$

and

$$S_1 = (1/2) \left(\sum_i \sum_j (w_{ij} + w_{ji}) \right)^2,$$

$$S^2 = \frac{1}{n} \left(\sum_i \sum_j w_{ij} x_i x_j + \sum_j \sum_i w_{ji} x_j x_i \right) .$$

The appropriate test of significance under the null hypothesis of zero spatial autocorrelation is defined as

$$Z = (MC - E[MC]) / (\sqrt{VAR(MC)}) .$$

Discussion of spatial autocorrelation methods are presented in Griffith (1987) and Odland (1988).

The interpretation of the Moran Coefficient is straightforward. If $MC \gg (<) E[MC]$, where $<<$ or $>>$ represent a statistically significant level of spatial autocorrelation that is above a spurious level (i.e., the absolute value of Z is found to be above 1.96), then positive (negative) spatial dependence is said to exist in the evaluation of some geographically distributed variable x . As with the Geary Ratio defined earlier, the Moran Coefficient measure the degree of geographic covariation of a variable with itself over space (as so defined by the weights/connectivity matrix W and the values of abutted x s). MC s and significance test results are given in Table 34 for the six week cable price data under the restriction that the expected value of the Moran Coefficient: $E[MC] = -.021739$. This value serves as the benchmark for a spatial pattern which is construed as being not significantly different from a pattern generated under a random process.

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