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A SPATIAL ECONOMIC ANALYSIS

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PRICING FLUID MILK WITHIN FEDERAL MILK MARKETING ORDERS:

A SPATIAL ECONOMIC ANALYSIS

By

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ABSTRACT

PRICING FLUID MILK WITHIN FEDERAL MILK MARKETING ORDERS:

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By

JAMES EDWARD PRATT

Processors who purchase milk and process and distribute fluid milk products are characterized by much larger scales of operation than the producers who provide them with milk inputs. As such, the bargaining power wielded by a processor, relative to individual producers, is immense. Combined with the perishability of milk, the seasonal and counterseasonal patterns of milk supply and consumption, as well as the strong weekly pattern of retail sales relative to a nearly constant weekly supply of milk, increase the potential for market disorder. This situation and the general plight of depression era farmers lead to enactment of the Agricultural Marketing Agreement Act of 1937, which formed the basis and established the authority for federal milk marketing orders (FMMO's).

Location adjustments, the major focus of this study, are used in nearly all FMMO's to provide for downward adjustment of prices paid by Class I processors located at increasing distances from the major consuming centers. These adjustments are intended to enhance the competitive environment among handlers and to provide an incentive for producers to deliver milk to plants located at or near market centers.

A spatial microeconomic model of the firm is used to demonstrate that costly transportation can lead to monopolistic/monopsonistic behavior, which includes price discrimination and freight absorption.

Using NEDSS, a network model of the spatial organization of the northeastern U.S. dairy industry, four theoretical spatial pricing systems for pricing Class I milk supplies are analyzed: discriminatory, uniform mill, uniform delivered, and cost-minimization. For each of three storability classes, the impacts of spatial pricing on optimal plant locations and milk and milk product movements are investigated.

Results indicate that optimal Class I and Class III processing locations are relatively insensitive to the type of spatial pricing system which is used. Class II processing locations, however, are sensitive. Although Class I assembly costs increase under each spatial pricing scenario, there are partially compensating cost effects which can occur in the costs of product distribution in all classes and in Class II milk assembly.

To Thomas Alvin Whitby and all the other young people

who have been asked to give so much,

on faith.

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In this dissertation, I benefitted greatly from the substantial mathematical and programming skills of David Jensen. Wendy Barrett, as always, provided me with first class assistance in the preparation of the final document and Joe Baldwin preformed his usually clean work on the figures. The NE-126 Regional Research Committe, provided a forum to discuss the issues addressed in this analysis. The New York Department of Agriculture and Markets, Division of Dairy Industry Services has provided valuable support for parts of this research and for much of my research effort at Cornell. A special word of thanks goes to my associates in dairy marketing at Cornell, who have made my work interesting and rewarding.

To my parents, Charles and Thelma Pratt, C. A., Helen, and Sonya, I express my thanks for years of support and encouragement. Also, I thank my many friends and associates at Kalamazoo College, Purdue, VPI, Michigan State, and Cornell for providing the personal exchanges which

make university education enjoyable. My many fishing buddies, especially Dale, have made my life much more enjoyable, particularly during those times when things haven't been going well.

Finally, I would like to thank Mildred Warner, who's encouragement and advice finally conviced me to make the effort to complete this dissertation.

BIOGRAPHICAL SKETCH

James Edward Pratt was born August 13, 1947 in Kalamazoo, Michigan. He was raised in Comstock Township, Kalamazoo County, where he graduated from Comstock High School in 1965.

From 1966 to 1970, he served with the U.S. Air Force as a weapons maintenance mechanic and crew chief of weapons loading crews. He was stationed in the U.S., Thailand, and Vietnam.

In January of 1970, James entered Kalamazoo College where he majored in economics and minored in religion/philosophy. He graduated in June of 1972 and then entered the master's program in the Department of Agricultural Economics at Purdue University, where his M.S. thesis work involved a study of low-income rural residents in southern Indiana.

After graduating from Purdue in May of 1974, James worked as a Research Associate at VPI & SU, returning to Purdue as a Research Associate in the area of dairy marketing in 1976. In 1978, James entered the PhD program in Agricultural Economics at Michigan State where he concentrated on spatial economics, transportation and logistics.

After completing his coursework and preliminary examinations in June of 1980, he accepted a Research Associate position in dairy marketing in the Agricultural Economics department at Cornell, where his work has emphasized transportation, logistics, and spatial economics as they relate to issues in dairy marketing.

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INTRODUCTION

1.1 Overview

> "...The earth is often in astronomical calculations considered as a point, and with substantially accurate results. But the precession of equinoxes becomes explicable only when account is taken of the ellipsoidal bulge of the earth. So in the theory of value a market is usually considered as a point in which only one price can obtain; but for some purposes it is better to consider a market as an extended region."[1]

We've all uttered or encountered the phrase 'time is money' at some point. Yet, except in the cases of personal travel and mail services, the thoughts that 'space is money' or 'distance is money' are less frequently entertained by most of us. The reality of economic life, however, is that all movements across geographic space are costly. Microeconomic theory has not generally embraced costly, or 'economic', space. Undoubtedly, some economic problems do not warrant the treatment of markets as extended regions, where multiple prices for a single commodity may exist contemporaneously. However, there are some economic problems which do warrent such treatment and in these cases, the typical use of the traditional microeconomic model does not serve well.

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[1]Hotelling, H. "Stability in Competition." The Economic Journal 39:41-57. 1929, p.45.

Early attempts to analyze the location of economic activity by Von Thunen, Losch, Weber, and Hoover faced this issue squarely, but were never fully integrated into generally received theory. Subsequent theoretical work by Smithies, Chamberlin, Hotelling, and Robinson and the antitrust analyses of Machlup, Stocking, and Loescher were treated as special cases. More recently, work by Greenhut, Ohta, Benson, and others has focused on the maturation of a general spatial microeconomic model.

The need for a general spatial microeconomic model for the study of spatial pricing and market organization becomes more important for economic sectors which are relatively localized and high in transportation intensity. In such sectors, the potential for spatial monopolistic or monopsonistic behavior is high and price surfaces which depart from the transportation cost gradient can be expected. Using data from the U.S. Bureau of the Census, coefficients of localization, measuring the geographic distribution of production relative to markets, can be calculated for manufacturing sectors [Nourse]. In Table 1.1, a value of zero for the coefficient indicates that production, measured by employment, is distributed exactly as the market size, measured by personal income. A value of one would arise if all production took place in one region which had little or no income. The food and kindred products sector shows a relatively high degree of localization across states. Printing and publishing and electric equipment are equally localized. Tobacco product manufacturing, textile products, and leather goods have among the lowest degrees of localization.

Table 1.1 Coefficient of Localization, Selected Groupings of Manufacturing Industries, 1980.

SIC Code	Industry	Coefficient*
20	Food and kindred products	.15
21	Tobacco products	.83
22	Textile mill products	.65
23	Apparel and other textile products	.34
24	Lumber and wood products	.37
25	Furniture and fixtures	.33
26	Paper and allied products	.23
27	Printing and publishing	.15
28	Chemicals, allied products	.24
29	Petroleum and coal products	.40
30	Rubber and miscellaneous plastic products	.27
31	Leather and leather products	.49
32	Stone, clay, and glass products	.30
33	Primary metal industries	.34
34	Fabricated metal products	.21
35	Machinery, except electric	.20
36	Electric and electronic equipment	.16
37	Transportation equipment	.32
38	Instruments and related products	.31
39	Miscellaneous manufacturing industry	.30

*Calculation done on the basis of individual states.

Source: U.S. Bureau of the Census, Annual Survey of Manufacturing 1981 and Statistical Abstract of the United States 1986.

In 1984, intercity rail and truck transportation activities accounted for approximately 7% of the total farm-to-consumer food marketing bill.[2] Indications are that for dairy products, this may fall

[2]United States Department of Agriculture. 1984 Handbook of Agricultural Charts. Agricultural Handbook No. 637.

more in the 20% to 40% range [Aplin and Hoffman, Agribusiness Associates, and Lee et. al.]. Due to its highly perishable nature, continuous, biological production system, and widely-dispersed farm production sites, raw milk (approximately 87% water) must be picked up from farms daily, or every-other-day, and routinely transported to processing centers which may be a few or several hundred miles away. Processed products must then be re-transferred through spatially dispersed marketing channels for ultimate distribution to consumers. Improvements in refrigeration and transportation technologies, public investments in road networks, and innovations in dairy product processing, which have introduced significant economies of size, have all tended to maintain or increase the geographic size of market areas for milk inputs and for dairy product sales. These circumstances, combined with increasing specialization of milk production on larger farms in more concentrated areas, which tend to be distant from dairy product consumption centers, have maintained the transportation activity involved in marketing milk and dairy products.

From the inception of specialized processing facilities, vs. on-farm processing, the retail markets for dairy products have been highly competitive, with numerous occurrences of 'price wars' initiated by processors to capture wholesale market segments, often geographic areas, from rival processors, or initiated by retailers in order to attract new consumers. Given the market characteristics of raw milk, these price wars often led to instability in producer prices and market opportunities. Counter seasonal patterns in fluid milk consumption, compared to raw milk production, also led to highly variable prices and to sudden changes in producer marketing opportunities. Producers, finding themselves in relatively weak bargaining positions, have formed bargaining agencies to counter the processors' market power. A major institutional goal of such agencies is a desire to achieve equity among members. This manifests itself in efforts to ensure that all producers share in the high-valued returns from sales to fluid processors and are paid on some type of equal basis. These two goals historically resulted in 1) 'pooling' schemes where groups of producers pooled their receipts from processors and then redistributed them, and 2) the quotation of a 'base' price paid to all producers which is adjusted to reflect the distance of each producer's milk from the processing plant, and consequently its value. Likewise, before the rigorous interpretation of antitrust statutes and legislation enabling the establishment of federal milk marketing orders (FMMO's), localized fluid milk processors formed committees, associations, and other organizations for the purpose of administratively determining the prices which all members would then offer for milk received at their plants.

Space is an important consideration in the pricing of milk within the area of a market's supply and has been recognized in the pricing systems, whether negotiated or administered, which have evolved since the time when the processing of dairy products became specialized. The consideration of a milk marketing area as a point may well serve the study of interregional trade and competition, however, it is a premise of this study that a single milk marketing area is characterized by a constellation of prices, because of the presence of costly, economic space within the marketing area. Therefore, the analysis of the prices of a single milk market must explicitly recognize its spatial character, in the same manner as the actual shape of the earth is important to studying the movement of the equinoctial points.

1.2 Purpose of the Study

With passage of the Agricultural Marketing Agreement Act of 1937, FMMO's, as they are known today, were authorized. FMMO's were intended to redress some of the marketing conditions which contributed to excessive market risks placed on milk producers.

FMMO's have developed, through the administrative, legislative, and judicial processes, a highly complex variety of tools used to establish the system of marketing rules and formulas under which the participants in a regulated market must operate. One of these tools is the enforcement of minimum prices which processors must pay for milk received in their plant; an administered pricing system. This administered pricing is only one of many aspects of FMMO's. Under the assumption that producers pay the cost of transporting their milk, FMMO-administered pricing systems typically take the form of a uniform f.o.b. basing-point price, where a market center is specified and used as the basing-point. Prices throughout the administrative area are then specified as the base-point price minus an estimate of transportation costs. This spatial price adjustment is intended to 1) provide an incentive to producers to ship their milk to consumption centers and 2) to equalize raw product costs to comparably located, competing processors.

In a theory of spatial microeconomics, where monopoly/monopsony power occurs naturally and price discrimination results, the absorption of some freight charges by the monopolist/monopsonist would be warranted by profit maximization. Additionally, administered prices which perfectly reflect transportation costs give no incentives for producers to ship their milk in the most efficient, market cost minimizing, pattern nor for processors to obtain their milk inputs or to locate in total market cost-minimizing locations. To encourage efficient movements of milk and efficient processing locations, administered milk prices, over space, must depart from the perfect values dictated by transportation costs.

The objective of this study is to analyze the use of transportation costs to spatially adjust the administratively determined milk prices received by producers and paid by processors who are regulated under FMMO's. While price location adjustments can be used to encourage efficient (i.e., marketing cost-minimizing) market performance, criteria other than full transportation costs may be appropriate to use in such location adjustments. An empirical investigation to measure the impacts of alternative location adjustments on efficient market performance is carried-out using a spatial network model of the northeastern U.S. dairy industry.

The specific objectives of this analysis are to:

1) Describe the general system of spatial pricing currently used in most FMMO's;
2) Define and describe several spatial pricing systems in the context of a general spatial microeconomic model;
3) Evaluate the potential market performance impacts of alternative price location adjustments, using a mathematical programming model of the northeastern U.S. dairy industry; and
4) Identify the implications for public policy suggested by the results.

1.3 Outline of the Study

In the following chapters, the dairy industry and federal milk marketing orders are described, a general microeconomic model of the spatial economy is presented, and a mathematical programming model of the northeastern U.S. is developed to analyze the impacts of using several alternative spatial pricing systems to specify administered prices for milk used in fluid products.

Chapter II describes the characteristics of the dairy industry which resulted in the promulgation of FMMO's and the general operational tools of FMMO's, including the spatial aspects of FMMO administered pricing. Chapter III presents the elements of a general model of spatial microeconomics. Three spatial pricing systems are defined and described using this model. In addition, the issues of competition over space and competitive equilibrium and efficiency are addressed. In Chapter IV, a mathematical programming model of the dairy industry in the northeastern U.S. is presented. While retreating to the position of specifying points in geographic space, the high degree of spatial disaggregation of the mathematical programming model is intended to closely approximate characteristics of the spatial microeconomic model. Chapter V presents an analysis of spatial pricing systems using the mathematical programming model, and Chapter VI discusses these results and their implications for public policy.

CHAPTER II

THE DAIRY INDUSTRY AND FEDERAL MILK MARKETING ORDERS

The production, consumption, processing, and marketing of milk and dairy products has undergone some very significant changes in the last century. New biotechnology innovations and processing techniques, which will maintain the pace of change, loom on the horizon. With all these past and current technological advances, however, milk still is and will likely remain a relatively perishable, transportation intensive product.

2.1 Production

Although the composition of milk varies slightly with breeds of cows, geographic location, season of the year, and management practices [Grippen], water remains the predominant component. The remaining components, especially the butterfat, can be separated from the water and used in the processing of various dairy products. The approximate average composition of a hundred pounds of milk is given in Table 2.1.

Milk is produced by means of a continuous, biological process. Cows are usually milked two (and occasionally three) times per day and the normal lactation period is about 300 days. It takes approximately 27 months for a newborn calf to mature enough to enter the milking herd, thus, short-run expansion of the milk supply is severely constrained biologically, even though some expansion can be obtained by altering feed composition and feeding rates, by more frequent milking, and by less culling of cows in operations which are not constrained by facility capacities.

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Table 2.1 Typical Milk Composition

	Mean	Range
Water	87.5%	
Lactose	4.9	(4.4-5.3)
Butterfat	3.7	(2.7-5.9)
Casein	2.7	(2.9-4.3)
Albumin (whey proteins)	.5	
Others (ash, minerals, vitamins)	.7	
	100.0	

Sources: Alexander, Grippen.

Farm milk is an excellent medium for the development of bacteria and consequently, very perishable in nature. It is essential to cool milk to about 38°F as quickly as possible after milking in order to retard the growth of bacteria. Improvements in storage and cooling facilities on farms as well as refrigerated transportation have made it currently possible to collect milk every-other-day instead of the everyday pick-up typical before the 1960s. New farm processes, which are on the technological horizon, may eventually extend this time period as well as reduce the amount of water which must be transported by a factor of 1.5 to 2.0 [Mortara].

Dairy production is characterized by specialized inputs; milk cows, milking machines, bulk tanks, coolers, piping and pumps, specially designed buildings, and skilled dairy farm management which are all resources with little or no value in alternative enterprises. The relatively high level of fixed costs associated with many of these specialized inputs retards both the rate of entry, when industry expansion is warranted, and the rate of exit for contraction.

Milk production is highly seasonal. May and June, with high quality pasture and fresh forages and early spring calving, are the peak months and November, with the end of summer pasture and drying-off of cows, is the low month.

Dairying has become a specialized farm enterprise with nine-tenths of all milk coming from farms which received at least half of their receipts from milk sales in 1978. It is also becoming specialized geographically. While all states produce milk, Wisconsin, California, New York, Minnesota, and Pennsylvania accounted for one half of the total production in 1983.

In summary, farm milk is a highly perishable, complex multi-attribute commodity whose image as a 'homogeneous' product is very misleading. The specialized, biologically based production technology makes short-term adjustments in quantity produced relatively unresponsive to price changes.

2.2 Consumption

The use of farm milk in consumer products consists primarily of fluid milk, cheeses, butter, and nonfat dry milk. These and other dairy products can be grouped by their storability, fluid products being the least storable and manufactured products, such as cheese, nonfat dry milk, and butter, being the most storable.

Table 2.2 Use of Market Supply of Milk, 1983 and 1980

Product	Billion Pounds (milk equivalent)*		Percent of Total	
	1983	1980	1983	1980
Fluid	49.7	50.9	36	40
Butter	25.8	22.8	19	19
Cheeses (including cottage)	41.9	35.0	31	27
Other dried, evaporated and frozen products	16.3	15.5	12	12
Miscellaneous	3.9	2.1	2	2
	137.6	126.3	100	100

*Fat basis.

Source: Dairy Situation and Outlook. DS-401, July 1985.

Among the above classes, the greatest seasonal variation in consumption is found in fluid milk products, for which consumption is highest in the fall and winter months and lowest in the spring and summer. Seasonality in fluid milk consumption is met by planning for large enough milk supplies to meet the needs during the peak consumption months. The resulting excess supplies in the low fluid milk consumption months is used in storable manufactured products. Population demographic characteristics such as age, race, and geographic area, as well as incomes and prices, play a significant role in determining the product mix and the quantities of dairy product consumption [Boehm 1976, Boehm 1975, Jacobsen].

The aggregate consumption of fluid products nationwide has been on a long-term decline. During the 1970's, the passage of the post World War II 'baby boom' population from the peak fluid milk consumption years to lower consuming adults has accelerated this decline. Four important changes in the consumption of fluid products have had and will continue to have strong impacts on the organization of fluid milk markets [Manchester].

i) Regulations which required the pasteurization of milk, implemented initially by local health authorities, were instituted between 1897 and 1924, by which time most large municipalities had such ordinances. These requirements effectively marked the end of milk product processing done on farms and farm-based retail sales, and marked the emergence of milk processors as powerful market participants. The emergence of recent innovations in relatively small-scale dairy processing technologies and the increasing size of farms may make it possible to move some part of the processing/marketing activity back to farms [Mortara].

ii) The system of daily or every-other-day home delivery of fluid milk products has been superseded by the dominance of supermarkets, both independents and chains, during the 1960s. Previously, thousands of individual customers were served by systems of delivery routes in particular market areas. These home delivery routes have been replaced by wholesale routes to a relatively small number of retail outlets. In addition, supermarket chains have integrated back into processing. It was estimated that 20% of the fluid milk sold in FMMO's in 1978 was processed by chain stores in their own plants. This estimate was 35% for California [North Central Project 117]. Store sales, in contrast to home deliveries, have introduced a significant level of daily variation in sales [Christensen et al.].

In order to supply stores with milk at peak times during a week, plants require greater deliveries of farm milk on Tuesdays and Wednesdays and much lower deliveries on Friday through Sunday.

iii) Consumer acceptance of innovations in the packaging of fluid milk products, such as the use of paper and plastic containers, and the use of larger container sizes, combined with improvements in refrigerated transportation and storage, have significantly expanded the geographic extent of fluid milk markets. Homogenization and the reduced need for the consumer to see the creamline paved the way for paper containers which reduced container weights by over 50% and eliminated the need for returnable bottles. The use of plastic containers which can be molded in the processing plant has reduced the cost of containers. The gallon sized containers have also reduced bottling and handling costs.

iv) Lowfat fluid products have recently emerged as a growing proportion of total fluid sales [Table 2.3]. The recent concerns with cholesterol and calcium will undoubtedly contribute to an increased consumer awareness of the specific component composition of all dairy products.

Table 2.3 Lowfat and Skim Sales as a Percent of Total Fluid Sales in FMMO's

Year	Percent
1965	9
1975	29
1984	40

Source: [Federal Milk Order Market Statistics: Annual Summaries]

Fluid product consumption, like milk supply, is relatively unresponsive to short-term price changes [Boehm 1976]. Demographic characteristics and changing tastes and perceptions are the prime movers.

Consumption of manufactured, storable, dairy products, such as cheese, butter, powdered milk, ice cream, etc., have had varying trends. Personal, at home, consumption of butter and nonfat dry milk has been steadily declining for a number of years and may have reached a stable, low level. Natural cheese consumption, especially that of American and Italian varieties, has shown significant growth. And, with increasing household incomes and changing tastes, the emergence of 'specialty' cheeses as a growth area may also prove to be significant. Ice cream and other frozen dessert consumption seems to be directly linked to population changes, while the consumption of other soft products, such as yogurt, have shown marked growth.

The less perishable nature and the typical weight-reducing processes for the storable, manufactured products has differentiated their role in milk markets from that of fluid milk. Many of these products can compete in wholesale markets on a national basis and storage can be used as a means for evening-out seasonality. By contrast, even the largest wholesale and retail fluid market areas of today are, at most, regional in scope.

2.3 Marketing

The characteristics of farm milk supply and dairy product consumption described above actually go a long way in determining the marketing characteristics present in the markets for farm milk. As noted above, perishability and high moisture content are distinguishing features of fluid milk markets and are less pronounced in manufactured product markets. The reduction of seasonality in production and the almost counter-seasonality in fluid consumption, combined with the emerging dominance of store sales of fluid milk, at the demise of home delivery, have diminished the necessity for carrying seasonal fluid reserve supplies, but increased the need for maintaining daily and weekly reserves which are immediately accessible.

Today's refrigeration and transportation equipment and facilities are impressive, yet even in the days before pasteurization and motor transport, milk in 40-quart cans moved significant distances to serve metropolitan fluid consumption. By 1916, the milkshed for the New York metropolitan area had expanded to a radius of 400 miles and more.

> "According to one well-informed writer, in 1879 milk trains ran regularly between New York and points more than 250 miles distant. He said that stations in Vermont located 210-250 miles out were shipping 400,000 gallons of milk a year to New York; also that milk held in a cooling tank for eight hours at Rutland, Vermont, 240 miles from New York, was being shipped at night and delivered to New York consumers by daybreak the next morning."[Spencer and Blanford, p.69]

The intermeshing of technological innovations, consumer preferences, and public interests have proven to be the catalysts for changes in the balance of market power in milk markets. Leland Spencer [Spencer and Blanford] has characterized the period of time before the federal government's role in milk marketing became forceful in 1933, as:

1) to 1880 - the era of small-scale competition,

2) 1880-1916 - the era of dealer pricing/dominance, and

3) 1916-1933 - the era of collective bargaining.

Subsequent to 1933, retailers, though not always directly involved in the bargaining of farm milk, emerged as an important market force.

Each of these eras has seen the shifting of market power from one group to another and much of the public policy response, at least with respect to FMMO's, has been characterized by attempts to redress these market power shifts relative to some perception of a 'good' market situation.

The pricing of milk by dealers was done on a 'flat-pricing' basis during much of the era of dealer pricing. Under this system, dealers paid a single price for all milk being used for fluid consumption. Dealer associations colluded to set a price which was not to be 'broken' to insure equal competition. Any changes which were desired in quantity were accomplished by adding or dropping producers. This single price was usually high enough above the prevailing manufacturing milk price to insure a ready reserve of producers.

Base-excess pricing plans emerged as mechanisms to avoid the risky, unstable positions producers experienced under flat pricing. These plans were instituted by both dealers and producer groups. Under such plans, short-season bases were established and producers were paid the manufacturing price for production above the base. These plans were weak due to the lack of market responsiveness to long-run changes in demand conditions in the setting of bases and ineffective policing of dealer and producer behavior. Producer equity issues such as allocation and distribution of bases were also difficult to resolve.

Classified pricing schemes, where milk was priced on the basis of its eventual use and proceeds were pooled among all producers, were instituted by milk marketing cooperatives in large metropolitan markets between 1910 and 1930. Such systems were very dependent on producers presenting a united front in negotiations with dealers and, later, with processors, since access to uncommitted milk supplies provided a strong bargaining advantage for dealers.

The development of the Babcock test for butterfat in 1890 brought about, albeit slowly [Spencer and Blanford, p.302], the system, still in effect today, of using butterfat differentials in pricing . Also, quality premiums, in the form of 'barn scores' based on farm inspections, were used by some dealers prior to 1920. There is also evidence of low-bacteria premiums being paid as early as 1910 [Spencer and Blanford, p.306].

Location and spatial pricing differentials, the focus of this study, also played a role in the early milk pricing systems. Prior to 1897, most producers were paid on the basis of the flat-pricing system. In addition, the railroads assessed the same freight charges throughout the milk-shipping area of the New York-New Jersey market. Producers' net prices were unaffected by their location respective to the markets for their milk. Producers located closer to the market, members of the Milk Producers Protective Association, complained to the Interstate Commerce Commission (ICC) that they were being exposed to unfair competition from more distant milk producers and in 1897, they won a judgment that the flat freight charge was indeed unfair [Spencer and Blanford, p.811]. The ICC established a four-zone rate system which stood until 1916 when nearby producers again petitioned the ICC to revise the rate system because of a significant expansion in the milkshed. The ICC issued a new rate schedule, based on 20-mile wide freight zones, for Boston in 1916, and in 1917 issued a schedule based on 10-mile wide zones extending 400 miles from the market for New York.

This 10-mile zone system in New York continued in effect through the 1920's, as dairy cooperatives gained bargaining strength, and it became the basis for negotiated pricing systems, even as motor transportation began to emerge as competition to the railways [Spencer and Blanford, p.875]. This same basic transportation differential system, negotiated before 1921, with 10-mile zones and a base pricing zone of 201-210 miles, is today an integral part of the New York-New Jersey Federal Milk Marketing Order.

2.4 Instability in Milk Markets

Milk production and fluid product demand are characterized by nearly perfectly counter-seasonal patterns. Combined with perishability, these seasonal patterns require the presence of seasonal reserves throughout much of the production cycle in order to meet the peak demands in the consumption cycle which occur during the trough in the production cycle. Because of higher farm standards for fluid grade milk, the cost of producing milk eligible for use in fluid products is higher than the cost for producing manufacturing grade milk. Thus, the cost of carrying these fluid reserves is higher than the average cost of all milk production. The market solutions resulting from how to deal with these reserves are at the heart of the issues of 'instability' and 'orderly marketing' in milk markets.

Processors and dealers who purchase milk from producers and perform the functions necessary to prepare and distribute it to retailers or directly to consumers are characterized by much larger scales of operation than the producers who provide them with milk inputs. As such, the bargaining power wielded by a processor/dealer in his negotiating position with respect to many individual producers is immense. In its extreme, as in the flat pricing scheme noted above, this bargaining power can result in a system whereby producers are faced with the absence of a purchase offer at an otherwise acceptable price. Processor/dealers simply added or dropped producers as their input needs dictated. Producers were often left in positions of trying to find markets for their highly perishable product on very short notice.

Producers, in order to redress this seeming imbalance in negotiating power formed associations to present a unified, stronger position in their negotiations with processors/dealers. Specific issues addressed by these associations included the equitable sharing of markets by all producers (the base-excess and classified pricing plans noted above) and assurance of markets for member milk (which eventually led to these associations running their own manufacturing plants as balancing operations).

Cooperative associations representing dairy producers reached a zenith of negotiating strength in the New York metropolitan milkshed during the period 1916-1922, when Dairymen's League Inc. (which became the Dairymen's League Cooperative Association in 1919) represented two-thirds or more of all producers serving the New York City market. This was a formidable market force which successfully carried out a general milk strike in October of 1916 to bring about negotiated contracts with New York City milk dealers. While the strength of the Dairymens League waned soon after 1922, the strength of dairy cooperatives in general has increased over time to the point where an average of 92% of producers marketing milk in Federal Orders belonged to cooperative associations in 1977. The average share of producers belonging to the largest four cooperatives was 86% and the average share of producers belonging to the largest cooperative was 64% [Babb et al. 1979].

Larger shares of producer membership in cooperative associations present opportunities for increased organizational efficiencies through centralized control and direction of milk movements.

> "...the movement of milk from the farm to market is generally directed by the management of the cooperative association which largely negates the action of individual producers in determining point of delivery of their milk."[1]

Additionally, it is sometimes contended that dairy cooperative association market power has become equal to or even eclipsed that of the processors/dealers in milk price negotiations and that a situation of bilateral monopoly (a monopsonistic buyer vs. a monopolistic seller) best represents the conditions present in most milk markets today. Microeconomic theory [Henderson and Quandt] suggests four possible market outcomes in such a situation:

1) the seller dominates and forces the buyer to accept his price,
2) the buyer dominates and forces the seller to accept his price,
3) the buyer and seller collude to set quantities in order to maximize joint profits and then bargain with respect to sharing these profits, and
4) the market breaks down.

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[1]Federal Register, Vol. 39, No. 137, Tuesday, July 16, 1974, p. 26035, 7 CFR.

"It is not possible for the seller to behave as a monopolist and the buyer to behave as a monopsonist at the same time " [Henderson and Quandt, p.244]. The levels of profits generated by the dominant side of the market in cases 1 and 2 above provide lower bounds for their negotiations in case 3.

2.5 Federal Milk Marketing Orders[2]

The continual struggle for associations to maintain sufficient membership to effectively bargain with processors/dealers [Spencer and Blanford, Chap.XXVI] and the highly competitive atmosphere in which the processors/dealers competed with each other resulted in a continual slipping of any negotiated pricing systems back toward the characteristics resulting from the flat-pricing system [Novakovic and Boynton]. This series of 'breakdowns' and the general plight of depression era farmers culminated in the Agricultural Adjustment Act of 1933, its amendments of 1935, and, finally, in the Agricultural Marketing Agreement Act of 1937, which formed the basis and established the authority for FMMO's as they are known today.

FMMO's are perceived by their administrators[3] as having four very general purposes:

1) promote orderly marketing in fluid milk markets,

2) stabilize milk prices and improve producer incomes,

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[2]Much of this material is based upon [USDA 1981, Kaiser, Boynton and Novakovic].

[3]See [Boynton and Novakovic].

3) establish the terms of trade between producers and processors/dealers, and

4) assure consumers of adequate supplies of fluid milk at reasonable prices.

Obviously, these are very general guides and their implementation into specific policy actions has evolved through a long history of administrative hearings and court cases. The term 'orderly marketing,' and its contemporaneous interpretation, [Manchester, Chap.8] has embodied the intent of FMMO's.

In the description which follows, many terms, which have precise legal definitions, will be used in a general manner. Since the focus of this study is the generic issue of location differentials, it is felt that the very detailed legal definitions, which are necessary for the administration of FMMO's, would be unnecessarily burdensome. Additionally, while the general provisions of FMMO's are common to most orders, the specific implementation of any provision may take several different forms. The following description of FMMO provisions is intended to be generic and, as such, <u>will not</u> match the entire set of specific provisions which have been implemented for any particular order. Even though the analytical model of Chapter IV is based on the northeastern U.S., the model and the analysis for which it is used in no way are intended to reflect the particular, specific administered pricing system now in effect in this geographic area. This will be clearly evident to those familiar with the federal and state regulatory specifications which are actually in effect in this area. The analytic model is used to investigate the general issue of location differentials.

Establishing or Amending an FMMO

FMMO's are legal instruments, authorized by the Federal government, to regulate the marketing of milk in specific geographic areas. They are initiated by the Secretary of Agriculture after milk producers in the specific geographic area approve, by a two-thirds margin, a referendum calling for the establishment of an order. Before a referendum is held, however, a public hearing is conducted and the Secretary must give a favorable recommendation for the formation of the specific FMMO. The Agricultural Marketing Service (AMS) issues written copies of specific rules and regulations which would govern the order. Producers must pass the entire set of rules and regulations and cannot vote on specific items. This also applies in the case of amendments to an FMMO.

Establishing the boundaries of the marketing area is crucial to the effective operation of an FMMO, since regulated handlers (i.e., milk dealers and processors who sell fluid milk products within an FMMO area), must conform to order regulations for milk sold inside and outside of the market area. With the natural expansion of fluid milk marketing areas, FMMO's have correspondingly expanded both through addition of new areas and by mergers, Table 2.4.

Handlers

Handlers are the focal point of most of the provisions which have been instituted under FMMO's. Handlers who deliver fluid milk products on routes to points within the specified market area of an FMMO are subject to the provisions of that FMMO whether or not their plant resides within the market area. Handlers are regulated on the basis of the location of their sales.

Table 2.4 Measures of Growth in Federal Milk Order Markets, Selected Years, 1947-84

Year	Number of markets 1/	Population of Federal milk marketing areas 2/	Number of handlers 1/	Number of producers 3/	Producer deliveries	Producer deliveries used in Class I	Percentage of producer deliveries used in Class I	Receipts as percentage of milk sold to plants and dealers: Fluid grade	Receipts as percentage of milk sold to plants and dealers: All milk
	Number	1,000	Number	Number	Million pounds		Percent	Percent	
1947	29	*	991	135,830	14,980	9,808	65.5	*	21
1950	39	*	1,101	156,584	18,660	11,000	58.9	41	25
1955	63	46,963	1,483	188,611	28,948	18,032	62.3	51	32
1960	80	88,818	2,259	189,816	44,812	28,758	64.2	64	43
1965	73	102,351	1,891	158,077	54,444	34,561	63.5	70	48
1970	62	125,721	1,588	143,411	65,104	40,063	61.5	79	59
1975	56	144,467	1,315	123,855	69,249	40,106	57.9	78	63
1980	47	164,908	1,091	117,490	83,998	41,034	48.9	80	67
1984	45	171,044	912	118,880	91,679	41,516	45.3	81	70

* Data not available.
1/ End of year. (Date on which pricing provisions became effective.)
2/ End of year. 1955-59, 1960-70, 1971-79, 1980-84 according to 1950, 1960, 1970, and 1980 U.S. census, respectively.
3/ Average for year.

Other provisions also govern the regulatory status of handlers such as:

a) the percent of total plant sales which are fluid sales in the marketing order,

b) if the plant is a producer-dealer which sells almost exclusively its own milk,

c) if the plant sells bulk milk to other regulated plants, and

d) cooperative associations shipping directly to pool plants may qualify as handlers.

Classified Pricing

FMMO's require that regulated handlers pay at least minimum prices for the milk which they purchase from producers, based on the product use to which they put the milk. In most orders there are three classes:

Class I	Perishable: Fluid products such as whole, lowfat, and skim milk,
Class II	Semi-perishable: Soft products such as fluid cream, cottage cheese, yogurt and ice cream, and
Class III	Storable: Hard products such as cheese, butter, and nonfat dry milk.

Until 1962, the year of the maximum number of separate FMMO's, each FMMO was responsible for determining the schedule of classified prices which would ensure adequate fluid milk for its market area and maintain an 'orderly' market. Subsequent to 1962 and the 'Nourse' report [UDSA 1962], FMMO's began to switch to a system whereby local FMMO's based their minimum Class II and Class III prices on the Minnesota-Wisconsin

(M-W) price series[4] for milk used in manufacturing, usually taking the M-W as Class III and the M-W plus 10 cents as Class II. At the same time, Class I prices in each FMMO were based on the M-W plus a transportation differential determined to represent the transportation costs of shipping milk from the upper midwest (approximately centered on Eau Claire, Wisconsin) to the basing-point in each order. In this manner, all FMMO's were linked to a barometer of the national supply/demand situation.

Pooling

Equity among producers shipping to regulated handlers is addressed through the practice of pooling the value of receipts from regulated handlers and redistributing these receipts to producers on the basis of their respective quantities shipped. Pooling has been done in the past on an individual handler basis, however, only one FMMO currently does this. Pooling on a marketwide basis is done in all other FMMO's.

Other FMMO Provisions

In addition to setting minimum prices, FMMO's perform many other functions. These are administered by a market administrator, appointed by the Secretary of Agriculture, who executes the directives of the order. Assisted by a staff of auditors, statisticians, economists, and technicians, each administrator is responsible for making the calculations necessary to determine monthly prices, auditing and verifying the

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[4] See [Babb 1980].

monthly reports made by handlers, and preparing and disseminating market information. The administrator is also responsible for the verification of weights, samples, and butterfat tests of milk received from producers for whom such services are not being provided by a cooperative. As deemed appropriate, the market administrator and his staff perform other tasks, such as special market research and establishment of voluntary promotion programs funded through deductions made from payments for producer marketings. In 1983 six such programs were in effect with many similar programs in effect under state and federal authorizations.

Qualifying cooperatives whose members market milk under FMMO's are entitled to special benefits and privileges under many FMMO's. These include bloc voting for members on proposed or amended orders, repooling of members' receipts, exemption from some market services payments for verification of weights and tests which they may provide for their members, and special pricing provisions.

Pricing Differentials

Several sources of pricing differentials are used by FMMO's. Class prices paid by handlers and blend prices received by producers are adjusted by fixed schedules to reflect the butterfat content of producer milk. Some FMMO's have instituted seasonal pricing plans to provide economic incentives for producers to reduce the seasonality of production. Location, or transportation, differentials are adjustments made to the minimum order prices on the basis of geographic location.

Location adjustments, the major focus of this study, are used in nearly every FMMO [USDA 1984, Table 14]. Location differentials are applied to both Class I and blend prices and currently these differentials are the same for both prices in all FMMO's. Nearly all orders provide for downward adjustment of prices paid by plants at increasing distances from the major consuming centers. These adjustments are intended to enhance the competitive environment among handlers by equalizing raw product cost across geographic points in the market. They are also intended to provide an incentive for producers to deliver adequate quantities of milk to plants located at or near market centers.

> "The principle of location economics and that of providing substantially equal raw product costs to all competing handlers (both of which we accept as desirable criteria) requires that different prices for Class I milk be established for various locations within any milkshed."
>
> "In addition, we are concerned with maintaining as high a degree of efficiency as possible in the organization of the milkshed. This can only be achieved where the fluid milk requirements are obtained from areas immediately adjacent to the market, so that surpluses will be processed into the more concentrated manufactured dairy products in the outlying areas of the milkshed, thus minimizing total transportation costs" [USDA 1962, P.II-1-15].

However, this is a very difficult task. If location differentials accurately reflect bulk milk shipping rates, then producers paying these transportation costs and receiving these perfectly adjusted prices have no incentive to deliver milk to the plants located closer, and presumably more efficiently, to the market center. If the rates of processor price adjustment over space are perfectly reflective of bulk milk shipping costs, the processors will be competing on the basis of processing and distribution costs and will have incentives to locate at points which minimize total costs of these two functions. However, such a system would tend to make processors indifferent to the location of milk suppliers.

Location differentials in most FMMO's are currently specified at fixed value rates in market order provisions and, as such, must go through the administrative process to be changed. These types of changes can be made when other order provisions are being amended, but the history has been that location differentials do not change with transportation costs [Gerhardt]. It is reasonable to suspect that changes in these differentials generally lag behind and are usually below transportation costs, a case which would make deliveries to plants nearer the market center more difficult to attract. Additionally, with fixed base points, geographic shifts in population and production can create situations where previously specified differentials do not encourage milk to move toward market centers or emerging multiple market centers.

Two Federal court cases have established the precedent that location differentials applied to Class I handlers must also be applied to the blend price of pooled producers [Blair vs. Freeman] and that 'nearby differentials,' i.e. differentials paid specifically to producers located close to the defined market base which cannot be justified on the basis of costs, are illegal [Zuber vs. Allen]. There is still some question as to whether the use of different rates of differentials for Class I and blend prices is illegal as well. Similarly, direct-delivery differentials, where processors located close to a market center pay an additional charge, intended to compensate for additional hauling costs due to traffic congestion near the market center, have not been tested through litigation.

The preceeding description of milk markets, pricing mechanisms, and location adjustments under FMMO's has shown the physical, economic, and historical importance of location adjustments in pricing fluid milk. The following chapter describes three spatial pricing systems in the context of a general microeconomic model. The issue of spatial competition is also addressed. In the subsequent chapters, a mathematical model of the northeastern U.S. dairy industry is used to analyse the impacts of using each of these three spatial pricing systems to price fluid milk.

CHAPTER III

THE ELEMENTS OF SPATIAL ECONOMICS

3.1 Introduction

The inclusion of space as an explicit variable in microeconomic theory, when distance is costly, will be referred to herein as 'spatial economics' or 'the spatial model'. The spatial model involves more than simply an added dimension which serves as a price linkage between distinct markets in the traditional Samuelson-Enke multi-market trading framework. In the spatial model, the location of the firm is not taken as fixed and invariant, but is treated as a decision variable. The economic agent who makes decisions for the firm is free to treat plant location in the same manner as input and output decisions are treated in the more traditional microeconomic analysis [Greenhut 1956]. The agent is also free to choose the pricing rule which will be used to achieve the economic goal. This choice would be based on 1) an assessment of the nature of demand over space, 2) the firm's production costs, 3) the cost of distance, and 4) the conjectural price variation, i.e. how the firm assumes that other spatial rivals, either actual or potential, will react to any changes made in price/output. The essential question involved in choosing a plant location in economic space, where distance is costly, and in choosing a pricing structure over this space, is to determine the optimal, feasible extent of the market which is served by the plant.

Individual demands and the density of consumers play an important role in the spatial model [Greenhut 1956 Chap VI, Benson 1980a, Greenhut et al. 1975]. In spaceless microeconomics, individual demand functions can be summed to derive an aggregate market demand function. In the world of economic space, individual demands do not sum as directly to the market aggregate [Greenhut 1978]. Since the price paid by the spatial consumer does not equal the price received by the plant, due to transportation, the plant faces consumers having demand functions which are net of transportation costs [Benson 1980a]. The gain or loss of a distant customer has a different impact on the demand facing the firm vis-a-vis an otherwise identical nearby consumer. As such, the spatial market is a differentiated market in which spatial price discrimination becomes a naturally feasible occurrence, even if individual gross demands are identical [Hoover, Greenhut and Ohta 1972].

Using models of the spatial economy with various sets of reasonable assumptions (i.e. assumptions used in spaceless microeconomic theory), many 'counter-intuitive' results can be obtained, vis-a-vis the spaceless microeconomic model of the firm. Among these are the following:

1) In the spatial model where consumers are located continuously on a line or plane from the plant's location,...price discrimination always yields greater output for the spatial monopolist than does simple f.o.b. pricing.[Greenhut and Ohta 1972, p. 713] The classical price discriminating monopolist operating in a spaceless economy, [Robinson, Henderson and Quandt, p.215] faced with two or more separate markets, will produce the same quantity of output under either f.o.b. or discriminatory pricing. The perfectly discriminating monopolist in the spaceless economy [Henderson and Quandt, p.217], on the other hand, will produce more output than

his nondiscriminatory counterparts and, from a maximum output perspective, discriminatory pricing might be preferred.

2) For a firm pricing its output at the plant (f.o.b. or 'mill' pricing) (see Section 3.4), operating as a monopolist with respect to nearby customers, but facing competition from distant rivals for more distant customers, it can be shown that the monopolistic portion of its net aggregate demand function will be more elastic than the competitive portion [Greenhut et al. 1975, Salop 1977, Salop 1979]. In addition, if the competitive rivals react to price changes by the firm with equal price changes of their own which are designed to protect their market area (Loschian competition), the equilibrium mill price for the firm operating in competition may be higher than the price under a pure spatial monopoly [Greenhut et al. 1975].

3) Under the same market conditions as in 2) above, with the added constraints that firms will enter a market area until there are zero profits for each firm, a decrease in unit transportation costs can increase the product price. Decreases in fixed production costs can increase the product price. And, decreases in marginal production costs can decrease or increase product prices [Capozza and Attaran].

The above results and other dissimilarities in comparative static results between the spatial and spaceless models often depend crucially on the shape of the individual demand curves [Benson 1980a, Greenhut et al. 1975] and on the assumptions made about the firm's conjectural variations with respect to its rivals [Benson 1980b]. Actual spatial price surfaces which do not conform to the predicted results of the point-trading spatial models, where prices between trading points which actually trade differ by transportation costs, can be predicted by the spatial microeconomic model. With its explicit treatment of spatially generated monopoly elements, the model naturally results in occurrences of discriminatory pricing and freight absorption. Given the highly dispersed and perishable nature of milk production, processing, and consumption, and the subsequent intensive transportation activity, the advantages of using an economic model which explicitly provides for space in analyzing intra-market pricing in FMMO's is deemed to be necessary.

In the sections which follow, a brief review of the evolution of spatial economics is given (3.2). An analytical model is then presented (3.3) to describe three forms of spatial pricing: discriminatory pricing, uniform mill pricing (f.o.b.), and uniform delivered pricing (c.i.f.) (3.4). Monopoly and several forms of competition in the spatial economy are presented (3.5) and issues of economic performance in the spatial economy are investigated (3.6).

Throughout this chapter, spatial pricing systems are presented from a spatial monopolist's point of view. This is done to conform with generally accepted practise in spatial economic literature. Fluid milk processors, however, are monopsonistic with respect to milk producers. Appendix A presents the three spatial pricing systems in the form of monopsonistic pricing and demonstrates the equivalence of these two points of view with regard to freight absorption.

3.2 The Evolution of Theories of Spatial Economics[1]

The early theories of plant location, which were forerunners to the more general spatial model used in this thesis; were not well integrated into microeconomics. Their focus was usually socio-historical or economic-geographical in nature. The few early studies which did attempt to integrate location with a more general economic theory were mostly of German origin and emphasized costs.

Von Thunen

Johann Heinrich Von Thunen's theory of the location of agricultural production[2] used transportation costs and a derived rent surface to explain the type of farm produce which would be most advantageously cultivated on plots of land which were successively more distant from a central town. The result drawn from his model is the familiar concentric circles of land use around the central town, where those products capable of returning higher rents (i.e. the highest net value per acre) are produced in the areas closer to the town.

Weber

Unlike Von Thunen's system, which was based primarily on transportation costs and which took the locations of economic activity as

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[1]The content of this section draws heavily from [Greenhut 1956] and [Isard].

[2]Johann Heinrich Von Thunen, Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalokonomie (3rd ed., Berlin, Schumacher-Zarchlin, 1875).

given, Weber's system[3] allowed for the inclusion of additional cost considerations, i.e., labor and agglomeration costs, and focused on the optimum location as the objective criteria. Similar to Von Thunen's system, however, Weber treated demand as an exogenous variable.

Hoover

Edgar Hoover[4] sharpened the cost considerations proposed by Von Thunen and Weber. He categorized the costs factors of location into transportation and production factors. The cost of distribution as well as the cost of procurement are included in Hoover's transportation factors. Like Weber, Hoover's analysis depended on substitution among costs to determine an optimum location. Unlike Weber, he drew much clearer and sharper distinctions between the cost elements involved by emphasizing their unique characteristics. As with Von Thunen and Weber, Hoover abstracted from demand in his system of least-cost location analysis.

Losch

August Losch[5] is the best known of the 'market area school'. The interest of this approach is in finding the optimum marketing area,

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[3]Alfred Weber, Uber den Standort der Industrien. Part I. Reine Theorie des Standorts (Tubingen, 1909) and Theory of Location, translation by C.J. Friedrich, Chicago University Press, 1928.

[4]Edgar M. Hoover, Location of Economic Activity, 1st ed., McGraw-Hill, New York, 1948.

[5]August Losch, Die raumliche Ordnung der Wirtschaft. Gustav Fischer, Jena, 1944.

given that buyers are distributed over space. Under such a premise, the demand curve facing a firm is no longer presumed to be horizontal, since customers at a distance face a higher gross delivered price.

Losch's model, unlike Von Thunen's and Weber's, places a heavy emphasis on demand. Firms locating in a spatial world, with costly transportation, realize that they face a downward sloping demand and that the presence of competitive rivals is a possibility.

Locational Interdependence

In attempts to extend the market area type of analysis, several authors[6] have suggested broadening its framework to include: 1) freely moveable locations or planned locations, and 2) more general forms of anticipated price reactions (conjectural variations) on the part of rival firms. These extensions are intended to stress the attraction or repulsion of a firm resulting from the presence (actual or potential) of a rival.

3.3 A Simple Model of Spatial Demand

To facilitate the exposition and analysis of the spatial pricing systems, the forms of spatial competition, and the measures of market

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[6]See [Greenhut et. al. 1975], [Hotelling], and [Smithies 1941b] for examples.

performance, a simple model of spatial demand will be presented in this section.[7] This model will be modified or extended as further topics warrant in following sections of this chapter.

For simplicity, assume that:

i) there is a homogeneous set of n buyers distributed along a line from a single firm, such that the first buyer is at the seller's location and each successive buyer is one additional unit of distance away from the seller,

ii) all buyers have identical downward sloping demand curves; and

iii) the freight rate per unit of distance is a constant, t,

such that:

$$p = a - bq \qquad a,b>0 \tag{3-1}$$

$$q = \frac{1}{b}(a-p) \tag{3-2}$$

or

$$q = \frac{1}{b}(a-(m+tD)), \tag{3-3}$$

where, m = the seller's mill price

t = the constant freight rate per unit

D = the buyer's distance from the firm

p = the delivered price, (m+tD)

q = the individual quantity demanded

and a and b are positive constants.

In a spaceless market, where t=0, individual demand becomes,

$$q = \frac{1}{b}(a-m) \tag{3-4}$$

[7]This section draws from [Greenhut and Ohta 1975], [Hsu], [Beckman], and [Greenhut 1978].

and aggregate demand facing the seller is,

$$Q = \frac{n}{b}(a-m). \tag{3-5}$$

In a spatial market, where $t > 0$, the maximum sales distance, i.e., the distance beyond which no buyers are willing to purchase the product, D_o, is given by setting q equal to 0 in equation (3-3), such that,

$$D_o = \frac{a-m}{t}. \tag{3-6}$$

The aggregate market demand would then be,

$$Q = \sum_{D=0}^{D_o} \frac{1}{b}(a-(m+tD)) \tag{3-7}$$

In the case of buyers evenly distributed along the line, with density V, aggregate market demand becomes,

$$Q = V\int_0^{D_o} \frac{1}{b}[a-(m+tD)]dD \tag{3-8}$$

$$= \frac{V(a-m)^2}{2bt}.$$

For a line extending in both directions from the firm, (3-8) becomes

$$Q = \frac{V(a-m)^2}{bt}. \tag{3-8'}$$

For the case of buyers evenly distributed over a homogeneous plane, aggregate demand becomes,

$$Q = \frac{V}{b}\int_0^{2\pi}\int_0^{D_o} (a-m-tD)D\, dD\, d\theta \tag{3-8"}$$

$$= V\frac{\pi(a-m)^3}{3bt^2}.$$

Taking the first and second derivatives of (3-8') and (3-8") with respect to m, the seller's mill price, reveals that over the range of economically relevant prices, i.e., a>m and m>0, both exhibit the expected negative slopes and both are concave, $d^2Q/dm^2>0$. In fact, regardless of the shape (convexity) of the identical individual demand curves, it can be shown that the aggregate demand curve facing a single firm over the relevant economic space will be convex [Greenhut 1978, p.23]. Since the elasticity of the aggregate demand curve at a price depends on the shape of the individual demand curves, this has strong implications for the comparative statics of various competitive spatial models [Benson 1980a].

For example, if (3-1) is redefined as,

$$p = m+tD = a-\frac{b}{x}\, q^x, \tag{3-9}$$

then

$$q = \frac{x}{b}\, (a-(m+tD))^{1/x}. \tag{3-10}$$

For $x>0$, of which $x=1$ is the special, linear demand case of Figure 3.1, at a price, p^*, the elasticity of demand increases for each successively more distant buyer. These increases of elasticity, when aggregated, increase the elasticity of the aggregate demand curve. In Figure 3.1, the elasticity at point B on the individual gross demand curve is less than the elasticity at the same price at point A on the individual's net demand curve. The net demand curve is adjusted to a delivered price by tD. As distance, D, increases, the individual net demand curves become relatively more elastic.

For $-1<x<0$,[8] of which $a=0$ is the special case of constant elasticity, we have a convex gross individual demand curve, such as in Figure 3.2. At P^*, the elasticity of demand decreases for each

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[8]If $x<-1$, marginal revenue becomes an increasing function and there is no profit-maximizing equilibrium.

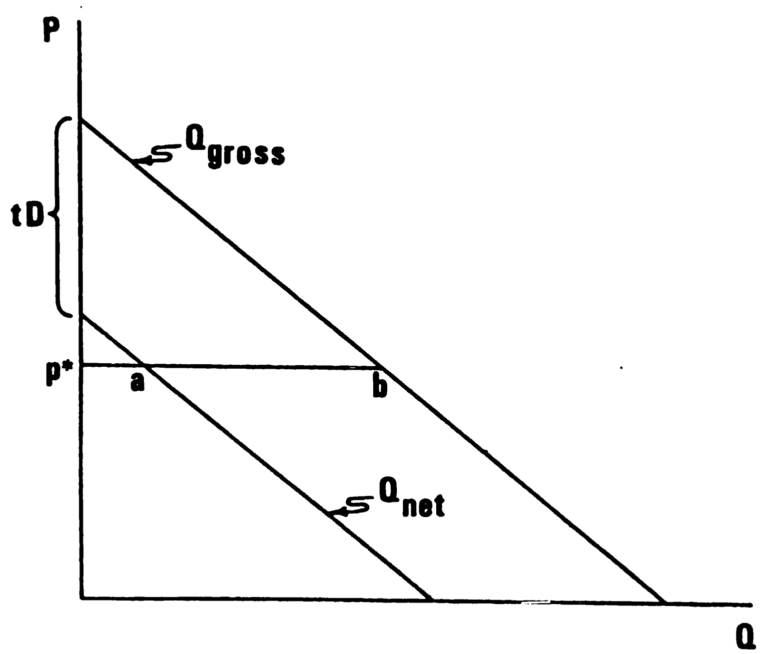

Figure 3.1 Individual Gross and Net Demand and Changing Elasticity; X=1

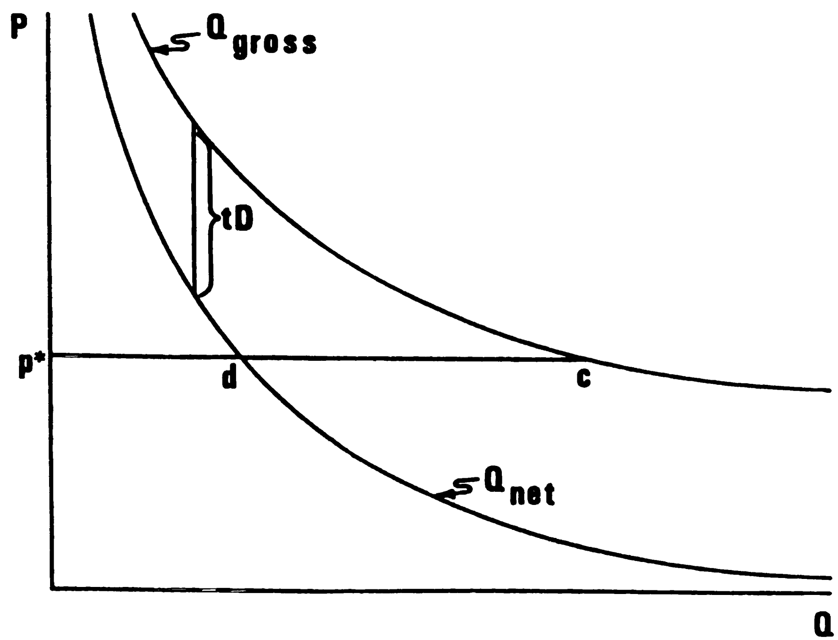

Figure 3.2 Individual Gross and Net Demand and Changing Elasticity; X= - 1/2

successively more distant buyer. These decreases reduce the elasticity of the aggregate demand curve and in contrast to Figure 3.1, Figure 3.2 depicts a situation such that, at price P^*, the elasticity of the gross individual demand at C is higher than that of the net individual demand at D. In short, "anything which causes a spatial firm to lose or gain distant consumers, changes the elasticity of the aggregate demand faced by the firm."[Benson 1980a, p.1103]

3.4 Three Spatial Pricing Systems

This section describes three spatial pricing systems which will be used in the analysis of intra-order milk pricing. These systems are hereafter referred to as 1) discriminatory pricing, 2) uniform mill pricing (f.o.b.), and 3) uniform delivered pricing (c.i.f.). In reality, firms could use modifications or mixtures of these systems. For example, a firm might price discriminatorily over a spatial range of customers and use f.o.b. pricing beyond that range, or a system of discriminatory freight zones might be used rather than individual discriminatory prices. For the purposes of this analysis, where the effects of each pricing system on market performance is desired, mixtures or modifications of these pricing systems, for the most part, will not be analyzed.

Discriminatory Spatial Pricing[9]

As was noted in section 3.1, a spatial market is characterized by differentiated individual demand curves. This provides a natural environment for the operation of a perfectly discriminating pricing system. Figures 3.1 and 3.2, however, indicate that, at a price, the elasticity of individual demand could be either increasing or decreasing with distance, depending on the shape of the individual demand curves. The optimal direction of price discrimination by a firm, i.e., against nearby buyers or against distant buyers, is determined by whether or not individual demand schedules vanish at some finite price and, if not, by the shape of the demand curve. If demand does vanish at a finite price, "spatial monopolists discriminate generally against nearer buyers regardless of the shape of the demand curve--concave, linear, convex, or some mixture of all" [Greenhut and Ohta 1975, p.77]. "Without vanishing demand, the monopolist will discriminate against distant buyers, to the extent possible due to resale possibilities, if the demand curve is more convex than a negative exponential, and will discriminate against nearby buyers if the demand curve is less convex than a negative exponential" [Greenhut and Ohta 1975, p.84]. In the absence of resale restrictions, discrimination against distant buyers is limited by the possibility of nearby buyers reselling the product to distant buyers. Distant buyers, however, taking delivery at their own locations will be unlikely to make up the double freight charge of reselling to nearby buyers.[10] Thus, it

[9]This section draws from Hsu.

[10]Note, in this instance, if the distant buyer actually contracts
(Footnote Continued)

is assumed in this study that discrimination against nearby buyers is the most likely possibility.

Figures 3.3 and 3.4 depict the situation for a price discriminating spatial monopolist. In Figure 3.3, let the line segments p_1q_1, p_2q_2, and p_3q_3 represent the individual net demand curves for three identical spatial buyers, each successively more distant from the firm. The dashed lines emanating from p_1, p_2 and p_3 represent the respective marginal revenues. In Figure 3.4, the line prsq is the horizontal summation of the average revenues and the discontinuous solid lines pb, cd, and ef represent the marginal revenue associated with prsq, i.e., the simple monopolist's marginal revenue, SMR. The continuous solid and dashed line pacgef is the summation of the individual marginal revenue curves, i.e., the discriminating monopolist's marginal revenue, DMR.[11]

If it is assumed that the monopolist has a constant marginal cost, MC, an intersection of MC with the line segment pa will produce the same results for the simple pricer as for the discriminator. In this case, only market 1 is served with the same quantity of output by each pricer. If MC intersects with ab above c, then the discriminator will produce more output than the simple pricer and he will serve both markets 1 and 2, while the simple pricer still serves only market 1. If MC intersects

(Footnote Continued)
the freight himself, he may be able to avoid the double hauling costs and would contract to have the product delivered to a nearby buyer instead. The characteristic of who actually contracts the freight service may be important with respect to enforcing a price discriminating system.

[11]Note that the aggregated average revenue has begun to take a convex shape and that as the number of buyers distributed evenly over space becomes larger, the DMR and SMR become more distinct with SMR lying below DMR at all points.

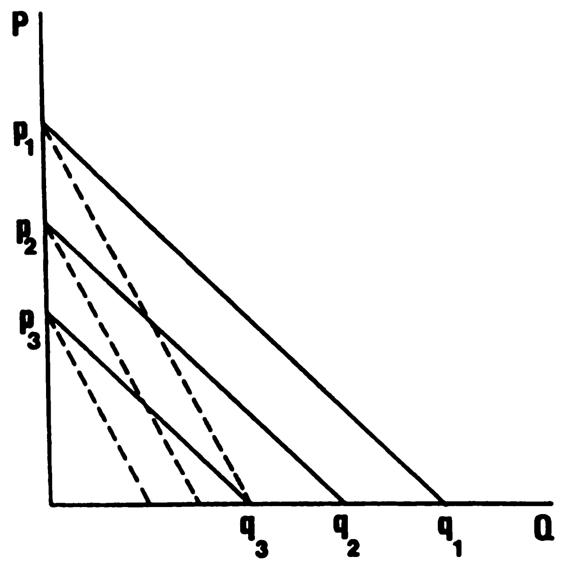

Figure 3.3 Individual Net Demands and Marginal Revenues

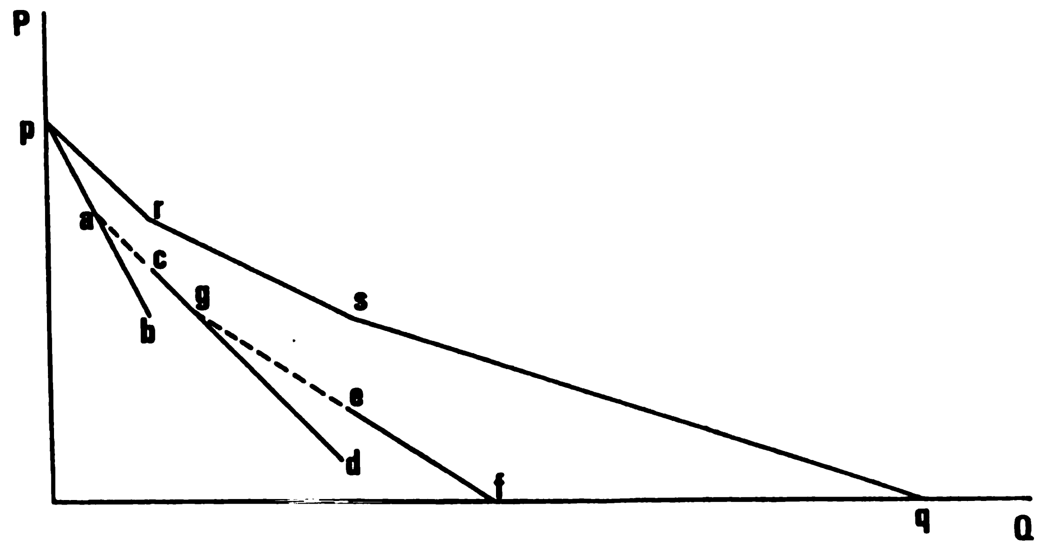

Figure 3.4 Aggregated Net Demand, Simple Monopolist's Marginal Revenue, and Discriminating Monopolist's Marginal Revenue

ab below c, the discriminator and simple pricer will produce the same level of output, but it will be distributed differently between markets 1 and 2, with the discriminator reallocating output from market 1 to market 2. A similar succession of cases follows as MC is decreased. As the spatial division of buyers becomes finer, i.e., more individual demand curves are present, cases where the discriminator's output is greater than that of the simple pricer become more prevalent.

Using the simple model presented in section 3.2, we can formulate the discriminatory spatial monopolist's pricing system such that:

$$q = \frac{1}{b}(a-p) \tag{3-2}$$

or

$$q = \frac{1}{b}(a-(m+tD)) \tag{3-3}$$

where,

m = the seller's mill price;

t = the constant freight rate per unit;

D = the buyer's distance from the seller;

p = the delivered price;

q = the individual quantity demanded; and

a and b are positive constants.

In addition, total costs are

$$T(Q) = cQ+F \tag{3-11}$$

where,

Q = total quantity produced and sold;

c = constant marginal production cost; and

F = total fixed cost.

To make this section more complete,[12] the buyer density, V in (3-8), will be defined by an arbitrary non-negative function over D, $\phi(D)$, such that the market area has a physical boundary, R;

$$\phi(D) = \begin{cases} \phi(D) & \text{if } 0<D\leq R \\ 0 & \text{if } D>R. \end{cases} \tag{3-12}$$

Monopoly output can be expressed as,

$$Q = \int_0^B q(D)\phi(D)dD \tag{3-13}$$

where $B\leq R$.

Assuming the monopolist wishes to maximize profit, profit can be written as:

$$\pi_d = \int_0^{B_d} (m_d-c) \frac{1}{b}(a-P_d) \phi(D) \, dD - F \tag{3-14}$$

where B_d = seller effective market area under spatial discrimination

m_d = discriminatory mill prices; and

$P_d = m_d + tD$.

The seller chooses a function of m_d defined over D to maximize profit, π. Using calculus of variations [Hsu, p.53-54], this problem can be

---

[12]The question of quantity of output under discriminatory prices has been debated, with contrasting results [Greenhut and Ohta 1972, Greenhut and Ohta 1975, Beckman]. These differences can be partially attributed to the assumption made with respect to the monopolist's market area. If you assume that he will sell to the extent of his market in simple or discriminatory pricing, i.e., that his market area is fixed, then the two pricing systems yield identical output results. If you assume that he can expand his market area, discrimination may lead to increased output. Thus, in Figures 3.3 and 3.4, we are explicitly assuming that the spatial monopolist can expand his market area.

solved to show that the necessary condition that m_d^* be an optimal discriminatory price schedule requires

$$m_d^* = a/2b + c/2 - tD/2. \tag{3-15}$$

Discriminatory prices for each buyer are a function of demand, cost of production, and cost of transportation, but are independent of buyer density. The extent of the market, B_d, however, does depend on the range of consumers since,

$$B_d = \begin{cases} D & \text{if } D < R = \dfrac{a-c}{t} \\ \dfrac{a-c}{t} & \text{if } D \geq R \end{cases}.$$

The price which a monopolist charges to each buyer can be independently chosen in the manner depicted in Figures 3.3 and 3.4, where he equates marginal cost with marginal revenue for the adjusted (net) demand for each buyer. This price does not depend on any other prices which he may specify. It does, however, involve a degree of freight absorption where the discriminating monopolist would absorb a proportion, fifty percent in this case, of the freight cost of serving each individual customer.

Uniform Mill Pricing (f.o.b. or simple monopoly pricing)[13]

A second spatial pricing system in which a firm quotes a single price which is effective at the firm's location is uniform mill or f.o.b. pricing. Under a uniform mill pricing system, the spatial monopolist charges a constant mill price to all buyers. Assuming the monopolist wishes to maximize profits,

---

[13]This section draws heavily from Hsu. The notation differs since Hsu began from a price dependent formulation, while I have chosen a quantity dependent start (3-2).

$$\pi_s = (m_s - c)\, Q_s - F \tag{3-16}$$

where m_s = the uniform mill price

and Q_s = the total output sold under a uniform mill pricing system.

The total quantity sold, Q_s, can be expressed as

$$Q_s = \int_0^{B_s} \frac{1}{b}\,(a - m_s - tD)\;\;\phi(D)\;\; dD, \tag{3-17}$$

Where B_s is the extent of the uniform mill pricer's market, i.e. the distance beyond which no sales will be made, such that from 3-3,

$$q(B_s) = 0 = \frac{1}{b}\,(a - m_s - tB_s) \tag{3-18}$$

and $B_s = \dfrac{a - m_s}{t}$

Marginal profit with respect to the uniform mill price, m_s, is

$$\frac{d\pi_s}{dm_s} = Q_s + (m_s - c)\,\frac{dQ_s}{dm_s} \tag{3-19}$$

Applying integral differentiation,[14]

$$\frac{dQ_s}{dm_s} = \frac{d\left(\frac{a - m_s}{t}\right)}{dm_s} \cdot \frac{1}{b}\,(a - m_s - tB)\;\phi(B_s)$$

$$+ \int_0^{B_s} - \;\frac{1}{b}\,\phi(D)\; dD \tag{3-20}$$

Since $0 = \frac{1}{b}\,(a - m_s - tB_s)$ from (3-18), (3-20) becomes

---

[14] If $g(t) = \int_0^b f(t,y)dy$, and $b = h(t)$,

$$\frac{dg(t)}{dt} = \frac{dh(t)}{dt} \cdot f(t,b) + \int_o^b \frac{df(t,Y)}{dt}\, dy.$$

$$\frac{dQ_s}{dm_s} = -\frac{1}{b}\int_0^{B_s} \phi(D) \quad dD. \tag{3-20}$$

Substituting (3-20) back into (3-19),

$$\frac{d\pi}{dm_s} = \int_0^{B_s} \frac{1}{b}(a-m_s-tD)\phi(D)\ dD$$

$$+ (m_s-c)(-\frac{1}{b}) \int_0^{B_s} \phi(D) \quad dD.$$

Solving for m_s^*, the optimum mill price, yields, at $d\pi/dm_s = 0$,

$$m_s^* = a/2 + c/2 - t\overline{D}/2 \tag{3-21}$$

where $$\overline{D} = \frac{\int^{B_s} D\ \phi(D)\ dD}{\int^{B_s} \phi(D)dD}.$$

B_s^*, the optimum extent of the uniform mill pricer's market is,

$$B_s^* = \frac{a-c}{2t} + \frac{\overline{D}}{2}. \tag{3-22}$$

The optimal uniform mill price, m_s^*, is a function of demand, a, production costs, c, transportation costs, t, and the distribution of buyers, $\overline{D} = f(\phi)$. The effect of transportation cost is dependent on the average distance, $\overline{D}$, to buyers who are being served at the optimum mill price, "...where there is no attempt to differentiate among buyers, the seller treats his entire market as if it were at the same location" [Greenhut 1956, p.156]. As with discriminatory pricing, the monopolist finds it advantageous to absorb some freight costs. Under optimal uniform mill pricing and the specified functional form, he will absorb fifty percent of the freight to the average distance customer.

Uniform Delivered Pricing (c.i.f.)[15]

To complete the possible theoretical extremes in spatial pricing, the uniform delivered pricing system is described here and used in the analysis reported in Chapter V. In a uniform delivered pricing system, the seller quotes an equal delivered price to all buyers within the extent of his market. Profit for the uniform delivered pricing monopolist is,

$$\pi_D = \int_0^{B_D} (\bar{P}_D - tD - c) \frac{(a - P_D)}{b} \phi(D)\, dD \tag{3-23}$$

Where B_D is the extent of the uniform delivered pricing monopolist's market, i.e. the distance beyond which he will not wish to make sales, that point where,

$$\bar{P}_D - tB_D - c = 0. \tag{3-24}$$

such that $\quad B_D = \dfrac{\bar{P}_D - c}{t}$

marginal profit with respect to the delivered price is,

$$\frac{d\pi_D}{d\bar{P}_D} = \frac{d\left(\frac{\bar{P}_D - c}{t}\right)}{d\bar{P}_D} \cdot (\bar{P}_D - tB_D - c) \frac{(a - \bar{P}_D)}{b} \phi(D)\, dD$$

$$+ \int_0^{B_D} \frac{a - 2\bar{P}_D + tD + c}{b} \phi(D)\, dD \tag{3-25}$$

From (3-24), the first term of (3-25) becomes zero, such that

$$\frac{d\pi_D}{d\bar{P}_D} = B_D \frac{(a - 2\bar{P}_D + c)}{b} + \frac{t}{b} \int_0^{B_D} D\, \phi(D)\, dD.$$

---

[15]This section draws from Hsu.

Solving for $\bar{P}_D$ at $\frac{d\pi_D}{d\bar{P}_D} = 0$,

$$\bar{P}_D^* = a/2 + c/2 + t\bar{D}/2 \tag{3-26}$$

Where $\bar{D}$ is the average distance to buyers over the market extent, and,

$$B_D^* = \frac{a-c}{2t} \quad \frac{\bar{D}}{2} \tag{3-27}$$

Under a uniform delivered pricing system, the spatial monopolist's price, $\bar{P}_D^*$, is a function of demand, production costs, transportation costs and the distribution of buyers over the space, ϕ.

Summary

In each of the three spatial pricing systems described above, the monopolist finds it advantageous to quote prices, either mill or delivered, which reflect his willingness to absorb some portion of the freight costs involved in delivering the output to his customers. The magnitude and particular form which the absorption takes will determine the way in which a price surface predicted by the spatial microeconomic model differs from one predicted by point-trading models which do not admit freight absorption. Given these general formulations of three pricing systems, section 3.6 attempts to investigate the implications of the spatial economic model on market performance and to draw some very general comparative welfare implications.

Before moving to these topics, however, the topic of competition over space must be addressed. Section 3.4 assumed complete spatial monopoly behavior, a very strong assumption. In the following section, 3.5, several forms of spatial competition will be considered and implications for spatial pricing systems discussed.

3.5 Competition Over Space

In section 3.4, the three spatial pricing systems, discriminatory, uniform mill, and uniform delivered, were described in the context of a spatial monopoly, where the optimum market extent of the monopolist was assumed not to overlap with any actual or potential rivals. In many spatial markets this would be an unwarranted assumption. Beginning with this section, the term 'competitive' will be used to refer to any market which is not monopolistic. More specifically, two firms whose optimum monopolistic market areas would overlap will be referred to as being 'in competition' or operating in a 'competitive market'.

In spaceless microeconomics, the entry of rival firms is assumed to occur at the same point as the existing monopolist, thus the emphasis of such models is on the splitting or sharing of a given aggregate spaceless demand as the number of firms increases. Cournot's original analysis [Cournot, Greenhut and Ohta 1975, Chap. 7], culminates with the result that, "assuming each seller behaves competitively and entry is open, an oligopoly approaches the competitive output and price as the number of sellers increases without limit" [Greenhut and Ohta 1975, p.109].

In the spatial model, however, rivals have more choice with respect to the place of entry. They might enter at the monopolist's point, Cournot's assumption, they might enter near, but not exactly at, the monopolist, or they may enter at some distance from the monopolist. However, if they entered at a distance so remote as to result in no market overlap at optimum, profit maximizing prices, then from the above definition, they would not be deemed to be in competition. Thus, entry at a distance, and its many consequences, is the essential difference between competition in the spaceless and spatial economic worlds. Rivals will only enter a spatial market at a distance if the freight cost advantage of serving nearby buyers offsets production cost disadvantages over a sufficient number of buyers to make the rival location feasible.

Entry at a distance in the spatial model increases supply, but also increases net, observed demand, since more customers are served, and/or average transportation costs are lowered. The subsequent price effect of a firm's entry at a distance in the spatial model is indeterminate without specific knowledge of the supply and demand functions. "Occurrences which affect only supply or demand in the spaceless world affect both supply and demand in a spatial world" [Benson 1980b, p.62].

Harold Hotelling, in his classic 1929 article on spatial competition, firmly established the foundation for most subsequent spatial competition work. He did so as an extension of Cournot's oligopoly model which was shown to be unstable, with radical all-or-nothing shifting of buyers between sellers with only slight price changes, whereas, reality suggests "...gradualness in the shifting of customers from one merchant to another as their prices vary independently..." [Hotelling, p.44].

In his analysis, Hotelling posits two firms located at positions A and B at $a=4$ and $b=1$ distances from the end of a line market of length ℓ, with uniformly distributed buyers who have completely inelastic demands of Z unit of quantity each (Figure 3.5). Both sellers' products or services are homogeneous and there is positive constant unit transportation cost.

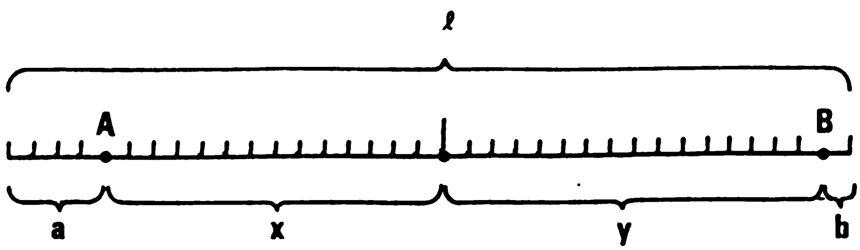

Figure 3.5 Hotelling's Extension of Cournot's Competitive Model

A and B may charge different mill prices, but neither must let his mill price be higher than the other's plus transportation costs to his own location or he will have no buyers. The simultaneous profit maximizing prices at A and B, acting independently, can be shown to be 36 and 34, respectively, with q_a=18 and q_B=17.

Hotelling dismisses the possibility of collusion, explicitly or by concerted behavior, by assuming that such a relationship would be too "fragile" to endure. If B is free to choose his location, given A, he will seek to make b, his monopoly advantage market area, as large as possible. He will locate as close to A, without being at A, as he can (thus approaching Cournot's model). Small changes in price will result in large numbers of buyers shifting between sellers, an unstable position.

In Hotelling's model, profits for each firm are directly related to transportation cost. Higher transportation costs increase the wedge separating the two firms, effectively stretching ℓ so that each firm's monopoly position is enhanced.[16] Under such a situation, it would be in each firm's best interest to "...make transportation as difficult as possible" [Hotelling, p.50].

A number of variations on Hotelling's basic model have been suggested. These usually differ with respect to their 'conjectural hypotheses,' i.e. how the firm views its rival's reactions to changes it makes in price [Benson 1980a, Greenhut et al. 1975, Capozza and Van Order 1978, Salop 1977, Salop 1979, Capozza and Van Order 1977, Ohta, Benson 1980b, Benson 1984].

Three assumptions about conjectural variations appear most often:

1) Loschian Competition (L)

Each firm assumes that its market area is fixed, i.e. that any reduction in its mill price, which is intended to expand its market area, induces an immediate and equal change in the price of its rivals so as to leave its market area unchanged. The Loschian competitor is assumed to price like a monopolist within its market area.

2) Hotelling-Smithies Competition (HS)

Each firm assumes that its rival's mill price is fixed. The firm may price monopolistically over its natural monopoly market area, but it must beat it's rivals delivered price in those areas where both can profitably sell.

3) Greenhut-Ohta Competition (GO)

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[16]With completely inelastic demands, all customers on ℓ are served. With more elastic demand, some buyers may not be served, limiting monopoly profits.

The firm's delivered price at its market boundary is taken as fixed, i.e. a delivered price ceiling for each firm is parametrically given.

Figure 3.6 depicts graphically the price relations in each type of competition. Two competitive firms, one located at 0 and one at a distance of $\bar{D}$ from 0 compete for buyers located between them. Each firm's delivered price increases with constant transportation costs. The boundary between the two firms will occur at the intersection of the delivered prices, R_L. At R_L, buyers will be indifferent as from which firm they purchase . Also at R_L,

$$P_o + t_i = P_{\bar{D}} + t(\bar{D}-R_i)$$

where P_o = mill price for firm A

$P_{\bar{D}}$ = mill price for firm B

$\bar{D}$ = Distance between firms

R_i = the market radius for firm A

and t = constant freight rate

solving for R_i,

$$R_i = 1/2t\ (P_{\bar{D}}-P_o+t\bar{D}). \qquad (3\text{-}28)$$

If firm A should lower its price by ΔP, then under Loschian competition, the rival will lower his mill price by ΔP, to keep the market boundary the same, R_L. Thus, under Loschian competition, the new boundary price would be at point B, and

$$dP_{\bar{D}}/dP_o = 1$$

and, from (3-28)

$$dR/dP_o = 0.$$

Under L competition, the firm is faced with a fixed marketing area over which to maximize its profits. Thus, B_d, B_S^*(3-22), and B_D^*(3-27) are

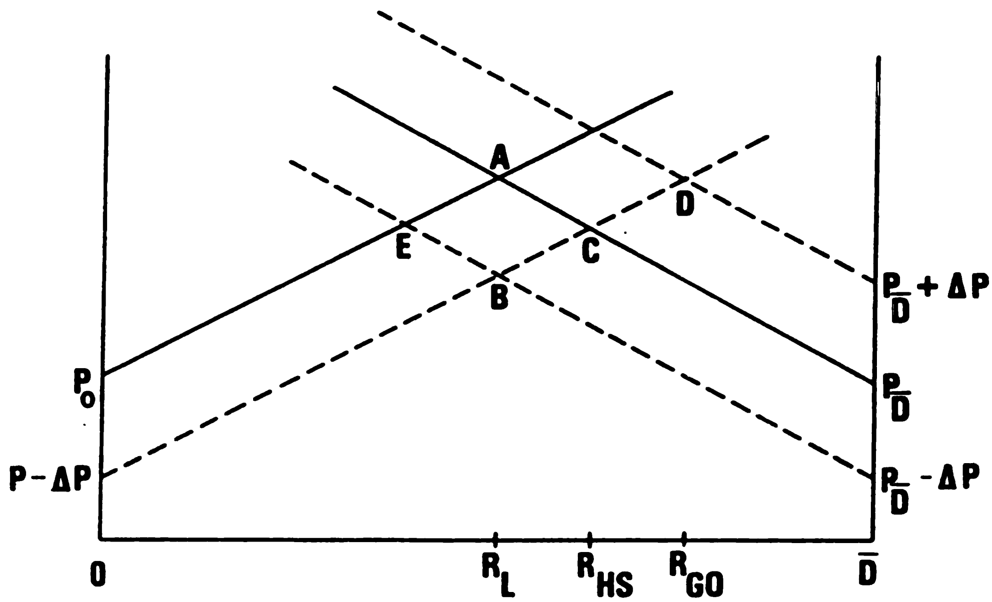

Figure 3.6 Price Reactions Under Three Types of Spatial Competition

parameters rather than variables. Under such a situation, discriminatory pricing is the most profitable system [Beckman].

Under HS competition, the rival firm at $\bar{D}$ is expected to maintain its mill price in the face of changes in the mill price of A, such that,

$$dP_{\bar{D}}/dP_o = 0$$

and the intersection of delivered prices occurs at C, with firm A having a new radius of R_{HS}, and from (3-28),

$$dR/dP_o = -1/2t.$$

Under GO competition, the border price is fixed so that if A drops its price by ΔP, then B will increase its price by ΔP such that,

$$dP_{\bar{D}}/dP_o = -1$$

and the intersection of delivered prices occurs at D, with firm A having a new radius of R_{GO}, and from (3-28),

$$dR/dP_o = -1/t.$$

GO competition, with maximum or ceiling delivered prices, takes neither its own market area as fixed (L) nor the prices of its rivals as fixed (HS), but only takes the maximum delivered price it can charge as fixed. It is unlikely to engage in pricing behavior which could result in delivered price schedules such as P_oEB and $P_{\bar{D}}CB$ in Figure 3.6, which could occur with Loschian competition.

Under GO competition, the firm is faced with pricing decisions such as those covered for monopolists in section 3.4, but with an added constraint: a maximum delivered price. By parametrically varying the maximum delivered price, it can be shown [Greenhut and Ohta 1975, Chap.8] that the profit maximizing firm will use uniform mill pricing up to a point and then switch to discriminatory pricing. The profit levels for f.o.b. and discriminatory pricing cross, for example in Figures 3.7 A and B, at some level of the maximum delivered price.

> "As the degree of competition increases, a spatial seller increases his profits by switching from discriminatory to nondiscriminatory pricing. Moreover, the switching point (i.e., when to switch) can be determined unambiguously if the demand conditions are known" [Greenhut and Ohta 1975, p.139]

This switching can be shown to occur and to be independent of the shape of demand. 1) Profits for the unconstrained discriminatory monopolist are greater than those for the unconstrained f.o.b. pricing monopolist, regardless of the shape of gross demand. 2) Over the monopolist's natural marketing area, profits must decrease monotonically with decreases in P′ (increased competition), regardless of the shape of gross demand. 3) The minimum P′ related to discriminatory profit is the mill price for the buyer located at the plant. This will be greater than marginal cost, while the minimum P′ related to f.o.b. profit for the same buyer will be equal to marginal cost.

Bressler argues elsewhere that the level of fixed costs plays no role in efficient plant location; however, it plays a decisive role in the determination of discriminatory vs. f.o.b. pricing under GO competition. In Figure 3.7A, if the level of fixed cost is F_2F_2, the zero-profit competitive equilibrium will occur at P_2' and the firm must use discriminatory pricing or suffer negative profits (assuming zero marginal costs). If fixed costs are F_4F_4, the zero profit equilibrium will occur at P_4' and the firm must use f.o.b. pricing.

In this section, three forms of spatial competition, each based on an alternative assumption about a rival firm's price reactions, were reviewed. In the introduction to Chapter III, section 3.1, a

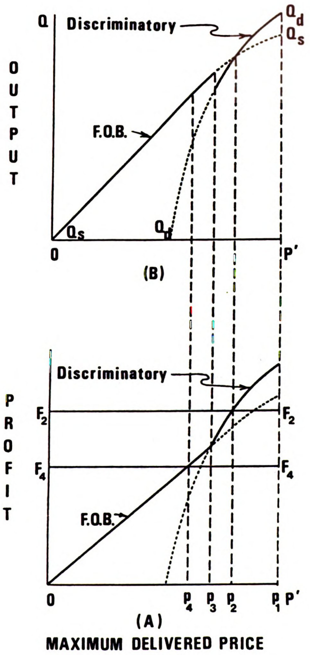

Figure 3.7 Profit Switching Point Under GO Competition

"counter-intuitive" example of prices rising with the level of competition was given. The basis of this example can now be seen.

If we assume that positive profits will attract new entrants in a market and that these rivals are most likely to enter at a distance, then any change which increases demand and, subsequently, profits, will lead to an increased number of firms. All firms will then be operating over smaller marketing areas and can face decreased elasticity (see section 3.3) of demand. This would occur under demand circumstances where the more elastic buyers are lost, leading to less elastic aggregate demands facing each firm. This situation results in greater monopoly power, i.e. a larger difference between price and marginal revenue, which could then produce the result of increased mill prices accompanying greater numbers of firms.

Under the above demand condition (increasing elasticity of more distant buyers), changes in any other parameters which affect market areas can similarly produce counter-intuitive results [Capozza and Attaran]. An increase in the density of buyers, a decrease in the freight rate, or a decrease in the level of fixed cost could all result in increased mill prices.

Finally, it is appropriate at this point to review one final form of spatial competitive behavior which has received much attention in the past; basing-point pricing. Under a basing-point(s) system, all sellers, wherever they are located, quote identical delivered prices to buyers. These are typically made up of a base price plus transportation costs from a base mill(s) to the delivery destination. With the U.S. Supreme Court decision of 1948, which upheld the illegality, under antitrust laws, of the use of a basing-point system in the cement industry, many studies of the basing-point pricing system and its consequences were done [Machlup, Loescher, Stocking].

Figure 3.8, which is essentially the same as Figure 3.6 with the market areas extending in both directions from each of two rival firms at O and $\bar{D}$, graphically presents the essentials of a basing-point pricing system. Under Loschian competition, firm A, at O, and firm B, at $\bar{D}$, will establish a mutual market boundary at R_L, where A's delivered price, mill plus transportation costs, 'beats' B's from O to R_L and to the left of O and even though B has a cost disadvantage, $\bar{D}P_{\bar{D}} > OP_O$, its delivered price 'beats' A's from $\bar{D}$ to R_L and to the right of $\bar{D}$, presumably a large enough market to warrant the establishment of firm B. Under basing-point pricing, with A as the base mill, instead of establishing its own mill price $P_{\bar{D}}$, B will take the delivered price schedule of A, P_{RL} to P'_O, as its own and compete with A over the same market area. The difference between $P_{\bar{D}}P_{RL}$ or $P_{\bar{D}}P'_D$ and $P_{RL}P'_O$ being known as 'phantom freight'. A third firm located at X would, under a basing-point system with A as the base mill, also quote delivered prices of $P_OP'_O$.

Basing-point systems can emerge and persist in the absence of explicit collusive behavior on the part of participating firms. Once the base mill price is determined, or simply announced, known freight rate schedules can be applied to determine the delivered price for every buyer location. Such a system usually results in very stable, if not greatly enhanced, prices since one firm or agency is making all decisions of price changes.

A slight variation on the single basing-point system is the multiple basing-point system where more than one base mill exists. If firms

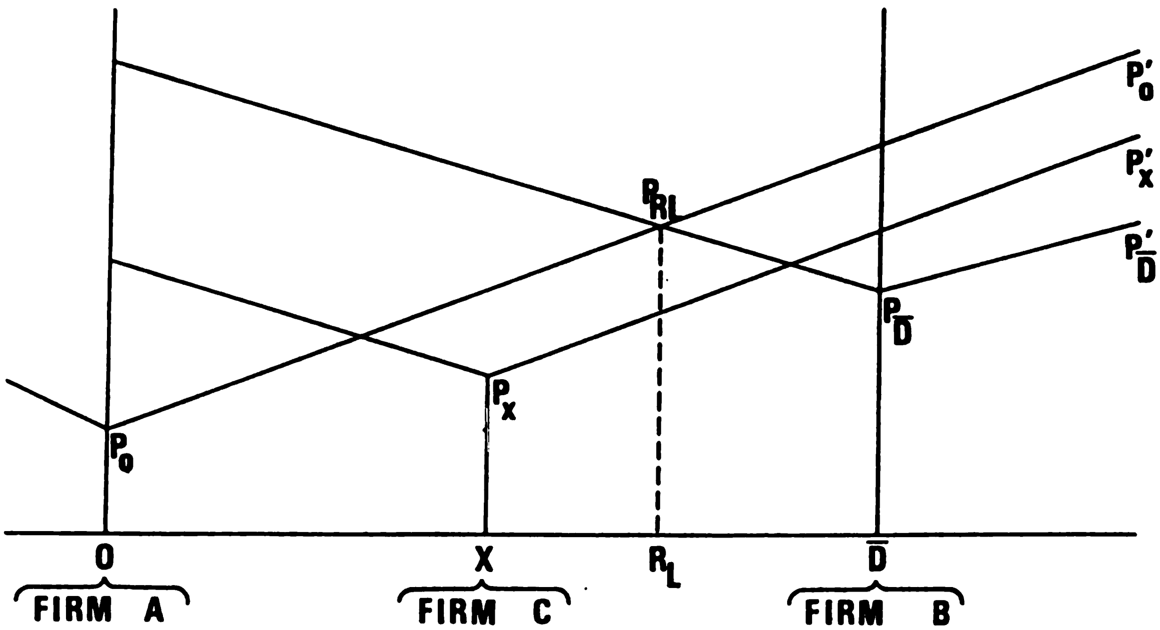

Figure 3.8 The Basing-Point Pricing System

A and B were regarded as base mills in Figure 3.8, firm C, at X, would use A's delivered price schedule for any delivery point to the left of R_L and B's delivered price schedule for delivery points to the right of R_L.

Under conditions where the firm locating at a distance, B, has a cost advantage, $\bar{D}P_{\bar{D}} < OP_O$, "the firm locating at a distance would be foolish not to set its own net-mill f.o.b. price independently of other existing prices, and thereby gain full control over the distant segment of the market" [Greenhut 1956, p.78] However, if the distant rival has no cost advantage and is relatively small, it may fear a price war with plants located at O and conform to the basing-point price schedule.

3.6 <u>The Spatial Model and Economic Performance</u>

As was seen in section 3.3, the elasticity, at a price, of the aggregate net demand facing a firm, which operates in the spatial model, depends on the shape of the individual demands. The gain or loss of distant buyers due to production or transportation cost changes or due to the entry of rival firms at a distance (section 3.5), can have opposite effects on some basic measures of performance such as price and output, depending on individual demand conditions [Benson 1980a]. Without specific information about the shape of individual demand and the level of costs, no clearly unambiguous comparative statics results can be generated. There are, however, two topics of social welfare in the spatial model which can be addressed in a more general fashion: 1) In a competitive spatial model, there are "agglomerative tendencies" which result in firms tending to "cluster unduly", [Hotelling] *ceteris paribus* and 2) the spatial model, with costly transportation, ensures that individual firms cannot have perfectly elastic demand and, consequently, any zero-profit equilibrium, where average revenues equal average costs, will necessarily result in a situation where price is higher than marginal cost.

Hotelling (section 3.5) addresses the first topic. He assumed a line market of length ℓ with firms located at points A and B, a and b units of distance from each end, respectively (Figure 3.5). There is a uniform distribution of buyers, each with an invariant one unit of demand. Given the fixed locations, total transportation costs can be minimized if X equals Y, i.e. if the firms charge the same mill price. Since a, the area in which A has a clear advantage, is larger than b, the area in which B has a clear advantage, A's price will be higher than B's and, consequently, X will be less than Y. Some buyers closer to A will find it to their advantage to buy from B and total transportation costs will not be minimized. "If the stores were conducted for public service rather than for profit their prices would be identical in spite of the asymmetry of demand" [Hotelling, p.53].

With moveable locations, the least transportation cost locations would be at the quartiles of ℓ. However, even if A chose one of these locations, it would be in B's best interest to locate as close to A as possible on the side of A with maximum length so as to gain control over the largest market segment. Subsequent entrants will similarly gravitate toward prior locations, rather than disperse in an optimum manner.

With greater than perfect inelasticity of individual demands, the incentive for B to locate as close to A as possible is diminished. B, however, would not move as far away as minimized transportation costs would require.

Benson addresses the second welfare issue. Free entry in spatial competition, prompted by positive profits for existing firms, combined with the necessarily downward-sloping demand facing each firm results in Chamberlinian tangencies between average revenue and average costs at points where both are downward sloping.[17] This occurs when profits are driven to zero. This presents a situation where price is higher than marginal cost and where average cost is not at its lowest point. This situation, brought about by the spatial element, is pointed-out as prima facie evidence of the inherent inefficiency in spatial markets. Bressler states, "in short, competition is not and cannot be effective in bringing about low costs and the optimum organization of plants and facilities...it is clear that spatial monopoly creates an unstable situation and can be expected to result in an excessive number of plants and correspondingly higher-than-optimum costs" [Bressler, p.119].

An alternative view of this situation takes the position that the inevitable difference between price and marginal cost is actually a payment to cover a social cost. The under-allocation of resources is offset because of social benefits which are external to the firm. "The excess of f.o.b. mill price over site-specific marginal production cost is the additional marginal cost of output due to the existence of alternative sites" [Benson 1984, p.283].

To see this argument, start with the following spatial price relationship,

$$P = P_m + tD \qquad (3\text{-}29)$$

[17]This section draws from [Benson 1984].

where P = delivered price

P_m = mill price

t = constant freight rate,

and D = the buyer's distance from the firm.

Individual net demand can then be represented as

$$q = f(P_m + tD) \tag{3-30}$$

and in a linear market extending two directions from the plant, a single firm's aggregate demand becomes

$$Q(P_m) = 2 \int_0^{D_o} f(P_m + tD)\, dD \tag{3-31}$$

$$D_o \le \frac{f^{-1}(0)-P_m}{t}, \quad D_o \le \frac{T}{2} \tag{3-32}$$

where T = the physical maximum market length.

Profit for the single firm becomes

$$\pi = P_m \cdot Q(P_m) - C(Q), \tag{3-33}$$

where $C(Q)$ = the firm's production cost function.

Aggregate market demand, when there is more than one firm, becomes

$$Q(P_m, N) = 2N \int_0^{D_o'} f(P_m+tD)dD \tag{3-34}$$

where N = number of firms.

Presuming N evenly spaced firms throughout the market area,

$$D_o' \le \frac{f^{-1}(0)-P_m}{t}, \quad D_o' \le \frac{T}{2N} \tag{3-35}$$

where D_o' denotes the maximum extent of the market.

If it is assumed that all potential buyers are served, i.e. $D_o'=T/2N$, then each firm's proportion of total sales, $S=Q/N$, is

$$S = 2\int_0^{D_o'} f(P_m+tD)\,dD/N \qquad (3\text{-}36)$$

$$= S(P_m,N;T)$$

and marketwide demand can be stated as a function of the number of firms and the mill price,

$$Q = N\cdot S(P_m,N).^{18} \qquad (3\text{-}37)$$

$$dQ/dN = S+N\ dS/dN$$

$$= S - D_o' \cdot f(P_m+tD_o'). \qquad (3\text{-}38)$$

As firms enter the market, the left term of (3-32) holds at an equality and entering firms can sell over their maximum potential market area without affecting the market areas of existing firms. In this situation, the entry of new firms should increase effective market demand by substantial amounts. Total aggregate demand continually increases, with entry, because more customers are served or because total transportation costs decline. However, at some point the left term of (3-35) holds at an inequality and all firms are unable to sell over their maximum potential market area and the increments to demand become smaller and smaller.

---

[18] $dS/dN = \dfrac{d(\int_0^{D_o} f(P_m+tD)dD)}{dN}$, $D_o' = T/2N = h(N)$.

From footnote 14 in section 3.4,

$$dS/dN = dD_o'/dN \cdot f(P_m+tD_o') + \int_0^{D_o'} \frac{d(f(P_m+tD))}{dN}\,dD$$

since $dD_o'/dN = -T/2N^2$ and $\dfrac{d(f(P_m+tD))}{dN} = 0$,

then $dS/dN = -T/2N^2 \cdot f(P_m+tD_o') = -D_o'/N \cdot f(P_m+tD_o')$.

Buyers' benefits which result from the entry of new firms are not reflected in the revenues of existing firms. Likewise, the costs of establishing new locations are not seen in the existing firms' cost functions.[19] As such, N, the number of firms, does not enter as a decision variable in any firm's profit equation, but does exist as a cost for the market.

A firm's total cost function, C, can be expressed as,

$$TC = C(N, S(P_m, N)) \tag{3-39}$$

and each firm's profits will then be

$$\pi = P_m \cdot S(P_m, N, D_o') - C(N, S(P_m, N, D_o')), \tag{3-40}$$

where D_o' appears in the cost and demand functions because competing firms will maximize their profits over their supply area of length D_o'. D_o' depends on the firm's mill price relative to his rival's.

Profit maximization requires,

$$\frac{d\pi}{dP_m} = S + P_m \cdot \frac{dS}{dP_m} + P_m \cdot \frac{dS}{dD_o'} \cdot \frac{dD_o'}{dP_m} - \frac{dC}{dS} \cdot \frac{dS}{dP_m} - \frac{dC}{dS} \cdot \frac{dS}{dD_o'} \cdot \frac{dD_o'}{dP_m} = 0 \tag{3-41}$$

$$P_m = dC/dS - \frac{S}{\frac{dS}{dP_m} + \frac{dS}{dD_o'} \cdot \frac{dD_o'}{dP_m}}. \tag{3-42}$$

Under Loschian competition, where,

$\frac{dD_o'}{dP_m} = 0$, (3-42) becomes

$$P_m = \frac{dC}{dS} - \frac{S}{\frac{dS}{dP_m}}. \tag{3-43}$$

---

[19] If the entry of new firms affects the costs of production, through competition for inputs, then part of entry costs may be borne directly by existing firms which have no decision control over N.

If it is assumed that 1) buyers have identical gross demand and are uniformly and continuously distributed over the market area, 2) firms face identical production costs, 3) firms are evenly dispersed, and 4) firms have identical conjectural price variations, they will all charge the same mill price, (3-43). Additionally, firms will enter the market until profits are driven to zero (necessitating the additional assumption of completely portable locations).

The equilibrium occurs when firms perceive their Loschian demand, $S(P_m,N,D_o')$, as being tangent to site-specific average cost (C/S), the Chamberlinian tangency (Figure 3.9A). At this point, total revenue, $P_m \cdot S(P_m,N,D_o)$, equals total cost, C. Market equilibrium, where market-wide total revenues equal marketwide total costs, can now be expressed as,

$$N \cdot P_m \cdot S(P_m,N,D_o') = N \cdot C(N,S(P_m,N,D_o)). \qquad (3\text{-}41)$$

If there is a change in some exogenous variable, K, which alters P_m (such as the price of substitutes), then the impact on the market can be expressed as,

$$N \cdot (S(P_m,N,D_o') + P_m \cdot \frac{dS}{dP_m} + P_m \cdot \frac{dS}{dD_o'} \cdot \frac{dD_o'}{dP_m}) \cdot \frac{d_m}{dK}\, dK$$

$$+ (P_m \cdot S(P_m,N,D_o') + P_m \cdot N \cdot \frac{dS}{dN}) \frac{dN}{dK}\, dK$$

$$= N \cdot (\frac{dC}{dS} \cdot \frac{dS}{dP_m} + \frac{dC}{dS} \cdot \frac{dS}{dD_o'} \cdot \frac{dD_o'}{dP_m}) \cdot \frac{dP_m}{dK}\, dK$$

$$+ (C(N,S(P_m,N,D_o')) + N \cdot \frac{dC}{dN} + N \cdot \frac{dC}{dS} \cdot \frac{dS}{dN}) \frac{dN}{dK} \cdot dK. \qquad (3\text{-}44)$$

From (3-41), the two terms in (3-44) which are multiplied by dP_m/dK can be seen to sum to zero, and

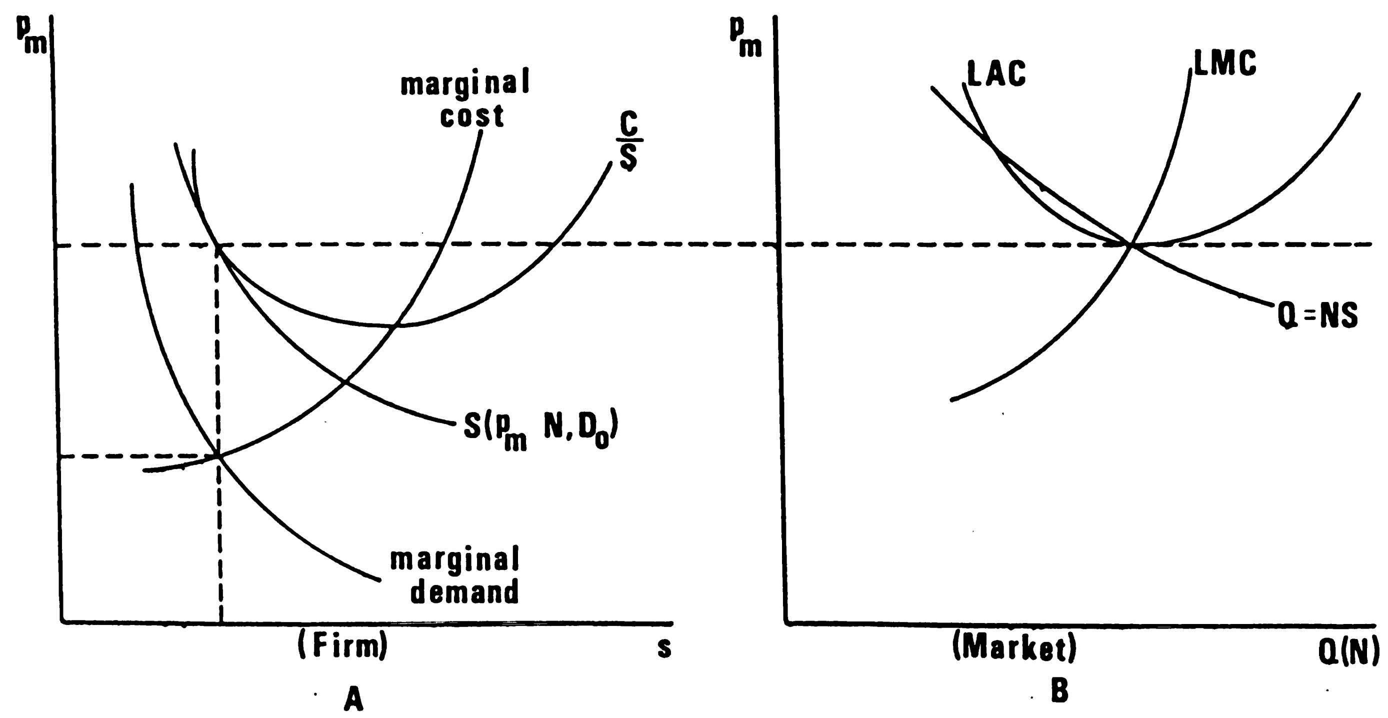

Figure 3.9 Zero Profit Equilibrium and Market-Wide Marginal Cost Pricing

$$[P_m \cdot (S(P_m,N,D_0') + N \cdot dS/dN)]\ dN/dK \cdot dK$$

$$- \quad [C(N,S(P_m,N,D_0')) + N \cdot dC/dN$$

$$+ N \cdot dC/dS \cdot dS/dN]\ dN/dK \cdot dK, \qquad (3\text{-}45)$$

and when $dN/dK \neq 0$ and from (3-38) where

$$S(P_m,N,D_0') + N \frac{dS(P_m,N,D_0')}{dN} = \frac{dQ}{dN},$$

$$P_m = \frac{C+N\cdot\ dC/dN + N\cdot dC/dS\cdot dS/dN}{dQ/dN} = \frac{dTC/dN}{dQ/dN}. \qquad (3\text{-}46)$$

For the zero profit equilibrium, the incremental cost of one additional firm, multiplied by the increment in the number of firms necessary to produce a unit change in output is equal to the marketwide mill price.

> "Thus, spatial firms are marginal cost pricers in long-run equilibrium. This price is greater than the plant-specific marginal cost of production, but the difference between price and this site-specific marginal production cost is the firm's share of a social cost. This social cost is a charge for the use of capital (and other inputs) to establish alternative locations."[Benson 1984, p.280]

Since all firms in the market break even and charge identical mill prices in the long-run, this price must be equal to marketwide long-run average cost (LAC) when it is at its minimum, where Q is changed by adding new plants. Therefore P_m also equals long-run marketwide marginal cost (LMC), again where Q is a function of N (Figure 3.9B).

3.7 Summary

The inclusion of a spatial dimension to individual demand results in condistions which are conducive to spatial price discrimination. Three distinct spatial pricing systems are described; discriminatory, uniform mill, and uniform delivered, and each is shown to involve freight absorption.

Competition over space is characterized by market entry at a distance and its comparative static results depend on how firms react to rivals, i.e. their conjectural price variations.

Finally, monopolistic market elements and the resulting Chamber-linian tangencies have often been pointed-out as prima facie evidence of market inefficiency. The inclusion of costs of establishing alternative locations as a social cost, to be borne by the market, results in long-run average industry cost being minimized.

CHAPTER IV

THE ANALYTICAL MODEL

4.1 Introduction

In Chapter II, the characteristics of milk production, fluid milk consumption, and marketing were presented. For production, these characteristics included perishability, seasonality, and highly specialized inputs. For consumption, they included variability, both seasonal and daily, continuous shifts in consumer tastes and preferences, and changes in the characteristics of the population.

Under various historical distributions of market power, which typically resulted in monopolistic behavior on the part of processors/dealers, producers were often left in precarious situations. The possession of a highly perishable product, which required many specialized inputs, by a large number of independent producers, gave the relatively small number of processors/dealers strong bargaining power. The resultant instability faced by producers supplying milk markets led to the enhanced strength of producer associations and eventually, in 1916, to a general 'milk strike' in the New York City milkshed, with similar actions in the Chicago area and elsewhere.

The spatial economic models of Chapter III showed that costly distance results in natural price discrimination. Even under situations which may be described as 'competitive', the spatial model contains naturally occuring monopolistic elements. Additionally, the spatial model reveals that the traditional implication of a Chamberlinian tangency as prima facie evidence of market inefficiency [Bressler] is unwarranted, when total market costs are considered. The point trading model where "prices between markets would differ by no more than transfer costs" [Babb et al., 1979, p.18], may well serve the analysis of inter-regional milk flows, but the intra-market model must account for monopolistic elements and the occurrence of freight absorption.

To accomplish this, a mathematical programming model of the dairy industry in the northeastern U.S. will be used. This model (Section 4.2) differs from previous point specifying models in its degree of spatial disaggregation. The imposition of pricing structures which are consistent with the spatial models of prices presented in Chapter III is done by parameterizing the costs of transporting milk from sources of supply to Class I processing locations.

4.2 The Northeast Dairy Sector Simulator

The Northeast Dairy Sector Simulator (NEDSS) was constructed under the auspices of the NE-126 regional research commitee [Pratt et al.] to provide a means of analysing changes in the spatial organization of the dairy industry in the northeastern U.S.

NEDSS is a transshipment and plant location model that combines network flow and facilities location methods. The model draws on the plant location formulation described by King and Logan in 1964 which has been used, in modified forms, in more recent dairy sector analyses [Beck and Goodin, Boehm and Conner, Buccola and Conner, Kloth and Blakley, McDowell, and Thomas and DeHaven]. It also builds on the plant location application discussed by Fuller et al., the transshipment model discussed by McLean et al., and the dairy sector networks constructed by Babb et al. 1977, and Novakovic et al.

NEDSS differs from its predecessors in the degree of its spatial disaggregation. NEDSSis highly disaggregated compared to similar models,duet the use of recently developed solution algorithms. Typically, plant location models have been forced to seriously restrict the size of the problems which they analyzed. This usually required limiting the numbers of possible supply or processing points or limiting the analysis to one storability class. Also, in many previous analyses, the movements of processed products from processing to consumption points were ignored.

The Northeast dairy sector is viewed at three market levels in NEDSS; these are referred to as supply, processing, and consumption. Raw milk production at the farm level is assumed to be homogeneous with respect to composition and quality, and suitable as input for any processed dairy product (Grade B milk, of which there is virtually none in the Northeast, is not included). At the processing level, milk is assumed to be processed into three dairy product groups: 1) fluid milk products (Class I under federal orders), 2) soft or perishable manufactured products (Class II under most federal orders), and 3) hard or storable manufactured products (Class III under most federal orders). All three product groups are assumed to be consumed at the retail level.

NEDSS is capable of simultaneously analyzing the optimal location of processing plants and corresponding optimal milk movements for each of the three product groups previously defined, by considering the cost of assembly, processing, and distribution among more than 1,500 economic units representing 284 geographic locations within the NEDSS study area. The study area includes 308 counties and independent cities located in fourteen northeastern states and the District of Columbia.

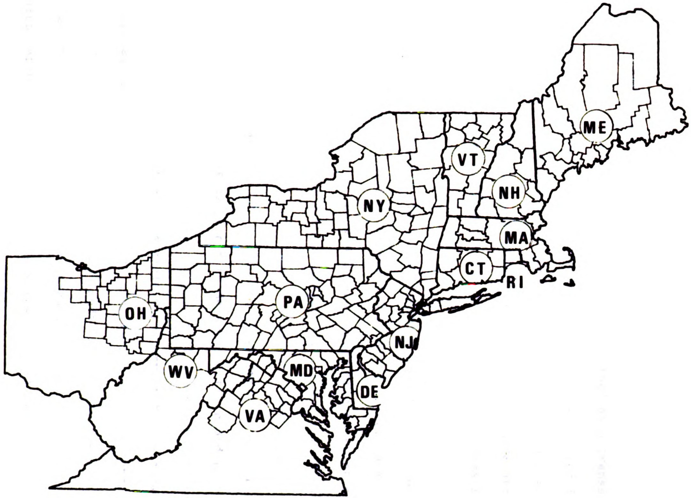

Figure 4.1 Counties and States in the NEDSS Study Area

Figure 4.1 depicts the study area. As currently implemented, NEDSS is a single time period model. The length of time is user determined. For this study, annual data are used.

Transshipment Formulation

The problem solved by NEDSS can be described as a transshipment problem. A transshipment problem is a network flow problem in which there are supply, demand, and transshipment nodes having positive, negative, and zero supply, respectively. In NEDSS, there are directed arcs from one node to another which are assigned a non-negative cost and capacity.

Figure 4.2 depicts the transshipment formulation of a problem very similar in concept to that represented by NEDSS. There are three unique geographic locations--A, B, and C--and supply originates at points A and B. There are also three product groups--I, II, and III--consumption of each exists at points A and C. Processing may occur at any of the geographic points A, B, or C. Product flows over the arcs from supply points through processing points to demand points in order to satisfy product demands. A flow is an assignment of non-negative values to each of the arcs. A solution is feasible with respect to the capacities and supplies if the flow on every arc is no larger than the capacity of that arc and the sum of flows out of any node is equal to the sum of flows into that node. The cost of the network is equal to the sum, over all arcs, of the flow on each arc times its cost. A transshipment problem is solved when a feasible solution of minimum cost is found.

In NEDSS, raw milk is aggregated at the farm level into geographic centers. These aggregation centers correspond to the supply nodes in the transshipment model (S_A and S_B in Figure 4.2). As in the case of farms, dairy processing plants are grouped into processing centers. The processing centers fall into three categories according to the type of finished product--fluid (I), soft (II), or hard (III) dairy products--into which the raw milk is converted. Each category forms a subset of the transshipment nodes. Each processing center may have a limit on the amount of raw milk which may be processed into each product type. Consumption of each product group is also grouped geographically into centers. Raw milk is shipped from the supply centers to the processing centers and from processing centers to the consumption centers subject to the following restrictions:

1) The amount of milk shipped from a supply center to the processing centers does not exceed the amount of milk originating at the supply center.

2) No processing center processes more raw milk than its capacity for any product type.

3) The summation of shipments from the processing centers to each consumption center meets the demand for each product type at each center.

There are transportation costs associated with shipments of the raw milk to the processors, as well as with shipments of the finished products to the demand centers. There is also a processing cost associated with each processing center, by product type. The model is solved when a set of shipments is found which satisfies the restrictions above while minimizing transportation plus processing costs.

For the purposes of the analysis reported in this publication, production and consumption at supply and consumption centers is estimated for the year 1980. Bulk milk transportation costs, processing costs for each product group, and final product transportation costs are estimated for 1980. These same costs are used in deriving least cost solutions for optimal plant locations, based on the supply and consumption estimates for 1980 and the spatial pricing systems described in Chapter III.

Many simplifying assumptions are made in the estimates, especially with respect to differences in production, consumption, and costs among the geographic points within the study area. These assumptions are necessitated primarily by a lack of information. For instance, it is assumed that raw milk originating at each geographic supply point is homogeneous. (Although virtually all milk in the Northeast is grade A, in reality, differences exist in the composition of milk across areas. These differences in fat and nonfat solids and other quality characteristics have implications for processing yields and conversion factors.) Per capita consumption of the various products which make up each product group are assumed to be the same throughout the study area. Transportation costs for raw milk and finished products as well as processing costs are assumed to be the same everywhere. These assumptions are made in the absence of information about different parameters among geographic points within the study area.

Supply

For the transshipment formulation of NEDSS, the study area's milk producing units were aggregated into subregions based on the 308 counties included in the study area. Basically, each county which had more than 1,000 dairy cows in 1978 defines a production region which is represented by a single geographic point within that county. Counties which had fewer than 1,000 cows were combined with neighboring counties to form multi-county subregions which were also represented by a single

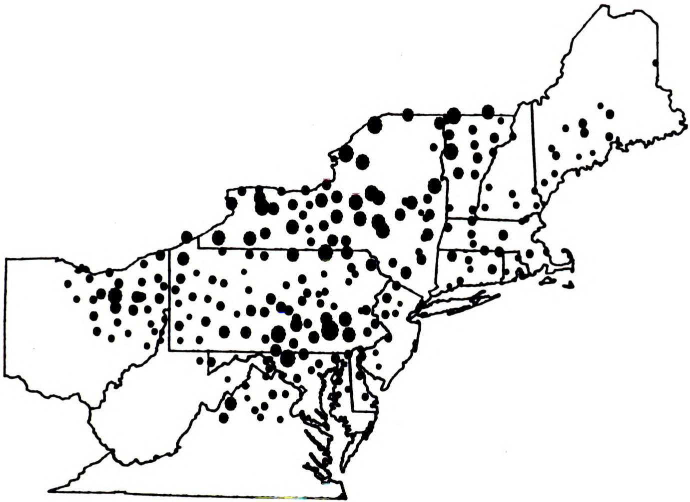

Figure 4.3 Supply Points Used in NEDSS

geographic point within the multi-county area. This aggregation process resulted in 236 geographic supply points being delineated (Figure 4.3), each geographic point corresponding to a node such as S_A or S_B in the transshipment network of Figure 4.2.

For the analysis reported herein, estimates of milk production for 1980 were required. Total 1980 milk marketings by northeastern states were obtained from the United States Department of Agriculture (USDA) Statistical Reporting Service (SRS), Crop Reporting Board (CRB), Table 4.1.

The 1980 state milk marketings are allocated to each state's counties according to that state's cow distribution as reported in the 1982 Census of Agriculture or by available 1980 county milk production estimates. These aggregated geographic supply point marketings for 1980 are used in the analysis reported in this publication. For the purpose of making conversions from raw milk to final products, raw milk is assumed to be 3.67% butterfat and 8.62% solids-not-fat.

Consumption

As with the supply sector of NEDSS, the study area's milk and milk product consuming units were aggregated into subregions. Beginning with the 100 most populous counties as aggregation points, the remaining counties were: 1) aggregated with one of the largest 100, 2) aggregated with other smaller counties into separate groups, or 3) left as single county subregions. This was done in a rather ad hoc fashion using county populations, geographic sizes, locations of major cities, and locations of major roads as guides. This aggregation process resulted in 141 geographic consumption points being delineated (Figure 4.4).

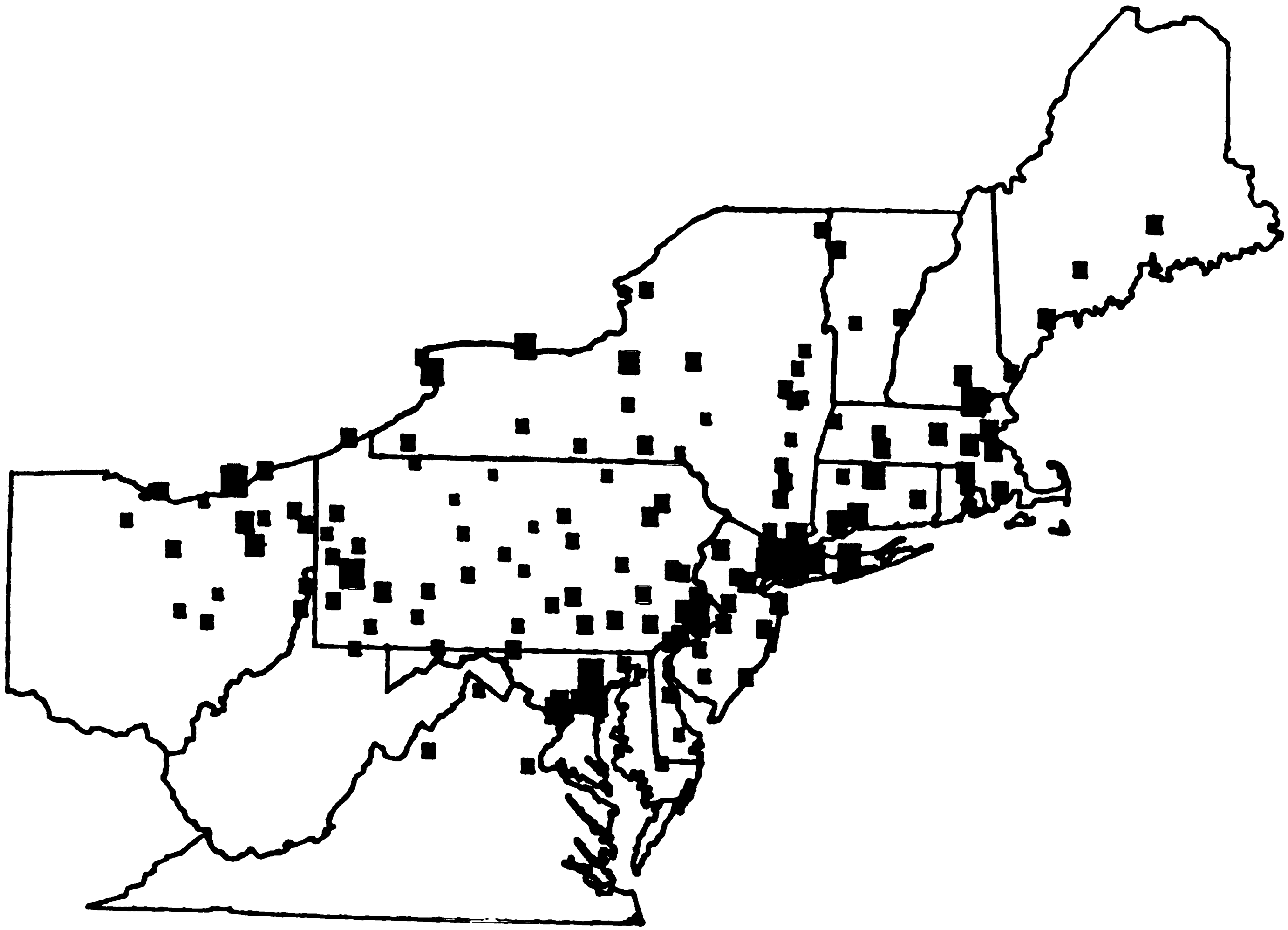

Figure 4.4 Consumption Points Used in NEDSS

Table 4.1. Estimated 1980 Milk Marketings in the NEDSS Study Area, by State.

State	1980 Total Milk[a] (100,000 lbs)
Connecticut	6,020
Delaware	1,230
Maine	6,530
Maryland	15,300
Massachusetts	5,600
New Hampshire	3,380
New Jersey	4,840
New York	107,490
Ohio[b]	24,250
Pennsylvania	83,940
Rhode Island	450
Vermont	22,450
Virginia[b]	7,930
West Virginia[b]	1,770

a/ "Total Milk Marketed by Producers", Milk Production, Disposition, Income 1979-81, USDA-SRS-CRB, May 1982, p.5.

b/ Includes only those counties which are in the study area.

Each geographic consumption point corresponds to a set of nodes such as $C^{I}{}_{A}$ - $C^{II}{}_{A}$ - $C^{III}{}_{A}$ or $C^{I}{}_{C}$ - $C^{II}{}_{C}$ - $C^{III}{}_{C}$ in the transshipment network in Figure 4.2, i.e. each geographic consumption point represents demand for each of the three dairy product groups.

A list of the primary products in each of the three product classes was assembled, using federal order classifications as a guide. Exceptions to the federal order classifications include the inclusion of yogurt in Class I and the inclusion of all ice milk in Class II. Table 4.2 lists the specific products included in the consumption component and the class in which each product is included.

Table 4.2. Products Included in NEDSS Demand Categories

Category	Included Products
Class I	Fluid Whole Milk Lowfat Milk (includes 2%, skim, buttermilk, flavored milk drinks, and yogurt)
Class II	Cream (includes half and half, light cream, heavy cream, and sour cream) Cottage Cheese Frozen Desserts (includes ice cream, ice milk, sherbet, and other frozen products)
Class III	Butter Total Cheese (includes American, Swiss, and Italian) Evaporated Whole Milk Condensed Skim Milk Dry Whole Milk Nonfat Dry Milk (NDM) Dry Buttermilk Whey

To convert the final products listed in Table 4.2 to units of raw milk necessary to produce these final products, two components of each product were used, fat solids (BF) and nonfat solids (SNF), using USDA standards.

The BF and SNF percentages for each product are shown in Table 4.3. Several of the product categories are combinations of more distinct products; lowfat milk, cream, frozen desserts, and cheeses. Component requirements for these categories are derived from weighted aggregations of their constituent products, as shown in Table 4.4.

Table 4.3. Percent Butterfat and Solids-Not-Fat in Each Product Category

	BF (%)	SNF (%)
Class I		
Fluid whole milk[a/]	3.4	8.99
Lowfat Milk[b/]	1.61	9.47
Class II		
Cream[c/]	17.10	8.32
Creamed cottage cheese	4.17	17.50
Frozen Desserts[d/]	10.58	9.48
Class III		
Butter	79.65	1.00
Total cheese[e/]	28.00	34.33
Evaporated whole milk	7.84	18.00
Condensed skim	.20	29.80
Dry whole milk	26.28	71.00
NDM	.79	96.20
Dry Buttermilk	5.26	91.90
Whey	.40	6.60

a/ The percents reported here were taken directly from USDA-ESCS,"Conversion Factors and Weights and Measures: For Agricultural Commodities and Their Products", Stat. Bul. 616, March, 1979.

b/ For the individual product weighting for the "lowfat milk" category, see Table 4.4.

c/ For the individual product weighting for the "cream" category, see Table 4.4.

d/ For the individual product weighting for the "frozen desserts" category, see Table 4.4.

e/ For the individual product weighting for the "total cheese" category, see Table 4.4.

Table 4.4. Calculations of Component Structures For Selected Product Categories

Product	1980*a/ Quantity	Relative Weight	BF*b/ (%)	SNF*b/ (%)
Lowfat Milk				
Lowfat milk	16,203	.71	1.88	9.04
Skim	2,673	.12	.55	9.95
Buttermilk	941	.04	.50	8.80
Drinks	2,313	.10	1.37	8.77
Yogurt	589	.03	1.66	21.09
	22,719	1.00	1.61	9.47
Cream				
Half & Half	562	.47	11.41	9.00
Light cream	55	.05	18.20	7.34
Heavy cream	149	.13	33.90	5.73
Sour cream	415	.35	18.35	8.50
	1,181	1.00	17.10	8.32
Frozen Dessert				
Ice cream	3,984	.67	13.89	9.00
Ice milk	1,609	.27	3.97	12.00
Sherbet	284	.05	1.99	2.00
Other	62	.01	10.00	11.00
	5,939	1.00	10.58	9.48
Total Cheese				
American	2,375,644	.66	30.25	30.50
Swiss	219,009	.06	25.19	33.60
Italian	982,607	.28	23.31	43.50
	3,577,260	1.00	28.00	34.33

a/ USDA-ERS, Dairy Outlook and Situation" DS-389, June 1982, Wash., D.C., Table-16, p.18.

b/ USDA-ESCS, "Conversion Factors and Weights and Measures; For Agricultural Commodities and Their Products", Stat. Bul. no. 616, March, 1979.

Having identified the primary products in each category and the BF and SNF component structure of each, per capita consumption estimates were used to derive per capita BF and SNF consumption for each class in 1980. Table 4.5 gives estimated per capita consumption of each NEDSS product category for 1980. Using these per capita consumption estimates and the percents BF and SNF from Table 4.3, the per capita consumption of final products can be broken down into per capita consumption of BF and SNF, which, in turn, can be aggregated for each class.

Table 4.5. Estimated Per Capita Consumption for Each Product Category, 1980

	Consumption (lbs/capita/year)
	1980
Class I	
Fluid whole milk	145
Lowfat milk	96.3
Class II	
Cream	5.7
Cottage cheese	4.5
Frozen desserts	26.4
Class III	
Butter	4.5
Total cheese	22.1
Evaporated milk	3.7
Condensed Skim	3.3
Dry whole milk	.3
Nonfat dry milk	2.9
Dry buttermilk	.2
Whey	2.7

Source: Hahn and Wu

Table 4.6 gives the results of this calculation. In Table 4.6, the numbers represent the amounts of BF and SNF contained in the products included in each class. For example, one year's per capita consumption of Class I products in 1980 requires 6.48 pounds of BF and 22.16 pounds of SNF. Similar interpretations apply to Class II and Class III products.

Table 4.6. Equivalent Per Capita Consumption for Each Product Category, 1980

	Consumption (lbs BF and SNF/capita/year)	
	1980	
	BF	SNF
Class I		
Fluid whole milk	4.93	13.04
Lowfat milk	1.55	9.12
	6.48	22.16
Class II		
Cream	.97	.47
Cottage cheese	.19	.79
Frozen desserts	2.79	2.50
	3.95	3.76
Class III		
Butter	3.58	.05
Total cheese	6.19	7.59
Evaporated milk	.29	.67
Condensed Skim	.01	.98
Dry whole milk	.08	.21
Nonfat dry milk	.02	2.79
Dry buttermilk	.01	.18
Whey	.01	.18
	10.19	12.65
	20.62	38.57

The amount of raw milk needed to furnish the components for each class is determined relative to a standard of 3.67% BF and 8.62% SNF in raw milk. This results in two numbers for each class, representing the amount of raw milk (in cwts.) necessary to furnish the required amount of BF or SNF to equal the BF or SNF content of products consumed on an annual per capita basis. Table 4.7 gives the results of this calculation. The higher of the two figures for each class represents the actual amount of raw milk needed.

Table 4.7. Per Capita Consumption for Each Product Class, Converted to Raw Milk Equivalents in Hundredweights

	Consumption (lbs Raw Milk/Capita/Year) 1980	
	BF	SNF
Class I		
Lbs of component	6.48	22.16
Raw milk equiv. (cwt.)	1.77	2.57
Class II		
Lbs of component	3.95	3.76
Raw milk equiv. (cwt.)	1.08	.44
Class III		
Lbs of component	10.19	12.65
Raw milk equiv. (cwt.)	2.78	1.47

a/ Raw milk equivalent on a butterfat basis is calculated by dividing pounds of component by 3.67 (average pounds of BF per 100 pounds of milk); raw milk equivalent on a solids-not-fat basis is calculated by dividing pounds of component by 8.62.

This procedure, absent any mechanism for interclass transfers of components, overstates the effective demand for raw milk since Class I is relatively SNF intensive while Classes II and III are relatively BF intensive. Thus, excess BF from Class I can be (and in practice often is) used in Class II and/or III products.

Since NEDSS is a single commodity network model, all demands for products, supplies of milk, plant capacities, and unit costs must be specified in the same units. There is no explicit allowance made for interplant shipments of by-products, such as BF in the form of cream, from Class I to Class II plants and such as SNF, in the form of skim, from Class III to Class I plants.

Some of this overestimation can be avoided by reducing Class II demand to reflect the excess fat available in Class I. For example, from Table 4.7, the 2.57 cwts. of raw milk necessary to provide the 22.16 lbs. of SNF needed in Class I also provides 9.4319 lbs. of fat (257 x .0367) which is 2.9519 lbs. more than is needed in Class I (9.4319 - 6.48). This extra Class I BF is assigned to Class II demand, reducing Class II BF needs to .9981 lbs. (3.95 - 2.9519), which would require only .27 cwts. of raw milk to provide. Class II becomes SNF intensive, requiring .44 cwts. of raw milk to provide the necessary SNF. Table 4.8 summarizes the results of such an adjustment for 1980.

Table 4.8. Per Capita Consumption of Product Categories, Adjusted for Class I-Class II Butterfat Transfers (cwts raw milk/capita/year)

	1980
Class I	2.57
Class II	.44
Class III	2.78

Once the per capita consumption of each product class has been determined, these results can be multiplied by the 1980 population figures for each of the 308 counties and then aggregated to the 141 demand points.

For 1980, county population estimates were taken from the U.S. Bureau of the Census. Table 4.9 gives an indication of the estimated production and consumption balance for 1980. As can be seen, the NEDSS area is estimated to be a deficit area with respect to total supply and consumption. NEDSS is structured to permit the importation of milk to any processing center or of dairy products to any consumption center. These potential imports, in either form, are assumed to come from the midwestern U.S. through Sandusky, Ohio. Given the relative base marketing costs, simulated flows usually result in significant levels of Class III products entering the study area at Sandusky for distribution to consumption points.

Table 4.9. Total Marketings and Consumption Estimates for the NEDSS Study Area

	1980
	(mil. lbs.)
Marketings	29,118
Imports	6,711
	35,829
Consumption	
Class I	15,903
Class II	2,723
Class III	17,203
	35,829
Consumption as a percent of Marketings	1.23%

Marketing Costs

Where production ends and marketing begins is often arbitrarily defined. For purposes of NEDSS, marketing will include costs of raw product assembly, of finished product distribution, and of processing. In fact, it is the sum of the foregoing costs that NEDSS will minimize, given the quantities and locations of both raw milk production and final product consumption that are estimated for the Northeast. Information pertaining to each of the three categories of marketing costs are presented below.

Assembly of Raw Milk

Dairy producers are assessed a wide range of hauling charges. Hauling rates vary according to farm location, milk volume, and the competitive environment. During the past decade, several studies of the costs of transporting bulk and packaged milk have been conducted. In virtually all of these studies, transportation costs were synthesized from information obtained from trucking firms and milk equipment dealers, and then applied to specific truck sizes. The results of these studies make it apparent that no one transportation function can accurately reflect transportation costs in all situations. Differences in initial truck costs, labor and fuel costs, driving conditions, and maintenance policies all affect transportation costs for a specific haul. Unfortunately, NEDSS cannot conveniently incorporate the complete set of cost functions that would be necessary to fully reflect all the differences in costs that seem to exist, except those directly related to geographic location and distances between locations. It was decided, lacking reliable descriptive information about possible regional differences, to use just one representative function that would simply relate cost of milk assembly to the distance the milk is hauled. Based on budgeted bulk milk hauling costs [Pratt et. al.], estimated 1980 bulk milk assembly costs, in cents/cwt., used in NEDSS are:

13.45 + .578 x (one-way miles)

Distribution of Finished Products

Tractor-trailer operating costs per driven mile and per unit of product hauled were compiled using vehicle leasing rates obtained from 20 firms located in the Northeast. Costs per unit of product were estimated using actual and model transportation systems of milk processors. Comparisons were made of costs for the New England and the Middle Atlantic areas. Projections of costs were also made for 1985.

The cost of operating a leased tractor-trailer in 1980 was estimated at 99.5 cents per mile, assuming an annual use of 50,000 miles. Substantial reductions in cost occur with higher levels of use.

Tractor-trailer and driver costs were $1.31 per mile for trips up to 300 miles and $1.36 to $1.38 per mile for trips of 300 to 600 miles. Costs per mile were $1.27 in New England and $1.34 in the Middle Atlantic states for round trips of up to 300 miles (from plant to destination and return).

Transport costs (for vehicle and driver) for 100 pounds of load were 37 cents for a 35,000 pound load hauled 100 miles and $2.33 for this load hauled 600 miles round trip. With a 40,000 pound load, these costs were 33 cents and $2.03 per hundredweight, respectively.

Transport costs developed for model delivery systems were 88 cents per hundredweight of fluid milk on a 200 mile round trip with a 1,000 case load. The cost was $1.10 per hundredweight of product to make a 200 mile round trip with a 6,000 gallon load of ice cream. For butter, the cost was $2.01 per hundredweight of 35,000 pound units hauled 400 miles round trip.

The regression of cost per hundredweight of product with distance, load, and truck use indicated that distance and truck use accounted for most of the variation in hauling costs. The regression with distance alone indicated that .351 cents per mile of round trip distance would reflect the cost of hauling a hundred pounds of fluid milk. For ice cream, .418 cents per cwt. per mile would equal this cost per cwt. The cost for butter would be 10.3 cents per cwt. plus .388 cents per mile. Results of similar regressions provided the bases for estimating costs for the New England and the Middle Atlantic states areas.

The equations, expressed in one-way, loaded miles are:

fluid milk (¢/cwt. of final product)	=	.702 x distance
ice cream "	=	.836 x distance
butter "	=	10.31 + .776 x distance

Because of NEDSS' single commodity structure, these final product costs must be converted to a raw milk equivalent basis. To do this, conversion factors of milk to final product were derived from Table 3.

1 pound of fluid milk	=	1.04 pounds of raw milk
1 pound of ice cream	=	3.78 pounds of raw milk
1 pound of butter	=	21.7 pounds of raw milk

Converting the distribution cost per pound of final product to a milk equivalent basis yields:

fluid milk (¢/cwt.)	=	241 + .675 x distance
ice cream "	=	.221 x distance
butter "	=	.475 + .036 x distance

These equations are incorporated into the NEDSS model to generate distribution costs for each product category for each plant location to every possible geographic point of consumption.

As defined above, transportation cost for moving raw milk from production points to processing points and finished products from processing points to consumption points is a function of the distance travelled. Generally, there are $(N^2 - N)/2$ distances which must be derived in some way for N points. For this problem, with 284 distinct geographic points, there are 40,186 such distances to be determined.

To determine all of these distances by hand would be an enormous task susceptible to significant error. Fortunately, a method exists whereby this task can be reduced to manageable proportions. Shortest path algorithms [Gilson & Witzgall] need only information on the distance between adjacent points in a network in order to find the shortest distance between any two points. Thus, by simply making measurements of the approximately 750 distances between adjacent points in the appropriate road network connecting all of the 284 geographic points used in NEDSS, it was possible to use a shortest path algorithm to quickly and efficiently determine the 40,186 distances which are needed to determine all possible transportation costs.

Processing

Processing of each class of product is allowed to take place at any of the 284 geographic points which are the union of the production points and consumption points, as shown in Figures 4.3 and 4.4. The choice of processing locations can be constrained or selected by the model in a cost-minimizing fashion. In all of the analyses reported in this study, NEDSS is allowed to determine the optimal location and size of processing plant for each product group. None of the reported analyses constrain processing locations or sizes.

Since NEDSS includes estimates of milk consumption in three product categories, it was appropriate to construct estimates of the cost of converting raw milk into each product category so that the optimal numbers and location of plants to service those markets could be ascertained.

Fluid milk processing, and soft and hard products manufacturing cost functions were developed for 1980 by synthesizing and updating several earlier NE-126 cost studies [Fischer, Lasley and Sleight, Metzger, and Smith]. The average cost functions that are incorporated in NEDSS for the analyses presented here are:

fluid (Class I)

$$AC_f = 224.25 + 427.54 \times (1/\sqrt{V})$$

hard products (Class III)

$$AC_h = -43.84 - 3860.72 \times (1/V) + 2537.68 \times (1/\sqrt{V})$$

soft products (Class II)

$$AC_s = 0.8 \times AC_f + 0.2 \times AC_h.$$

All functions yield the average cost of processing raw milk in cents per hundredweight, and V is 100,000 pounds of raw milk processed, on a monthly basis. Table 4.10 lists costs for each type of plant for representative volumes processed. Each function shows average costs of processing decreasing at a decreasing rate, characteristic of the typical relationship between output and unit costs.

Table 4.10. Average Cost of Processing Raw Milk Into Fluid, Soft, and Hard Manufactured Products, 1980[a/]

Monthly Volume of Raw Milk	Type of Plant		
	Fluid	Soft	Hard
(pounds)	(cents per cwt.)		
250,000	495	--	--
500,000	415	--	--
1,000,000	359	--	--
2,500,000	310	310	309
5,000,000	285	276	238
7,500,000	274	259	198
10,000,000	267	248	171
12,500,000	262	240	152
15,000,000	259	235	137
17,500,000	257	231	126
20,000,000	254	226	116
22,500,000	253	224	108
25,000,000	251	221	101
27,500,000	250	219	95
30,000,000	249	217	90
35,000,000	247	216	90
40,000,000	246	215	90
45,000,000	244	213	90
50,000,000+	243	212	90

a/ Based on the formulas presented in the text above.

While complete information about actual assembly and distribution movements for milk and products in each class is generally unavailable, actual plant locations and estimates of aggregated plant throughput were obtained in order to provide a basis for comparisons of actual and simulated plant locations. A list of 595 dairy processing plants operating within the NEDSS study area in 1982 was compiled. Each plant was then categorized with respect to its major product; fluid, soft, or hard dairy products [Table 4.2]. The plants in each category were combined into groups of three or more, based on their geographic locations. With the aid of the Dairy Division of the Agricultural Marketing Service of USDA, state milk marketing officials, and university staffs, estimates of processing capacity for the resulting 80 fluid processing groups, 10 soft product groups, and 17 hard product groups were made. Figures 4.5-4.10 depict the actual plant locations and the locations of the chosen aggregation points for each product class.

In general, the figures indicate that actual and weighted, i.e., aggregated, Class I processing locations, while numerous, tend to be concentrated in areas with large populations. Class I processing capacity tends to follow the geographic distribution of population. Class II processing capacity is divided between the major metropolitan areas of Boston, New York City, and Philadelphia and major supply areas in northern and western New York, western Ohio, and south-central Pennsylvania. Class III processing capacity tends to follow more closely the major supply areas of northern Vermont, northern and western New York, western Ohio, and south-central Pennsylvania, with relatively little capacity located in the major metropolitan areas.

Numerical Implementation

To allow for consideration of processing capacities, the network formulation depicted in Figure 4.2 needs to be modified as shown in Figure 4.11. A second set of processing nodes has been added to the structure so that a single arc goes from each processing node to a corresponding 'dummy', D, processing node. These arcs allow for the inclusion of a capacity limitation or constraint (cap. = i) and a processing cost (RI_i, RII_i, $RIII_i$). The number in parentheses at the

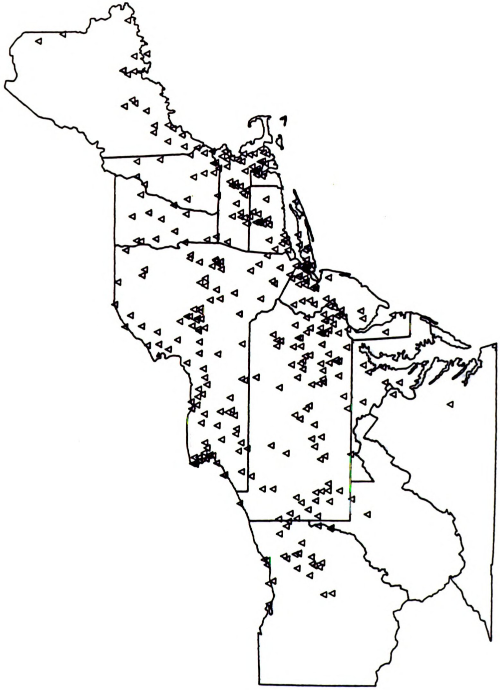

Figure 4.5 Actual Locations of Fluid Product Processing Plants

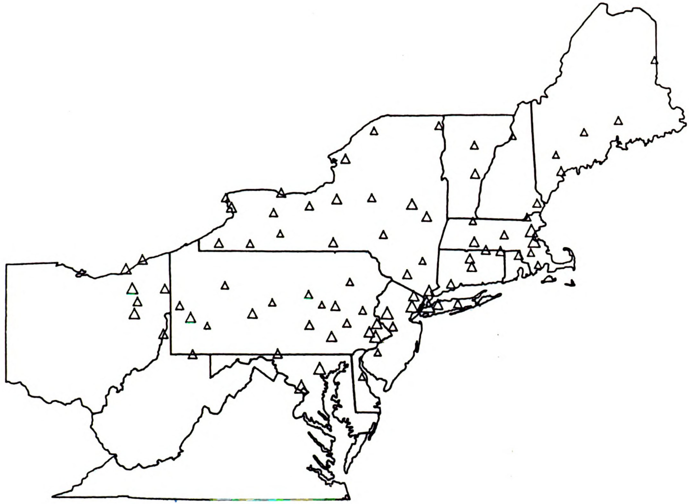

Figure 4.6 Locations of 80 Aggregated Fluid Product Processing Centers Estimated for the NEDSS Study Area

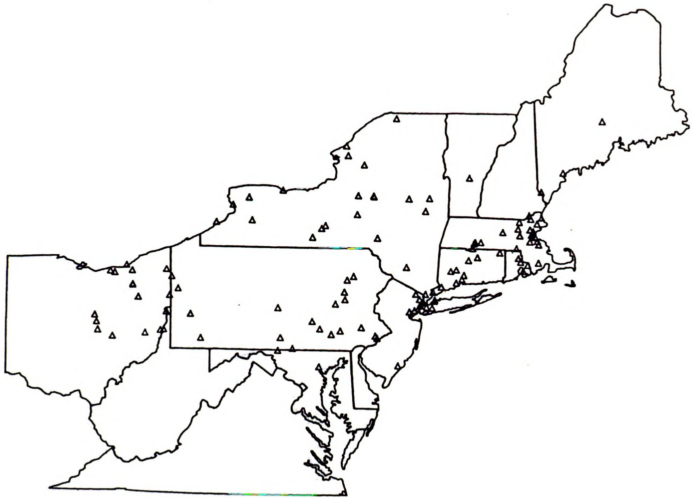

Figure 4.7 Actual Locations of Soft Dairy Product Processing Plants

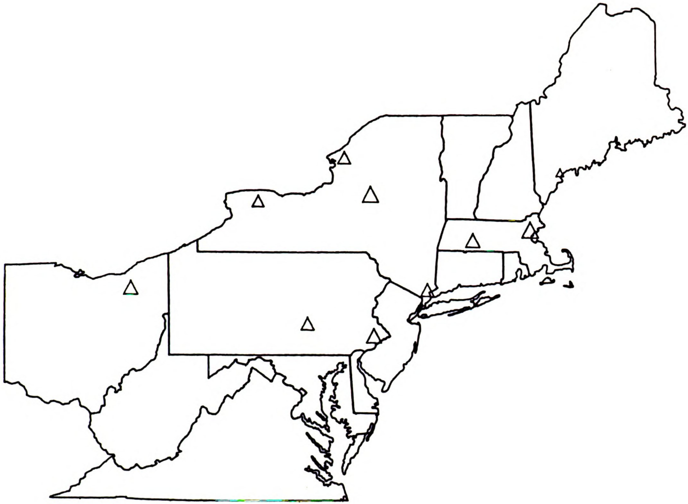

Figure 4.8 Locations of 10 Aggregated Soft Dairy Product Processing Centers Estimated for the NEDSS Study Area

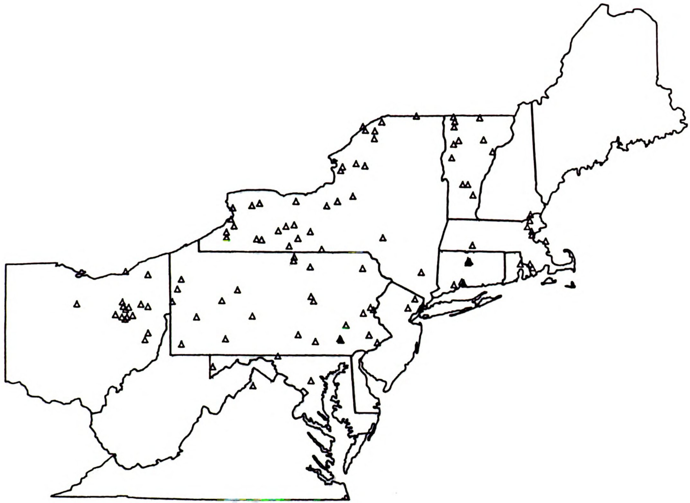

Figure 4.9 Actual Locations of Hard Dairy Product Processing Plants

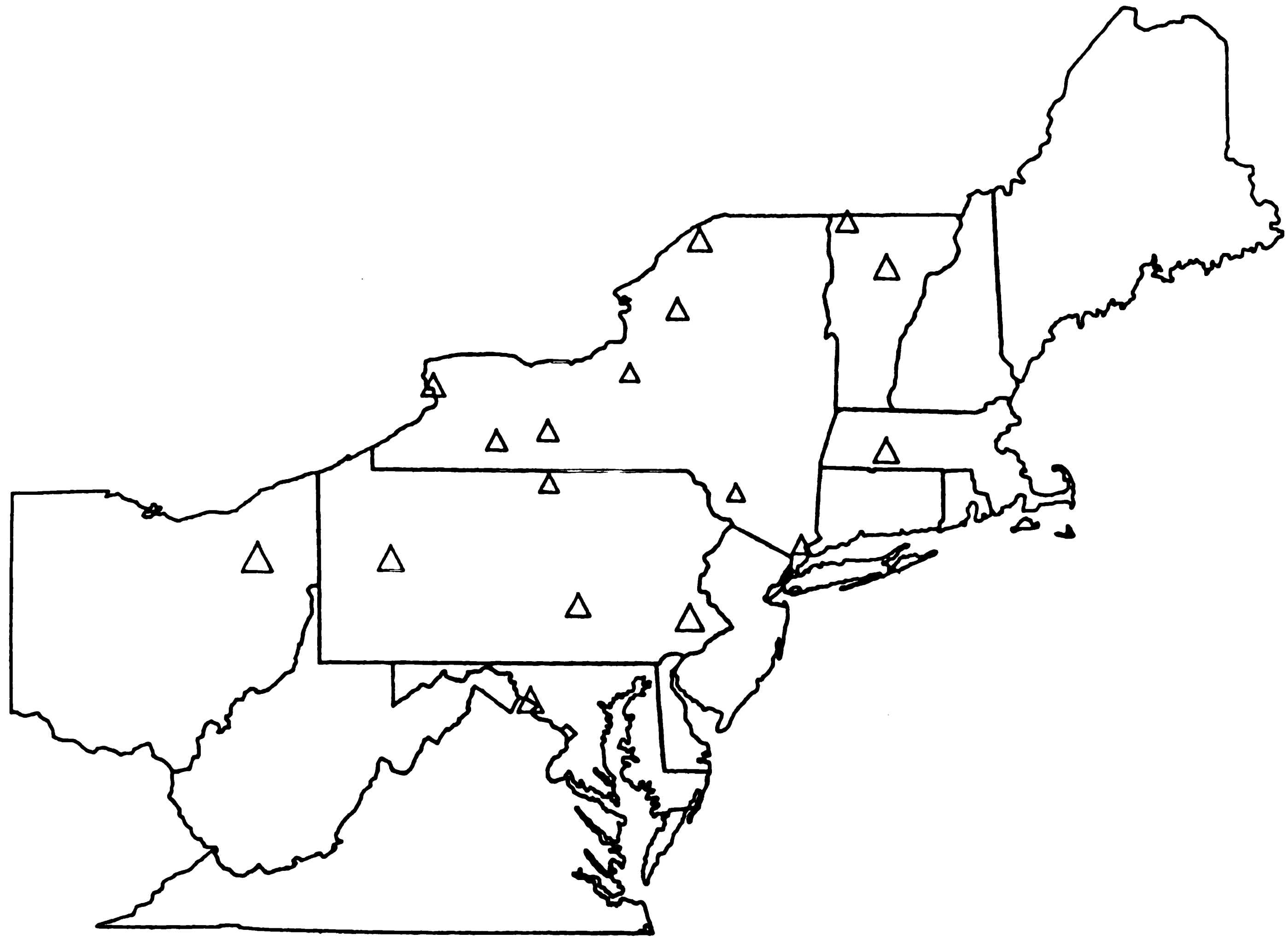

Figure 4.10 Locations of 17 Aggregated Hard Dairy Product Processing Centers Estimated for the NEDSS Study Area

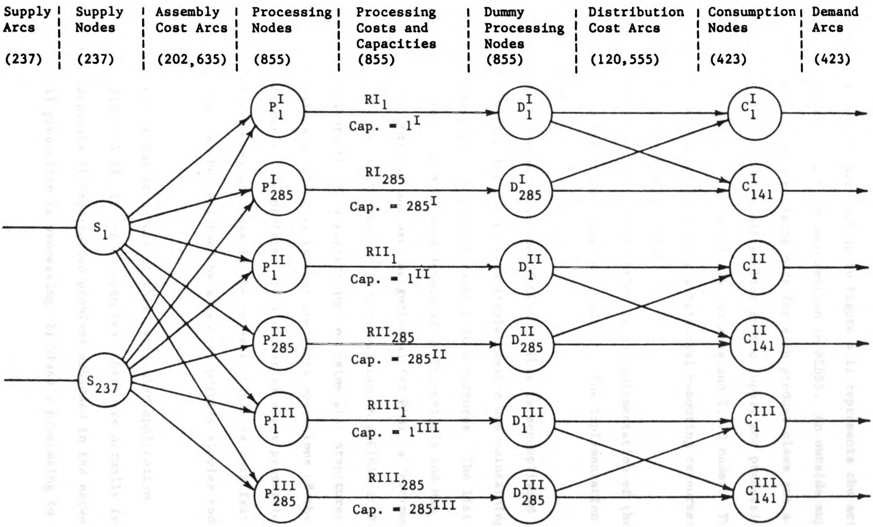

Figure 4.11 Network Representation of NEDSS

top of each node or arc section in Figure 4.11 represents the actual number of nodes or arcs in each section in NEDSS. An outside supply node and an outside processing node for each product class are added to the number of nodes described earlier in the supply and processing sections. There are a total of 324,705 arcs and 2,370 nodes. This is a very large problem which requires substantial computing resources simply to generate, as well as to solve.

The network solver used in NEDSS is an implementation of the primal simplex method for linear programs [Jensen]. The implementation takes advantage of:

1) the network structure of NEDSS. This is accomplished by implementing the revised simplex method and maintaining the basis and its inverse using list structures. The list structures used are those developed by Grigoriadis and Hsu [Grigoriadis and Hsu, Grigoriadis] for RNET, a "minimum cost network flow" computer program written in FORTRAN at Rutgers University. The significance of using list structures to maintain the basis is that the pivot operations of the simplex method can be performed in a number of steps proportional to the number of nodes in the network. This is much faster than they can be performed by a general purpose simplex code.

2) the unique structure of this particular application. In Figure 4.11, it can be seen that there are actually four separate transportation problems embedded in the network: 1) production to processing, 2) Class I processing to Class I

consumption, 3) Class II processing to Class II consumption, and 4) Class III processing to Class III consumption. Each of these sections is "bipartite", i.e., the set of nodes can be partitioned into two subsets so that all arcs begin in one set and end in the other. This information may be used to store the endpoints, (FROM(i) and TO(i)), of an arc (i), as functions or subroutines with very efficient internal storage processes that are independent of the size of the problem.

3) the small percentage of arcs which are capacitated. From the problem description, the only arcs which are capacitated are the processing arcs. There are fewer of these arcs than there are nodes in the network. This observation is used to store the capacities as a function with internal storage equal to the number of processing nodes plus some amount independent of the problem size.

The exploitation of these special properties (along with the implementation of a program capability for using prior feasible solutions as initial, restart solutions for a subsequent problem) allows for the efficient solution of this very large problem.

NEDSS can be operated in several different modes with respect to processing capacities and processing costs: 1) processing capacity at any potential location may be assumed to be unlimited and processing costs per unit can be assumed to be constant with respect to volume processed, 2) processing capacities at each potential processing location may be constrained to some amount and processing costs assumed constant, 3) processing capacities can be unlimited with processing costs per unit assumed to decline with increased volume, and 4) processing capacities can be constrained and processing costs assumed to decline. When operated with variable processing costs. For all the results reported in Chapter V, NEDSS is not guaranteed to find the global optimum solution [King and Logan] due to the inclusion of nonlinear processing costs which are introduced by economies of scale in processing. An iterative heuristic procedure is used to find an approximate solution.

The usual avenue of approach to analysis of intermarket trading problems is to specify production and consumption quantities or functions, marketing costs, and any applicable constraints and then to solve for approximate, cost minimizing flows and corresponding prices. For this analysis, it is proposed to start with this cost minimizing problem formulation and then to extend it by the use of pre-determined pricing systems, which will be imposed on processors as additional marketing costs. The pricing structure will be based on the three spatial pricing systems presented in Chapter III.

The Minimum Transportation Cost Scenario

For this problem, estimated 1980 supplies (Table 4.1), consumption (Tables 4.7 and 4.8), and bulk and processed product transportation costs (see earlier sections) are used. The processing of products is not constrained to occur at any particular locations. Processing of each class of product may take place at any of the 284 geographic points which are the union of the production points and consumption points (Figures 4.3 and 4.4). For these potential processing points, capacities of each product processed at a particular location are not restricted. In addition, the processing costs of each location are made a function of the volume of milk processed at that location (Table 4.10). In this way, if the processing cost reductions due to increased volume processed at a particular location are larger than the increased assembly and distribution cost incurred by assembling and distributing over a larger area, NEDSS will increase the location's volume. This scenario is intended to represent NEDSS's "idealized" or "rationalized" organization of the processing and transportation of milk and milk products for 1980.

4.3 The Proposed Analysis

Typically, it is assumed that the markets which are being modelled in a spatial mathematical programming framework are ones in which competition prevails, i.e., that there is but one price in each market. Subject to the market clearing constraints, a solution to the transportation cost minimization problem also solves the maximum valuation problem. If market coordination is directed toward minimizing transportation costs, then producers will receive the largest possible net returns.

As was seen in Chapter III, however, the spatial economy is distinguished by a natural tendency toward monopolistic behavior, where price discrimination and freight absorption will be a natural element under various spatial pricing methods. Under conditions of spatial competition, where a firm may find that its market is bounded at some distance which is less than the optimum, it may still find absorption advantageous. As such, market transportation cost minimization may be an inappropriate objective function.

4.4 Summary

The specification of each spatial pricing system in NEDSS is accomplished by modifying the objective function values for bulk milk movements from supply points to Class I processors. These values can be considered as the actual differentials which processors face, rather than the total costs of transportation.

Under discriminatory pricing, actual transportation costs are modified by reducing all possible transportation costs from supply to Class I processors to a proportion of their estimated values. The proportion represents the percent of freight absorption. For example, reducing all Class I supply costs to 30% of their estimated values, implies a 30% rate of freight absorption. At 100%, the discriminatory and base pricing scenarios are identical.

Under uniform mill pricing, objective function values associated with movements of milk from supply to Class I processing are specified as a constant amount, limited to the actual transportation costs for each particular movement. As the constant is increased, that is, as the fixed rate of freight absorption increases to a level as high as the highest estimated transportation cost, the uniform mill prices and the base prices approach each other.

Under uniform delivered pricing, objective function values associated with Class I supply movements are all reduced by a constant amount. These reduced values are limited to a level of 1¢ for each 75 miles. As the constant amount of reduction approaches zero, the uniform delivered prices approach the base prices.

In Chapter V, the three spatial pricing systems described in Chapter III are specified and a variety of parametric solutions to NEDSS are obtained. Based upon estimated bulk milk transportation costs, the levels of FMMO location differentials, and on an implied rate of freight absorption, a single discriminatory pricing solution is selected for comparison to the base scenario. Particular uniform mill and uniform delivered pricing solutions are also chosen such that the total marketing costs of the chosen solutions nearly equal that of the chosen discriminatory solution. Plant locations, milk and milk product movements, and marketing costs for each of the chosen solutions are compared to the base solution.

Chapter VI summarizes the results of the comparisons among spatial pricing solutions and draws conclusions based upon these results.

CHAPTER V

ECONOMETRIC ANALYSIS AND RESULTS

5.1 Introduction

Using NEDSS, a mathematical programming model of the spatial organization of the northeastern U.S. dairy industry, three spatial pricing systems for pricing Class I milk supplies are analyzed. For each class of milk product, the impacts of spatial pricing on optimal plant locations and milk and milk product movements are investigated. Each pricing system is characterized by freight absorption, whereby neither Class I milk processors nor producers pay the full amount of transportation costs, but each pays only a portion. In the mathematical model, where the locations and levels of milk supplies are given and fixed, prices specified under each of the three pricing systems determine the geographic price surface, or gradient, which, in turn, determines optimal plant locations and milk and milk product movements.

A base, cost minimizing, solution of NEDSS is compared to a solution from each of the three spatial pricing systems described in Chapter III: discriminatory, uniform mill, and uniform delivered. A number of solutions for each pricing system are obtained and reported. However, only a single solution from each pricing system is chosen for comparison to the cost minimizing, base scenario. The solutions which are chosen for comparison are chosen such that each results in total marketing costs (assemble, processing, and distribution) which are nearly equal.

The specification of each pricing system is accomplished by modifying the objective function of NEDSS to reflect each particular pricing structure. For each analyzed structure, the cost of transporting bulk milk from supply points to Class I processing locations is modified. These costs are then considered as the actual differentials faced by Class I processors, rather than the marketwide bulk milk hauling costs. All other costs remain as specified in Chapter IV.

In the sections which follow, the particular specification of each of the spatial pricing systems in NEDSS and the resulting solutions are described. Comparisons of physical characteristics as well as marketwide costs between the pricing systems are made.

5.2 Base

To provide a standard of comparison, the parameters described in Chapter IV are specified and a solution to NEDSS is obtained which represents an idealized, total marketing cost minimizing solution. In this problem, the markets for all three storability classes are assumed to function in concert to minimize total marketing costs. Tables 5.1 to 5.3 and Appendix Figures B.1 to B.6 describe this cost-minimizing solution.

As expected, fluid milk processing plants (indicated by triangles in Appendix Figures B.1 and B.2), locate at or near the consumption centers (indicated by squares) which they serve. These plants must then reach out from these consumption centers to obtain their required milk supplies (indicated by circles). The consumption orientation of Class I processing is apparent from the relatively large number of processing sites and distinct assembly movements and the much longer average

Table 5.1 Summary Characteristics of Milk Assembly for Each Product Class: Base Solution

	CLASS I	CLASS II	CLASS III
Movements			
Number*	185	10	35
Distance (miles)			
Weighted Average**	62.4	15.0	10.1
Longest	220	81	73
Cost			
Total ($1,000)	7,782	584	1,972
Average (¢/cwt)	49.0	21.6	18.8

*Represents only those movements between two distinct geographic points.

**Includes all movements.

Table 5.2 Summary Characteristics of Processing for Each Product Class: Base Solution

	CLASS I	CLASS II	CLASS III
Number of Locations	69	7	19
Pounds Processed (100,000)			
Total			5,509
Average	2,303	3,867	9,515
Largest	24,871	7,865	2,365
Smallest	253	1,298	
Cost			
Total ($1,000)	40,106	5,892	9,522
Average (¢/cwt)	252.4	217.6	91.0

Table 5.3 Summary Characteristics of Product Distribution for Each Class: Base Solution

	CLASS I	CLASS II	CLASS III
Movements			
Number*	74	144	158
Distance (miles)			
Weighted Average**	12.8	152.7	381.2
Longest	108	349	822
Cost			
Total ($1,000)	39,644	898	2,329
Average (¢/cwt)	249.4	33.2	13.6

*Represents only those movements between two distinct geographic points.

**Includes all movements.

assembly distances as well as the much shorter average distribution movements. The large number of assembly movements are indicated in Appendix Figure B.1, while the relatively few distinct point-to-point distribution movements are indicated in Appendix Figure B.2.

Class II (Appendix Figures B.3 and B.4) and Class III (Appendix Figures B.5 and B.6) plants locate at a distance from the major consuming areas, toward the major sources of milk supplies, minimizing the number and distance of relatively expensive assembly movements. This results in a relatively large number of distribution movements between points.

As noted in Chapter IV [Table 4.9], a deficit in total milk supply is filled by the importation of Class III products from the midwestern U.S. through Sandusky, Ohio [Appendix Figure B.6].

The base solution also provides shadow prices, or imputed values, for milk delivered to processing plants. These shadow prices indicate the value of an additional hundred pounds of milk delivered to a plant. The shadow prices at the optimal Class I processing locations can then be used to map the optimum, market cost-minimizing Class I price gradient for the study area. Figure 5.1 indicates these shadow prices (normalized to zero at Altoona, Pa.) and visually estimated positions of isovalue lines at 30-cent intervals.

These imputed Class I values are highest in the New York-New Jersey-Connecticut-Boston area and fall as the distance from this population corridor increases. The highest differential is 149 cents on Long Island. Somewhat isolated population centers, closer to milk supplies, such as Buffalo, Pittsburgh, and Syracuse lay at much lower levels on the price surface.

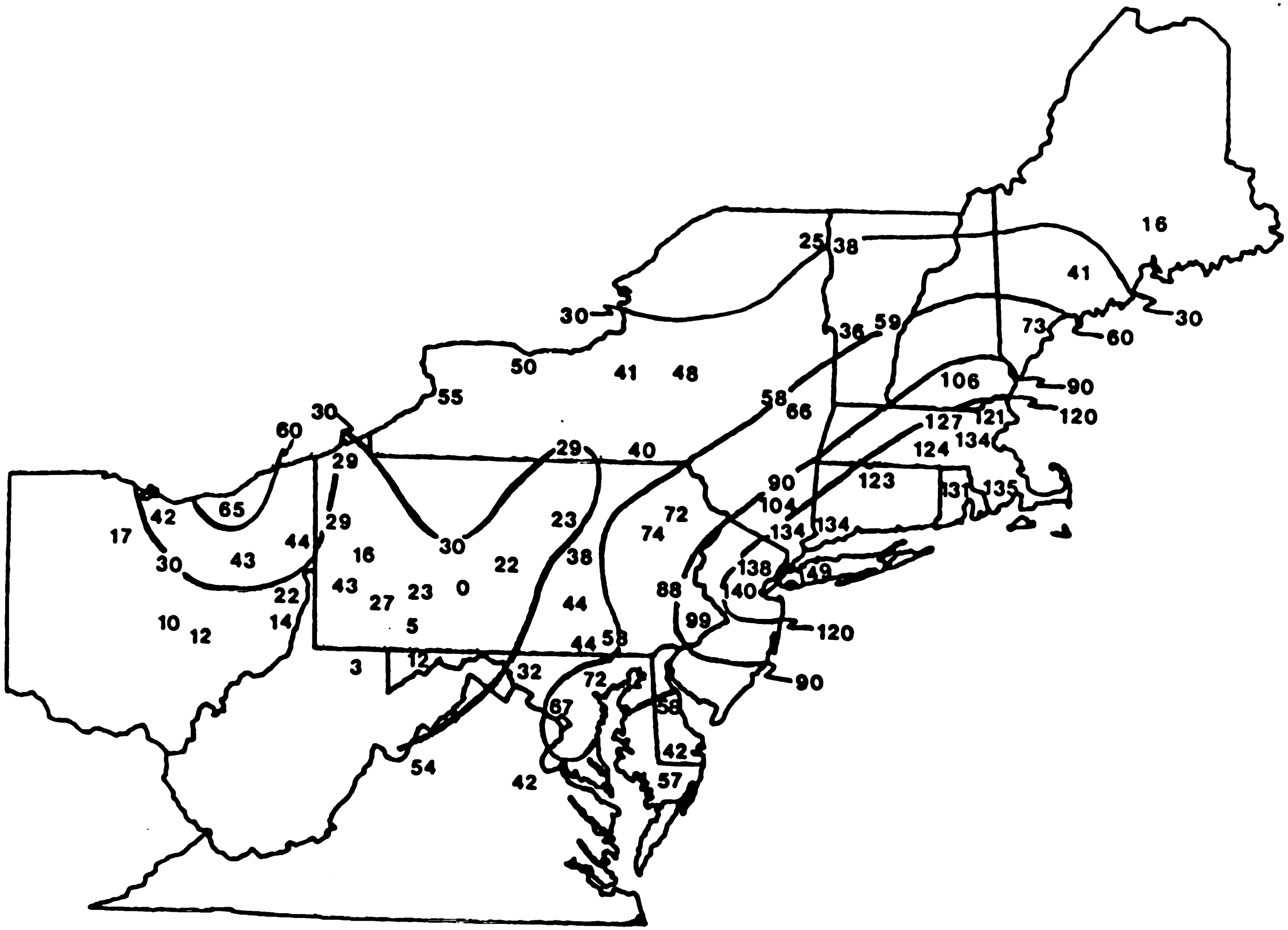

Figure 5.1 Price Surface for Class I Milk Supplies: Base

5.3 Discriminatory Pricing

To specify the discriminatory spatial pricing system in NEDSS, the objective function values for Class I bulk milk transportation costs are modified. Specifically, bulk milk transportation costs from every supply point to all potential Class I processing points are parametrically reduced to a percent of their initial values.

The base solution serves as the point of departure for the discriminatory pricing systems and may be thought of as a discriminatory system where the Class I processors absorb 100% of the freight cost. This results in a uniform delivered price schedule (c.i.f.), where all producers would receive the same net price. As Class I bulk transportation costs burdens borne by the Class I processors are reduced to proportions of the actual hauling costs, both the mill and the delivered prices to producers at unequal distances from a given plant will not be uniform. Since the plants bear only a proportion of the costs, mill prices for supplies increase less rapidly at increasing distances from the plants as the percent levels of plant freight absorption are reduced. When the absorption proportion is zero, i.e., when Class I plants pay no part of the bulk milk transportation costs, a uniform mill pricing schedule (f.o.b.) results. Since transportation costs are the only criteria NEDSS has for assigning supplies to plants, a minimum Class I price gradient is specified. None of the stipulated pricing systems are allowed to push particular prices below this surface. This minimum surface is specified as 1¢ per 75-mile zone, such that a 13¢ differential would apply at 975 miles.

At each percent reduction level, NEDSS is solved. Tables 5.4 to 5.7 indicate the initial percentages chosen and give a summary of the

Table 5.4 Class I Summary Characteristics of Discriminatory Pricing Solutions

Pricing Scenario	PROCESSING Number of Plants	PROCESSING Average Size (100,000) lbs	PROCESSING Average Cost (¢/cwt)	ASSEMBLY Number of Movements	ASSEMBLY Average Length (miles)	ASSEMBLY Average Cost (¢/cwt)	DISTRIBUTION Number of Movements	DISTRIBUTION Average Length (miles)	DISTRIBUTION Average Cost (¢/cwt)	Total Marketing Cost (¢/cwt)
Base	69	2,303	252.4	185	62.4	49.0	74	12.8	249.4	550.8
90%	66	2,408	251.8	181	66.2	51.1	76	10.9	248.2	551.1
80%	68	2,337	252.5	191	68.1	52.3	75	9.3	247.1	551.9
70%	72	2,207	253.2	198	69.2	52.9	70	7.9	246.2	552.3
60%	78	2,038	254.4	199	71.8	54.4	66	5.9	244.9	553.7
50%	78	2,038	254.4	204	74.6	56.1	65	5.7	244.7	555.2
40%	75	2,119	253.6	223	79.6	58.9	67	6.6	245.3	557.8
30%	75	2,119	253.8	213	89.5	64.7	66	6.4	245.1	563.6
20%	75	2,119	253.9	220	96.5	68.8	66	6.5	245.3	568.0
10%	73	2,177	253.7	232	100.7	71.1	68	7.0	245.6	570.4
5%	69	2,303	252.8	202	164.8	108.2	72	7.6	246.0	607.0

Table 5.5 Class II Summary Characteristics of Discriminatory Pricing Solutions

	PROCESSING			ASSEMBLY			DISTRIBUTION			
Pricing Scenario	Number of Plants	Average Size (100,000) lbs	Average Cost (¢/cwt)	Number of Movements	Average Length (miles)	Average Cost (¢/cwt)	Number of Movements	Average Length (miles)	Average Cost (¢/cwt)	Total Marketing Cost (¢/cwt)
Base	7	3,867	217.6	10	15.0	21.6	144	152.7	33.2	272.4
90%	6	4.512	216.1	11	17.3	22.9	143	153.6	33.4	272.4
80%	6	4.512	216.0	11	14.4	21.3	142	150.9	32.8	270.1
70%	7	3,867	217.4	11	12.6	20.2	142	150.3	32.7	270.3
60%	6	4,512	216.1	11	15.2	21.7	143	151.9	33.0	270.8
50%	6	4,512	216.5	7	10.1	18.8	142	150.7	32.8	268.1
40%	4	6,767	213.0	3	2.4	14.4	142	137.1	29.7	257.1
30%	7	3,867	217.9	12	13.5	20.9	138	85.4	18.3	257.1
20%	7	3,867	218.3	15	16.7	22.6	138	79.1	16.9	257.8
10%	5	5,414	214.3	11	18.9	24.0	139	94.0	20.2	258.5
5%	8	3,384	218.5	31	23.4	26.5	137	66.6	14.2	259.2

Table 5.6 Class III Summary Characteristics of Discriminatory Pricing Solutions

Pricing Scenario	PROCESSING Number of Plants	PROCESSING Average Size	PROCESSING Average Cost	ASSEMBLY Number of Movements	ASSEMBLY Average Length	ASSEMBLY Average Cost	DISTRIBUTION Number of Movements	DISTRIBUTION Average Length	DISTRIBUTION Average Cost	Total Marketing Cost
		(100,000) lbs	(¢/cwt)		(miles)	(¢/cwt)		(miles)	(¢/cwt)	(¢/cwt)
Base	19	5,509	91.0	35	10.1	18.8	158	381.2	13.6	123.4
90%	18	5,815	91.0	41	12.8	20.4	156	280.7	13.5	124.9
80%	19	5,509	91.0	37	10.7	19.1	158	279.9	13.5	123.6
70%	19	5,509	91.1	33	10.5	19.1	158	380.5	13.5	123.7
60%	20	5,233	91.1	31	9.4	18.4	158	381.3	13.6	123.1
50%	19	5,509	91.1	37	11.3	19.5	157	382.5	13.6	124.2
40%	19	5,509	91.6	31	11.0	19.3	158	375.1	13.3	124.2
30%	19	5,509	90.9	30	10.3	19.0	158	378.7	13.4	123.4
20%	17	6,157	90.5	32	12.6	20.2	155	371.9	13.2	123.9
10%	15	6,978	90.0	32	14.2	21.2	153	370.9	13.2	124.4
5%	10	10,466	90.0	46	20.3	24.7	146	311.8	11.1	125.8

Table 5.7 Total Marketing Cost Summary: Discriminatory Pricing Solutions

Pricing Scenario	PROCESSING Classes I	II	III	TOTAL	ASSEMBLY Classes I	II	III	TOTAL	DISTRIBUTION Classes I	II	III	TOTAL	
							($1,000)						
Base	40,105	5,892	9,522	55,519	7,782	584	1,972	10,338	39,644	898	2,329	42,871	108,728
90%	40,022	5,850	9,521	55,393	8,122	621	2,135	10,878	39,444	904	2,326	42,674	108,945
80%	40,123	5,847	9,522	55,492	8,306	576	2,003	10,885	39,271	888	2,316	42,475	108,852
70%	40,232	5,885	9,535	55,652	8,408	547	1,996	10,951	39,124	884	2,322	42,330	108,933
60%	40,424	5,849	9,535	55,808	8,645	588	1,924	11,157	38,918	894	2,331	42,143	109,108
50%	40,430	5,861	9,535	55,826	8,910	509	2,040	11,459	38,897	888	2,335	42,120	109,405
40%	40,311	5,766	9,592	55,669	9,361	390	2,025	11,776	38,981	804	2,289	42,074	109,519
30%	40,329	5,899	9,517	55,745	10,275	566	1,985	12,826	38,961	495	2,306	41,762	110,333
20%	40,345	5,910	9,471	55,726	10,930	613	2,118	13,661	38,980	458	2,265	41,703	111,090
10%	40,325	5,801	9,420	55,546	11,305	649	2,219	14,173	39,033	548	2,268	41,849	111,568
5%	40,172	5,915	9,420	55,507	17,194	718	2,590	20,502	39,094	385	1,908	41,387	117,396

results at each level. Since base is the marketwide cost-minimizing solution, solutions to each discriminatory level will necessarily involve higher total marketing costs. However, as the total marketing costs for Class I increase, there are some partially compensatory savings generated in Classes II and III. Generally, lower rates of freight absorption result in substantially higher assembly costs for Class I milk while distribution costs are slightly lowered. Class II and III assembly costs generally increase, but only slightly, while distribution costs for Class II decrease substantially at lower rates of absorption and Class III distribution costs remain relatively unchanged until very low absorption rates. Processing costs in all three classes remain relatively constant as average plant sizes do not change appreciably.

As the proportion of freight absorption by Class I processors decreases, average Class I marketing costs increase, Class II average marketing costs decrease and Class III average marketing costs remain essentially the same.

Appendix Figures B.7 to B.12 and Tables 5.8 to 5.10 describe the solution for a 30% freight absorption rate. This rate is very nearly the median absorption rate implied by current Class I mileage differentials used in many FMMO's, .22¢/mile and .15¢/mile, as proportions of the estimated bulk milk hauling cost mileage rate of .578¢/mile.

Relative to the base solution, discriminatory pricing with 30% absorption resulted in more Class I processing locations with longer assembly distances and shorter distribution distances. Class II resulted in significantly reduced distribution costs with little change

Table 5.8 Summary Characteristics of Milk Assembly for Each Class: Discriminatory Pricing, 30% Freight Absorption

	CLASS I	CLASS II	CLASS III
Movements			
Number*	213	12	30
Distance (miles)			
Weighted Average**	89.5	13.5	10.3
Longest	369	61	52
Cost			
Total ($1,000)	10,275	566	1,985
Average (¢/cwt)	64.7	20.9	19.0

*Represents only those movements between two distinct geographic points.

**Includes all movements.

Table 5.9 Summary Characteristics of Processing for Each Product Class: Discriminatory Pricing, 30% Freight Absorption

	CLASS I	CLASS II	CLASS III
Number of Locations	75	7	19
Pounds Processed (100,000)			
Total			5,509
Average	2,119	3,867	9,361
Largest	20,339	9,273	2,728
Smallest	253	1,705	
Cost			
Total ($1,000)	40,329	5,899	9,517
Average (¢/cwt)	253.8	217.9	90.9

Table 5.10 Summary Characteristics of Product Distribution for Each Class: Discriminatory Pricing, 30% Freight Absorption

	CLASS		
	I	II	III
Movements			
Number*	66	138	158
Distance (miles)			
Weighted Average**	6.4	85.4	378.7
Longest	108	287	818
Cost			
Total ($1,000)	38,961	495	2,306
Average (¢/cwt)	245.1	18.3	13.4

*Represents only those movements between two distinct geographic points.

**Includes all movements.

in assembly, while Class III assembly and distribution costs were essentially unchanged. With the increased number of small processing locations than in the base scenario, Class I processing costs showed a small absolute increase. Class II and III processing costs remained nearly unchanged.

As indicated by the increased weighted average Class I assembly distances (Tables 5.7 and 5.8), Class I processors located in some large metropolitan areas, New York City, Washington, D.C., Pittsburgh, and Cleveland reach out further for their milk supplies under a discriminatory 30% freight absorbing pricing system (Appendix Figures B.1 and B.7). Processors in Boston, Philadelphia, and Baltimore do not change their supply areas appreciably. The greater number of Class I processors present under the discriminatory pricing system results in fewer and shorter Class I distribution movements.

While the number and average processing costs of Class II processing locations remain the same between the base and the 30% discriminatory freight absorption solutions (Tables 5.2 and 5.9), the locations of these centers change dramatically (Appendix Figures B.3 and B.9). Under discriminatory pricing, the extended supply areas of some metropolitan area processors has left a 'seam' or 'pocket' in the supply areas close to these centers, where Class II processors find it advantageous to locate. While the assembly costs of these Class II processors do not change much with this relocation (Tables 5.1 and 5.8), their distribution costs are reduced by over 40%.

Class III processors, on the other hand, experience minor changes in processing costs (Tables 5.2 and 5.9), assembly costs (Tables 5.1 and 5.8), and in distribution costs (Tables 5.3 and 5.10). Similarly, there are minor changes in Class III processing locations and supply areas (Appendix Figures B.5 and B.11) with the exception of two centers moving into central Pennsylvania which was previously the site of Class II processing.

Shadow prices at Class I processing locations for the discriminatory pricing solution with 30% freight absorption are presented in Figure 5.2. The magnitudes of Class I differentials relative to the lowest value (at Newark, Ohio) are much lower than in the base scenario. The highest differential is 64 cents on Long Island. However, the same general shape of the price gradient, relative to the base scenario, is obtained. Imputed Class I values are highest in the New Jersey-New York City-Connecticut-Boston corridor and decrease with distance from this area. Cleveland, Pittsburgh, and most of central and western New York and central Pennsylvania lay at a lower level, while northern New York and Vermont, most of Maine, and much of western Pennsylvania comprise the lowest value area.

In summary, the imposition of a discriminatory pricing system, with 30% freight absorption, on Class I milk supplies results in an expansion of the supply areas for the major metropolitan area Class I processors and an attendant increase in the marketwide cost of Class I assembly. This is accompanied by a relocation of Class II processing centers to points closer to these metropolitan centers. This results in significantly reduced marketwide Class II distribution costs. Other assembly and distribution costs are relatively unaffected, as are processing costs and Class I and Class III plant locations.

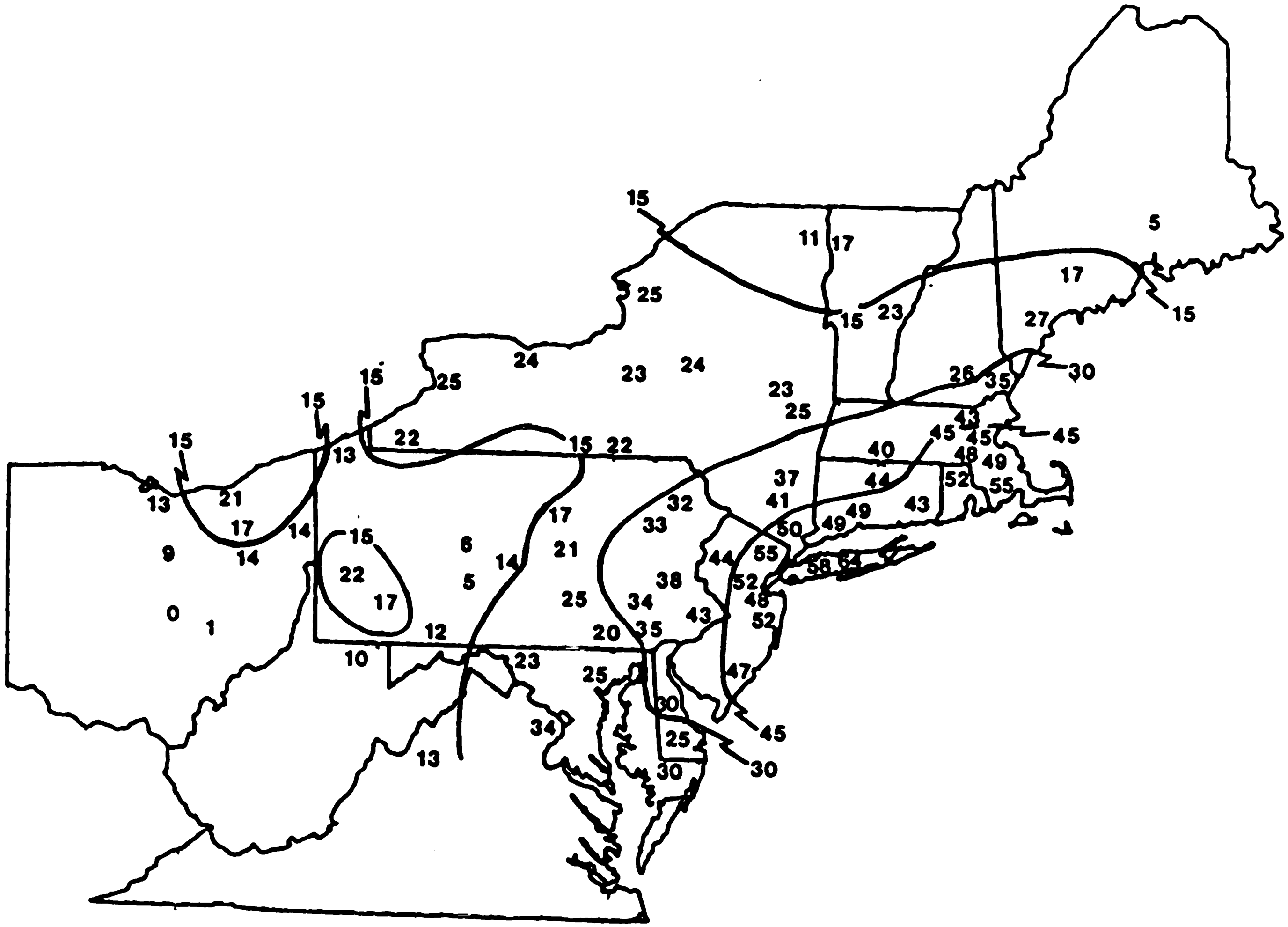

Figure 5.2 Price Surface for Class I Milk Supplies: Discriminatory Pricing, 30% Freight Absorption

5.4 Uniform Mill Pricing (f.o.b.)

As in the discriminatory pricing system, Class I bulk milk transportation costs between supply points and potential processing locations are modified in the objective function of NEDSS. Specifically, Class I bulk milk transportation costs from every supply point to all potential Class I processing points are parametrically increased by constant amounts, up to the level of actual cost for any movement. The base solution again serves as a point of departure. At a significantly high level, the constant is larger than all actual movement costs.

By absorbing a constant amount of transportation costs, Class I processors offer a uniform mill price to all potential suppliers. At each level of the constant, NEDSS is solved. Tables 5.11 to 5.14 indicate the levels chosen and give a summary of the results at each level. As in the discriminatory pricing systems, all scenarios necessarily result in higher total marketing costs than the marketing cost minimizing base solution. As the constant level of freight absorption paid by Class I processors is increased, total marketing costs approach those of the base solution, since the level of absorption on any particular supply to processing movement is limited to the actual transportation cost of that movement.

To facilitate specific comparisons, a constant level of +129¢ is chosen. For this level, total marketing cost of the uniform mill pricing solution closely approximates that of the 30% freight absorbing discriminatory solution. Tables 5.15 to 5.17 and Appendix Figures B.13 to B.18 describe the solution for the uniform mill pricing and +129¢ freight absorption.

Table 5.11 Class I Summary Characteristics of Uniform Mill Pricing Solutions

Pricing Scenario	PROCESSING Number of Plants	PROCESSING Average Size (100,000) lbs	PROCESSING Average Cost (¢/cwt)	ASSEMBLY Number of Movements	ASSEMBLY Average Length (miles)	ASSEMBLY Average Cost (¢/cwt)	DISTRIBUTION Number of Movements	DISTRIBUTION Average Length (miles)	DISTRIBUTION Average Cost (¢/cwt)	Total Marketing Cost (¢/cwt)
+15¢	70	2,270	253.0	198	163.5	107.5	71	7.9	246.2	606.7
+30¢	79	2,012	254.4	196	156.2	103.2	66	5.9	244.9	602.5
+45¢	87	1,827	255.7	199	145.9	97.3	58	4.4	243.9	596.9
+60¢	83	1,915	255.1	197	134.6	90.7	63	4.8	244.1	589.9
+75¢	89	1,786	256.4	200	125.4	85.4	55	4.3	243.8	585.6
+105¢	77	2,064	253.9	197	104.1	73.0	66	8.8	246.8	573.7
+129¢	69	2,303	252.5	198	77.4	57.6	73	12.4	249.2	559.3
+135¢	68	2,337	252.2	197	73.1	55.1	75	12.7	249.4	556.7
+165¢	65	2,445	251.5	185	69.0	52.7	77	12.6	249.3	553.5
Base	69	2,303	252.4	185	62.4	49.0	74	12.8	249.4	550.8

Table 5.12 Class II Summary Characteristics of Uniform Mill Pricing Solutions

	PROCESSING			ASSEMBLY			DISTRIBUTION			
	Number	Average		Number	Average		Number	Average		Total
Pricing Scenario	of Plants	Size	Cost	of Movements	Length	Cost	of Movements	Length	Cost	Marketing Cost
		(100,000) lbs	(¢/cwt)		(miles)	(¢/cwt)		(miles)	(¢/cwt)	(¢/cwt)
+15¢	7	3,867	216.9	31	25.3	27.6	139	67.4	14.4	258.9
+30¢	8	3,384	219.4	14	17.3	23.0	144	85.6	18.4	260.8
+45¢	8	3,384	218.8	11	9.9	18.7	144	84.8	18.2	255.7
+60¢	7	3,867	218.2	9	11.1	19.4	143	113.8	24.6	262.2
+75¢	6	4,512	217.1	4	2.8	14.6	144	115.7	25.0	256.8
+105¢	6	4,512	215.4	9	11.1	19.3	143	137.5	29.9	264.6
+129¢	5	5,414	212.8	7	7.2	17.2	141	154.2	33.6	263.6
+135¢	5	5,414	213.8	7	11.7	19.8	142	150.0	32.6	266.2
+165¢	5	5,414	213.8	12	15.3	21.8	144	160.6	34.9	270.5
Base	7	3,867	217.6	10	15.0	21.6	144	152.7	33.2	272.4

Table 5.13 Class III Summary Characteristics of Uniform Mill Pricing Solutions

Pricing Scenario	PROCESSING Number of Plants	PROCESSING Average Size (100,000) lbs	PROCESSING Average Cost (¢/cwt)	ASSEMBLY Number of Movements	ASSEMBLY Average Length (miles)	ASSEMBLY Average Cost (¢/cwt)	DISTRIBUTION Number of Movements	DISTRIBUTION Average Length (miles)	DISTRIBUTION Average Cost (¢/cwt)	Total Marketing Cost (¢/cwt)
+15¢	13	8,051	90.9	34	13.6	20.9	148	319.0	11.3	123.1
+30¢	14	7,476	90.9	30	12.3	20.1	150	319.8	11.3	122.3
+45¢	13	8,051	90.6	32	16.6	22.6	150	320.6	11.4	124.6
+60¢	19	5,509	92.0	34	13.1	20.6	155	329.3	11.7	124.3
+75¢	16	6,542	90.4	39	17.6	23.1	154	334.6	11.9	125.4
+105¢	18	5,815	90.8	32	12.8	20.4	157	344.7	12.2	123.4
+129¢	18	5,815	92.0	33	14.1	21.2	157	365.6	13.0	126.2
+135¢	20	5,233	91.4	31	9.2	18.3	159	369.1	13.1	122.8
+165¢	19	5,509	91.0	38	11.2	19.5	156	372.6	13.3	123.8
Base	19	5,509	91.0	35	10.1	18.8	158	381.2	13.6	123.4

Table 5.14 Total Marketing Cost Summary: Uniform Mill Pricing Solutions

Pricing Scenario	PROCESSING Classes I	II	III	TOTAL	ASSEMBLY Classes I	II	III	TOTAL	DISTRIBUTION Classes I	II	III	TOTAL	
							($1,000)						
+15¢	40,214	5,872	9,510	55,596	17,084	748	2,183	20,015	39,130	391	1,944	41,465	117,076
+30¢	40,427	5,940	9,517	55,884	16,408	622	2,100	19,130	38,916	498	1,943	41,357	116,371
+45¢	40,632	5,924	9,479	56,035	15,469	506	2,361	18,336	38,758	494	1,962	41,214	115,585
+60¢	40,546	5,907	9,627	56,080	14,421	526	2,152	17,099	38,791	665	2,005	41,461	114,640
+75¢	40,742	5,880	9,464	56,086	13,576	396	2,421	16,393	38,750	677	2,042	41,469	113,948
+105¢	40,359	5,831	9,500	55,690	11,609	523	2,132	14,264	39,228	808	2,100	42,136	112,090
+129¢	40,132	5,762	9,629	55,523	9,156	465	2,216	11,837	39,602	909	2,235	42,746	110,106
+135¢	40,089	5,788	9,566	55,443	8,758	537	1,914	11,209	39,631	883	2,251	42,765	109,417
+165¢	39,967	5,788	9,521	55,276	8,380	589	2,038	11,007	39,620	945	2,279	42,844	109,127
Base	40,105	5,892	9,522	55,519	7,782	584	1,972	10,338	39,644	898	2,329	42,871	108,728

Table 5.15 Summary Characteristics of Milk Assembly for Each Product Class: Uniform Mill, +129¢

	CLASS I	CLASS II	CLASS III
Movements			
Number*	198	7	33
Distance (miles)			
Weighted Average**	77.4	7.2	14.1
Longest	742	62	61
Cost			
Total ($1,000)	9,156	465	2,216
Average (¢/cwt)	57.6	17.2	21.2

*Represents only those movements between two distinct geographic points.

**Includes all movements.

Table 5.16 Summary Characteristics of Processing for Each Product Class: Uniform Mill, +129¢

	CLASS I	CLASS II	CLASS III
Number of Locations	69	5	18
Pounds Processed (100,000)			
Total			5,815
Average	2,303	5,414	10,428
Largest	18,172	6,820	2,233
Smallest	297	4,400	
Cost			
Total ($1,000)	40,132	5,762	9,629
Average (¢/cwt)	252.5	212.8	92.0

Table 5.17 Summary Characteristics of Product Distribution for Each Class: Uniform Mill, +129¢

	CLASS I	CLASS II	CLASS III
Movements			
Number*	73	141	157
Distance (miles)			
Weighted Average**	12.4	154.2	365.6
Longest	111	349	818
Cost			
Total ($1,000)	39,602	909	2,235
Average (¢/cwt)	249.2	33.6	13.0

*Represents only those movements between two distinct geographic points.

**Includes all movements.

Uniform mill pricing with a +129¢ constant results in lower average assembly costs for Class I and Class II and higher costs for Class III relative to the discriminatory, 30% freight absorption solution. With fewer Class I and Class II processing plants and larger average sizes, processing costs for these two classes are reduced. Class III processing costs increase. Distribution costs for Class I products increase and those for Class II products increase substantially. Class III distribution costs decrease slightly.

Class I processing plants locate at or near the major population centers under the uniform mill pricing scenario, just as in the base and discriminatory cases. Class I assembly movements, however, which are shorter on average than those under the discriminatory system, include many very long distance movements. Movements from Ohio and Virginia to the New York City area are prevalent. With a constant level of freight absorption, which is limited to actual transportation costs, the difference between the value of a unit of milk supply and the amount of freight which a Class I processor must absorb increases with distance. To a processor, these very distant supplies look the same as those located at a distance where absorption equals actual costs. Class I distribution movement patterns appear to be quite similar to those in the base and discriminatory solutions.

Class II processing plants locate in areas more closely resembling the base rather than the discriminatory solution. They are farther from the metropolitan areas than in the discriminatory case, but their assembly areas are still local in nature. Class II distribution movements are also similar to those in the base solution.

Class III processing plants, assembly movements, and distribution movements are very similar in each of the three solutions.

Shadow prices at Class I processing locations for the uniform mill pricing scenario with a +129¢ adjustment are presented in Figure 5.3. Magnitudes of the differentials, relative to the lowest value point (Tiffin, Ohio), are lower than those in the base scenario, but higher than those in the discriminatory pricing scenario with 30% absorption. The highest differential is 126¢ at Boston, MA.

Although the steepness of the price gradient is dampened, uniform mill pricing differentials display the same general pattern as the base and discriminatory pricing scenarios. The highest value area extends from Boston to the New York City metropolitan vicinity. Values generally decline with distance from this corridor. Cleveland and Pittsburgh lay at higher levels than their surrounding areas.

In summary, a uniform mill pricing system with a +129¢ absorption level, limited on each particular movement to actual transportation costs, results in total marketing costs which are essentially the same as in the discriminatory pricing system with 30% absorption. In the uniform case, however, total assembly costs are about $1 million less than in the discriminatory case, while distribution costs are about $1 million more. Assembly costs are less, despite the presence of a number of very long movements to the New York City area. Plant locations in the uniform pricing case are similar to those for the base solution, with Class II plants locating at greater distances from the metropolitan areas than under discriminatory pricing.

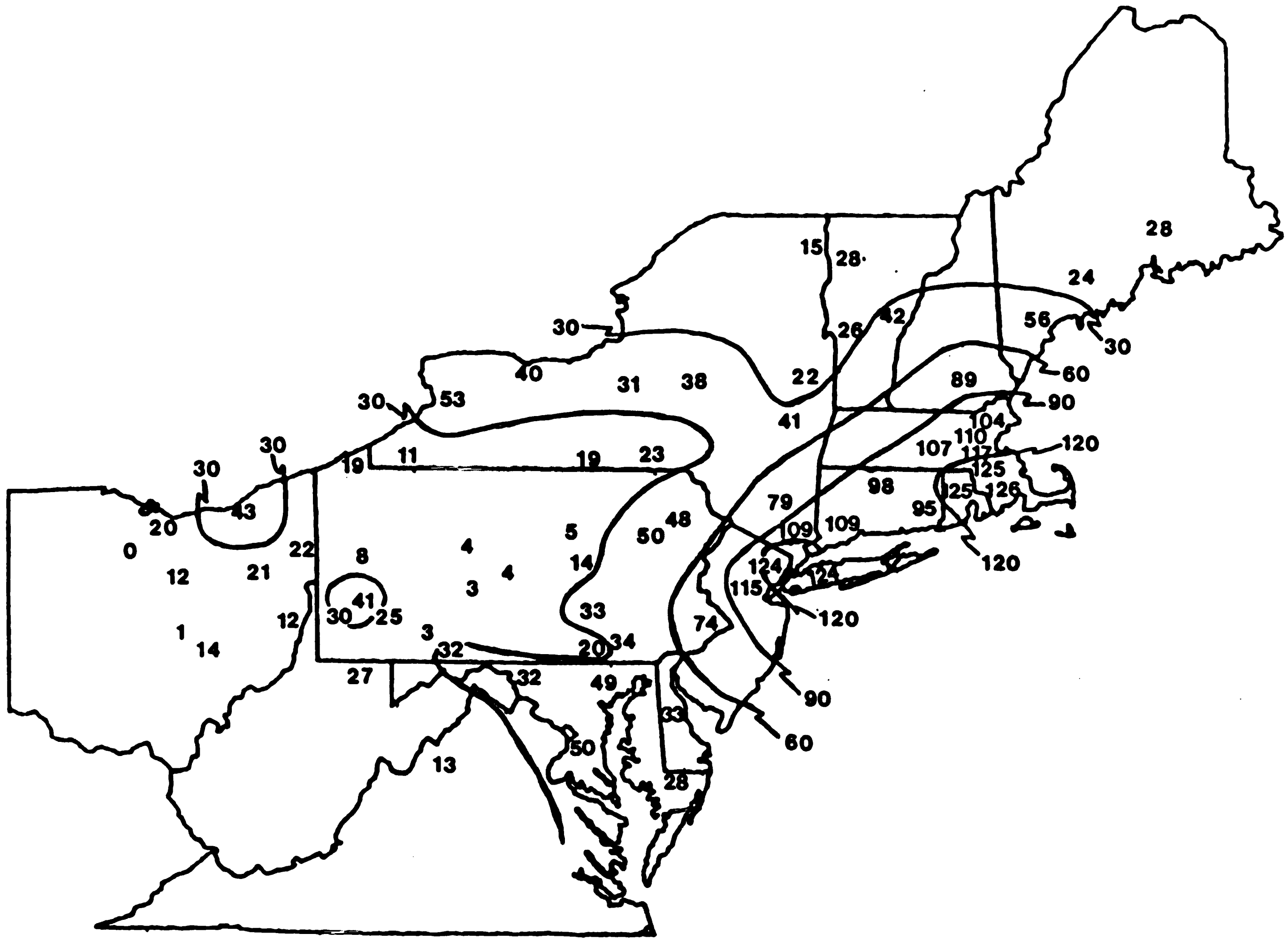

Figure 5.3 Price Surface for Class I Milk Supplies: Uniform Mill Pricing, +129¢ Location Adjustment

5.5 Uniform Delivered Pricing (c.i.f.)

As in the two previously discussed pricing systems, Class I transportation costs between supply points and potential Class I processing locations are modified to reflect the uniform delivered pricing system. Specifically, all Class I bulk milk transportation costs are reduced from their actual levels by constant amounts. No cost is allowed to fall below the minimum level of 1¢ for each 75 miles. The base solution serves as a point of departure, where Class I processors absorb the entire amount of freight to all supplies.

At each level of constant freight absorption, NEDSS is solved. Tables 5.18 to 5.21 indicate the chosen levels of constant freight absorption and give a summary of the results at each level. At a constant absorption level of cost minus 60¢, the resulting total marketing costs are similar to those of discriminatory pricing with a 30% absorption rate and to uniform mill pricing with +129¢ absorption. Tables 5.22 to 5.24 and Appendix Figures B.19 to B.24 describe this solution.

Relative to discriminatory pricing with 30% absorption, uniform delivered pricing with 60¢ absorption results in lower assembly costs for Class I and Class II supplies and higher costs for Class III. Processing costs for each class are similar in each pricing scenario. Class I distribution costs are higher in the uniform delivered pricing case and Class II distribution costs are much higher. Class III distribution costs are essentially the same.

Relative to the uniform mill pricing scenario, assembly costs for Class I and Class II are again higher in the uniform delivered case, while Class III assembly costs are slightly lower. Likewise, Class I

Table 5.18 Class I Summary Characteristics of Uniform Delivered Pricing Solutions

Pricing Scenario	PROCESSING Number of Plants	PROCESSING Average Size (100,000) lbs	PROCESSING Average Cost (¢/cwt)	ASSEMBLY Number of Movements	ASSEMBLY Average Length (miles)	ASSEMBLY Average Cost (¢/cwt)	DISTRIBUTION Number of Movements	DISTRIBUTION Average Length (miles)	DISTRIBUTION Average Cost (¢/cwt)	Total Marketing Cost (¢/cwt)
Base	69	2,303	252.4	185	62.4	49.0	74	12.8	249.4	550.8
-15¢	66	2,408	252.1	186	65.1	50.5	78	11.5	248.5	551.1
-30¢	64	2,483	251.7	219	68.6	52.5	79	12.0	248.9	553.1
-45¢	60	2,649	251.2	220	75.2	56.4	81	11.9	248.8	556.4
-60¢	74	2,148	253.7	240	84.4	61.7	68	7.7	246.1	561.5
-75¢	73	2,177	253.5	242	93.6	67.0	68	7.3	245.8	566.3
-90¢	74	2,148	253.7	244	107.7	75.2	67	7.1	245.6	574.5
-105¢	73	2,177	253.4	241	119.4	81.9	68	7.1	245.6	580.9
-120¢	69	2,303	252.7	234	142.6	95.4	72	7.7	246.1	594.2

Table 5.19 Class II Summary Characteristics of Uniform Delivered Pricing Solutions

	PROCESSING			ASSEMBLY			DISTRIBUTION			
	Number	Average		Number	Average		Number	Average		Total
Pricing Scenario	of Plants	Size	Cost	of Movements	Length	Cost	of Movements	Length	Cost	Marketing Cost
		(100,000) lbs	(¢/cwt)		(miles)	(¢/cwt)		(miles)	(¢/cwt)	(¢/cwt)
Base	7	3,867	217.6	10	15.0	21.6	144	152.7	33.2	272.4
-15¢	6	4,512	215.4	11	10.9	19.2	142	150.3	32.7	267.3
-30¢	4	6,768	212.6	8	13.9	21.1	141	156.0	33.9	267.6
-45¢	5	5,414	213.0	8	9.5	18.5	140	151.5	32.9	264.4
-60¢	7	3,867	217.2	9	12.8	20.4	140	136.0	30.0	267.6
-75¢	7	3,867	215.5	4	3.1	14.8	141	134.5	29.2	259.5
-90¢	6	4,512	214.8	13	17.8	23.2	140	117.0	25.3	263.3
-105¢	7	3,867	216.9	18	23.5	26.5	139	84.4	18.2	261.6
-120¢	6	4,512	214.8	22	23.8	26.9	138	72.7	15.5	257.2

Table 5.20 Class III Summary Characteristics of Uniform Delivered Pricing Solutions

	PROCESSING			ASSEMBLY			DISTRIBUTION			
	Number	Average		Number	Average		Number	Average		Total
Pricing Scenario	of Plants	Size	Cost	of Movements	Length	Cost	of Movements	Length	Cost	Marketing Cost
		(100,000) lbs	(¢/cwt)		(miles)	(¢/cwt)		(miles)	(¢/cwt)	(¢/cwt)
Base	19	5,509	91.0	35	10.1	18.8	158	381.2	13.6	123.4
-15¢	20	5,233	91.3	41	12.5	20.2	157	377.7	13.4	124.9
-30¢	20	5,233	91.1	35	9.9	18.7	158	378.6	13.5	123.3
-45¢	20	5,233	91.2	38	11.2	19.5	156	373.7	13.3	124.0
-60¢	17	6,157	90.5	35	14.1	21.1	157	377.7	13.5	125.1
-75¢	18	5,815	90.6	33	11.6	19.7	155	370.5	13.2	123.5
-90¢	17	6,157	90.6	29	11.6	19.7	157	362.3	12.9	123.2
-105¢	15	6,978	91.0	29	14.0	21.1	153	359.5	12.8	124.9
-120¢	13	8,051	90.1	34	14.8	21.5	151	341.3	12.1	123.7

Table 5.21 Total Marketing Cost Summary: Uniform Delivered Pricing Solutions

Pricing Scenario	PROCESSING Classes I	II	III	TOTAL	ASSEMBLY Classes I	II	III	TOTAL	DISTRIBUTION Classes I	II	III	TOTAL	
							($1,000)						
Base	40,105	5,892	9,522	55,519	7,782	584	1,972	10,338	39,644	898	2,329	42,871	108,728
-15¢	40,070	5,831	9,557	55,458	8,028	521	2,114	10,663	39,501	886	2,306	42,693	108,814
-30¢	39,999	5,756	9,532	55,287	8,344	571	1,957	10,872	39,564	918	2,313	42,795	108,954
-45¢	39,924	5,765	9,542	55,231	8,961	501	2,037	11,499	39,547	892	2,280	42,719	109,449
-60¢	40,333	5,879	9,472	55,684	9,805	553	2,208	12,566	39,104	803	2,312	42,219	110,469
-75¢	40,289	5,835	9,487	55,611	10,647	400	2,058	13,105	39,067	789	2,264	42,120	110,836
-90¢	40,314	5,814	9,482	55,610	11,951	629	2,061	14,641	39,038	685	2,214	41,937	112,188
-105¢	40,279	5,873	9,522	55,674	13,020	716	2,205	15,941	39,036	492	2,197	41,725	113,340
-120¢	40,168	5,815	9,430	55,413	15,159	727	2,250	18,136	39,108	421	2,080	41,609	115,158

Table 5.22 Summary Characteristics of Milk Assembly for Each Product Class: Uniform Delivered Pricing, -60¢

	CLASS I	CLASS II	CLASS III
Movements			
Number*	240	9	35
Distance (miles)			
Weighted Average**	84.4	12.8	14.1
Longest	183	51	60
Cost			
Total ($1,000)	9,805	553	2,208
Average (¢/cwt)	61.7	20.4	21.1

*Represents only those movements between two distinct geographic points.

**Includes all movements.

Table 5.23 Summary Characteristics of Processing for Each Product Class: Uniform Delivered Pricing, -60¢

	CLASS I	CLASS II	CLASS III
Number of Locations	74	7	17
Pounds Processed (100,000)			
Total			6,157
Average	2,148	3,867	11,792
Largest	21,571	6,710	2,607
Smallest	286	1,144	
Cost			
Total ($1,000)	40,333	5,879	9,472
Average (¢/cwt)	253.8	217.2	90.5

Table 5.24 Summary Characteristics of Product Distribution for Each Class: Uniform Delivered Pricing, -60¢

	CLASS I	CLASS II	CLASS III
Movements			
Number*	68	140	157
Distance (miles)			
Weighted Average**	7.7	136.0	337.7
Longest	108	302	822
Cost			
Total ($1,000)	39,104	803	2,312
Average (¢/cwt)	246.1	29.7	13.5

*Represents only those movements between two distinct geographic points.

**Includes all movements.

and II processing costs are higher while Class III processing costs are lower. Distribution costs for Class I and II are lower and are higher for Class III.

As in all the previous scenarios, Class I processors remain oriented to the consumption centers. Assembly movements closely resemble those of the discriminatory case, lacking the long-distance movements present under uniform mill pricing and lacking the compact assembly areas present in the base solution. Class I distribution movements in all four scenarios are similar, with discriminatory and uniform delivered pricing having slightly less movement.

Class II processing center locations are similar in the base, uniform mill, and uniform delivered cases. Discriminatory pricing, however, departs from this pattern with Class II processing centers locating much closer to the major population centers. Assembly patterns for Class II are also quite similar in all cases with uniform mill pricing having slightly more compact assembly. Class II distribution movements show similarities in those cases with like plant locations, and relatively less movement in the discriminatory pricing case.

Class III processing center locations are nearly the same in all three scenarios presented. The presence or lack of plants in central Pennsylvania and eastern Ohio being the only identifiable differences. Class III assembly patterns appear to be as compact under all four pricing schemes. Class III distribution movements are also quite similar in all four pricing scenarios.

The magnitudes of price differentials under uniform delivered pricing with 60¢ absorption is similar to those in the discriminatory scenario [figure 5.4]. The highest value is 84¢ at New York City and the lowest value point is at Plattsburgh, NY.

Although the uniform delivered pricing scenario displays the same high-valued corridor as the other scenarios, there are differences in the shape of the gradient in other areas. The Cleveland to Pittsburgh area displays a constant level of approximately 20¢. Much of central Pennsylvania and the southern tier of New York also have a very flat price surface.

5.6 Summary

A base, cost minimizing solution of NEDSS is compared to a solution from each of the three spatial pricing systems: discriminatory, uniform mill, and uniform delivered. The three particular scenarios chosen for comparison are chosen so that each results in nearly equal total marketing costs which are approximately 1 1/2% higher than the total marketing cost of the base, cost minimizing solution [Table 5.25].

While Class I assembly costs in each of the three scenarios show relatively large increases (18-32%), other components of the total dairy marketing bill, including processing costs, distribution costs, and assembly costs for Class I and Class II milk, reveal compensatory capabilities. As a group, these other components are able to maintain or even decrease their base solution levels.

The locations of processing centers for all three product classes are very stable among pricing scenarios with the exception of Class II processors in the discriminatory pricing scenario analyzed. In this case, Class I processors in some large metropolitan areas find it advantageous to pass over nearby supplies in order to obtain more

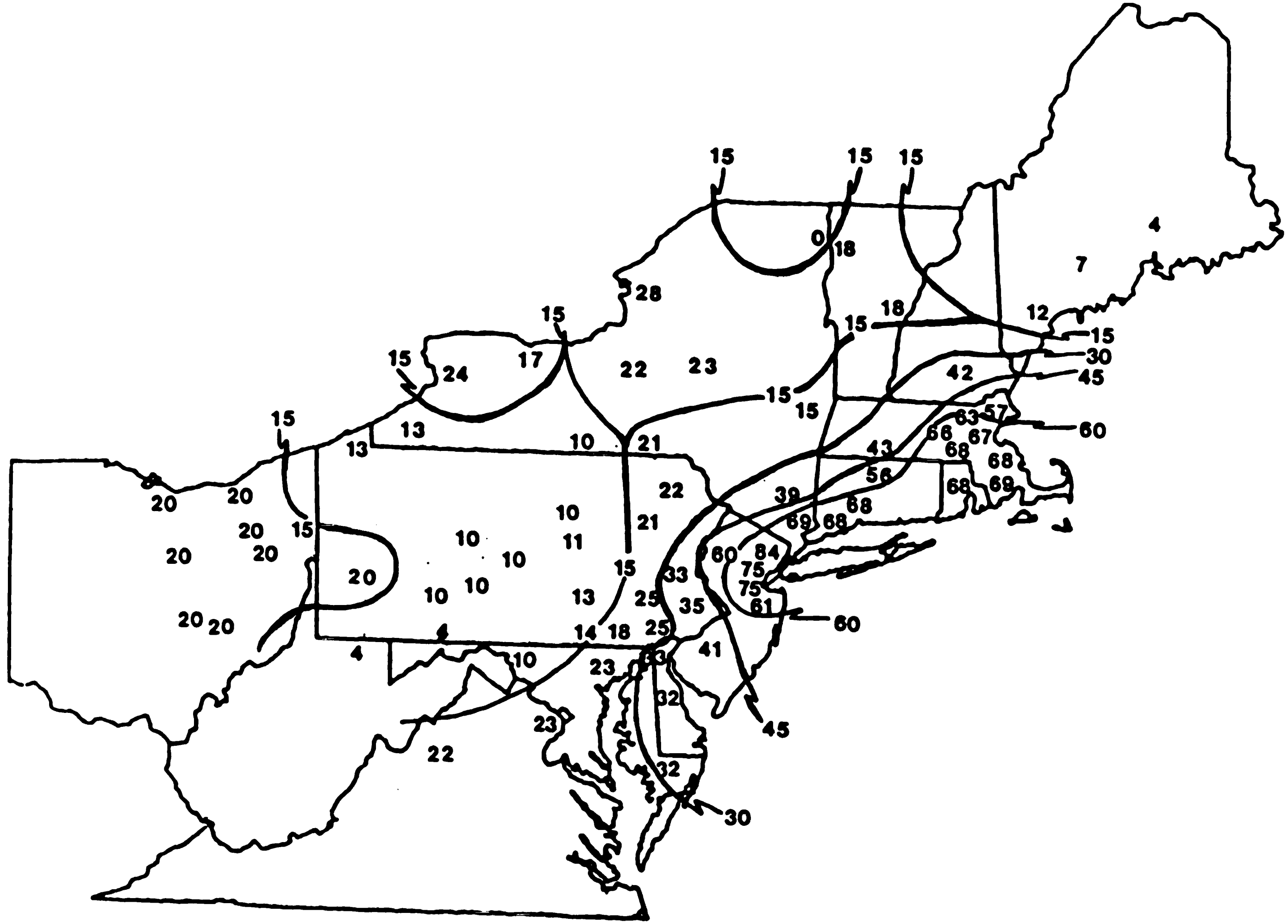

Figure 5.4 Price Surface for Class I Milk Supplies: Uniform Delivered Pricing, -60¢ Location Adjustment

Table 5.25 Total Marketing Cost Comparison: Three Spatial Pricing Scenarios

	PROCESSING				ASSEMBLY				DISTRIBUTION				
	Classes				Classes				Classes				
Pricing Scenario	I	II	III	TOTAL	I	II	III	TOTAL	I	II	III	TOTAL	TOTAL
							($1,000)						
Base	40,105	5,892	9,522	55,519	7,782	584	1,972	10,338	39,644	898	2,329	42,871	108,728
dis. 30%	40,329	5,899	9,517	55,745	10,275	566	1,985	12,826	38,961	495	2,306	41,762	110,333
(% of Base)	100.6	100.1	99.9	100.4	132.0	97	100.7	124.1	98.3	55	99.0	97.4	101.5
fob 129¢	40,132	5,762	9,629	55,523	9,156	465	2,216	11,837	39,602	909	2,235	42,746	110,106
(% of Base)	100.1	97.8	101.7	100.0	117.7	80	112.4	114.5	99.9	101	96.0	99.7	101.3
cif 60¢	40,333	5,879	9,472	55,684	9,805	553	2,208	12,566	39,104	803	2,312	42,219	110,469
(% of Base)	100.6	99.8	99.5	100.3	125.0	95	112.0	121.6	98.6	89	99.3	98.5	101.6

distant supplies. Class II processors then find it possible to locate within these pockets of supply, close to the population centers.

Milk assembly and milk product distribution movements generally follow the same patterns in each scenario with slight variations in the apparent compactness of the shipping areas, except for the case of Class I assembly in the uniform mill pricing scenario. In this solution, the New York metropolitan area receives some Class I shipments from eastern Ohio and northern Virginia. Even with these long-range movements, Class I assembly costs in this scenario are lower than in the other two spatial pricing scenarios.

At equal levels of total marketing costs, the three spatial pricing systems which were analyzed had very little impact on the optimal locations of Class I processing centers. These centers remain consumption center oriented. Class III processing center locations also remain supply center oriented in each scenario. The movements of milk to Class I processors and the location of Class II processors are among the most notable impacts of discriminatory pricing.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Federal milk marketing orders evolved, at least partially, in response to the presence of unequal bargaining power between dairy producers and processors. Among other things, FMMOs set minimum prices which regulated processors must pay to producers for milk supplies. On the basis of location theories and a desire to equalize the cost of raw milk supplies for Class I processors who are comparably located with respect to a defined market center, FMMOs have generally evolved systems of spatial price adjustments. In these systems, minimum Class I prices are adjusted to reflect the lower value of Class I milk supplies at greater distances from the market center. These adjustments are most often made through the implementation of a basing-point pricing system with constant adjustments per unit of distance.

Redressing the imbalance in bargaining power between market participants has been one aim of FMMOs, however, the character of the imbalance has changed over time. Today, much of the milk marketed under FMMO regulation is represented by producer cooperative associations. Many bargaining situations for Class I milk supplies may be more aptly described as bilateral monopolies, rather than simple monopsonies. Theoretically, in such situations, one side must dominate in the setting of output levels and prices, then the two sides bargain for the resultant profits. It is one of the premises of this study that Class I milk processors dominate the output decisions and that at least part of the bargaining for profits between producers and processors takes place in the form of FMMO hearings on the level and form of price location adjustments.

The monopsonistic market position of fluid milk processors manifests itself in a particular form--that of a spatial monopsonist. Spatial pricing theory indicates that spatial monopolists/monopsonists have incentives to absorb freight and to practice spatial discriminatory pricing, where possible. Based upon this second premise, three spatial pricing systems for spatial monopoly pricing--discriminatory, uniform mill, and uniform delivered--are described and their freight absorbing characteristics are demonstrated. Using NEDSS, a mathematical programming model of the spatial characteristics in the northeastern U.S. dairy industry, each of these spatial pricing systems is formulated by appropriately modifying the objective function for milk movements from supply points to Class I processing points. These problems are then solved at various levels of freight absorption and specific solutions are compared to a base, cost-minimizing solution.

The particular discriminatory pricing solution which is chosen for comparison is one with a 30% rate of freight absorption. This rate is close to an implied rate based on current estimates of bulk milk hauling costs and rates of location adjustment used in many FMMO's. The solutions for the uniform mill pricing system and the uniform delivered pricing system which are chosen for comparisons are those solutions resulting in total marketing costs nearly equal to the total marketing costs which occur under the discriminatory pricing system with 30% freight absorption.

The solution to the base, cost-minimizing scenario yields shadow prices, or imputed values, for milk supplies at the optimal Class I processing locations. The geographic distribution of these values over the study area indicates a pattern which is very similar to what would be expected under a basing-point system with a base zone, or corridor, rather than a simple base point. This pattern results when Class I processors are assumed to have total marketing cost minimization as their objective.

Producer blend prices are also adjusted for location under current FMMO rules. Individual producers cannot be expected to ship milk to more distant plants unless they are fully compensated for their share of any additional transportation cost burdens. With the emergence of dominant regional producer cooperative associations and their reblending authority, many individual producers are no longer directly faced with these alternatives. Decisions with respect to milk movements are made by means of a central coordinating mechanism. As such, producers may not directly feel the impacts of decisions concerning the destination of their milk. A third premise of this analysis is that the implied Class I price level is of sufficient magnitude to call forth the desired Class I milk supplies. Location differentials are viewed as signals used to direct otherwise willing supplies to Class I processors. Blend price differentials are not explicitly considered in this study. The repooling of receipts and the central coordination of shipments by producer associations preempt this individual producer decision.

The results of the comparisons between the base solution and the chosen solution for each spatial pricing system indicate that optimal Class I processing locations are very similar among solutions to the three pricing systems which result in similar levels of total marketing costs. Class I product distribution costs dictate that the location of

Class I processing centers be at or near major or isolated population centers. Class III distribution costs also result in very similar processing locations among the three pricing scenarios studied. Class III processing centers locate at or near supply centers which are relatively long distances from the major population centers. These results conform to expectations which are consistent with the cost-based theories of location. In the base scenario and in both uniform pricing scenarios, Class II processing centers also conform to expectations in which they occupy spaces intermediate to those of Class I and Class III supply areas. However, in the discriminatory pricing scenario, which most closely resembles current FMMO pricing adjustment, some Class II processing centers find it advantageous to locate close to the major population centers, well inside the supply procurement areas of local Class I processors.

Although accurate and complete information about actual assembly and ditribution movements for each product class were unavailable, actual plant locations and estimates of aggregated plant output were obtained. Actual locations of Class II and Class III processing centers do not match precisely the pattern which would be predicted by cost-based location theory or by the cost-minimizing solution of NEDSS.

Most actual Class III processing takes place in the areas of concentrated supply which are distant from the major population centers, however, a small portion of Class III processing does take place at or near the major population centers. Class III processing is found near Boston, New York City, and Philadelphia. Similarly, significant actual Class II processing facilities are also found at or near these metropolitan areas. A cost-based theory of location, as well as the base solution of NEDSS, however, predict that these processing centers would locate at intermediate positions relative to consumption-oriented Class I centers and distant, supply-oriented Class III centers. Assembly areas for the three product classes would be distinct with little or no overlapping.

Many factors could account for the discrepancy between observed and predicted behavior. Agglomeration behavior generated by complimentarities in processing between classes, metropolitan sources of component by-products provided by the relative solids-not-fat intensity of Class I products, compared to the butterfat intensity of Classe II and III products, the availability of existing processing facilities formerly used for Class I products, or simple management misconceptions or mistakes could all result in the observed behavior. However, it is a major finding of this analysis that the monopsonistic character of Class I processing and the natural occurrence of discriminatory pricing and freight absorption can also result in the observed behavior.

Seemingly by design, FMMO location adjustments generally do not represent the full cost of transporting milk from supply points to processing centers within a market area. As such, these adjustments represent price surfaces with less than 100% freight absorption. These location adjustments are generally specified as fixed rates per unit of distance, a method which results in a discriminatory price surface. The price of Class I supplies delivered to processors located at increasing distances from the market center decreases at a lower rate, with distance, than the total market costs of moving those supplies to the market center.

Voluntary or administered freight absorption and discriminatory pricing of milk supplies on the part of Class I processors results in total Class I milk assembly costs which are greater than the minimum achievable levels. Total marketing costs, however, do not increase by the total amount of increase in Class I assembly cost because changes in Class I assembly present opportunities for Class II and Class III processors to reduce their total assembly and distribution costs. The existence of compensating effects reduces the rate of marketing cost penalization for setting Class I differentials which increase Class I assembly costs and, similarly, reduce the rate of potential marketing cost gains for setting Class I differentials which decrease Class I assembly costs. Additionally, if the initially chosen location differentials result in processing center locations which differ from those in some subsequent set of differentials (such as in moving from the discriminatory price surface analyzed to the base solution), an additional cost of relocation of facilities is incurred.

The presence of a downward sloping demand for milk supplies and the resultant Chamberlinian tangencies are often pointed to as prima facie evidence of market inefficiency relative to an idealized, perfectly competitive model. Reformulations of this situation, however, suggest that what appear to be economic profits could also be interpreted as returns to processors for the establishment of new plants at distances from the market center.

Four FMMOs and at least three state-regulated orders operate within the geographic area covered by this study. The particular location differentials currently in place in these regulated areas are not studied. Location differentials which closely resemble the same freight absorption level and discriminatory type as are currently specified in many FMMOs are studied. These differentials result in plant location patterns which do not conform to the patterns expected from cost-based location theory where Class II processing centers find it advantageous to locate inside the area of Class I milk supplies for the major metropolitan areas. If the goal of efficiency in total marketing cost is to be met by approximating the location patterns of the marketing cost minimizing solution, pricing mechanisms other than the discriminatory mechanism now in use might be considered. Uniform mill and uniform delivered pricing may provide alternative location adjustment mechanisms.

However, if the use of rates of location adjustment which are equal to actual transportation costs would result in a total loss of incentives for Class I processors to pursue total marketing cost minimizing objectives, then discriminatory pricing, which does provide at least a partial incentive, may be appropriate. The losses in efficient Class I assembly which are induced by use of discriminatory adjustments, are partially offset by the optimizing behavior of Class II (and possibly Class III) processors. The presence of Class II processors at sites nearer to population centers than would be expected in a cost-minimizing organization, i.e. withing the assembly areas of market center Class I processors, is consistent with discriminatory pricing.

Allowing location differentials to become, in effect, negotiating instruments for producer-processor price bargaining through the FMMO hearing process adds a degree of instability to optimal plant location decisions. The use of specific modifications to the differentials to address individual competitive situations between Class I processors should also be avoided. The establishment of stable location adjustments, and the implied price surfaces, through the use of predictable rules should be a goal of the FMMO system. The choice of pricing mechanisms may be relatively broad. The results of this analysis indicate that at a chosen level of total marketing costs, uniform mill and uniform delivered pricing, two distinctly different systems, produce very similar market results with respect to plant locations and milk and milk product flows.

The use of a basing-point system for establishing location adjustments may not be necessary, given the strong distribution orientation of Class I processing centers, which is demonstrated by the location of Class I processing at or near major or isolated population centers in each of the simulated pricing scenarios studied. In the presence of centralized coordination, differentials which encourage nearby procurements, regardless of the processor's location could have the same locational and total cost effects as those which attempt to direct milk toward a perceived market center. The use of adjustments which are based on the actual costs of moving supplies to each actual or potential center may be sufficient to ensure efficient plant locations and milk movements.

APPENDICES

APPENDIX A

MONOPSONISTIC SPATIAL PRICING

The three spatial pricing systems described in Chapter III are presented from a spatial monopolist's point of view. This appendix reformulates these systems in terms of spatial monosonistic pricing, which is more descriptive of fluid milk processors, and demonstrates the equivalence of the two approaches with respect to the presence of freight absorption.

Assume that:

i) there is a homogeneous set of sellers distributed over a plane by the density function $\phi(D)$,

ii) there is one buyer,

iii) all sellers have identical supply curves, and

iv) there is a constant freight rate, t,

such that:

$$p_s = a + bq_s = p_b - tD$$

$$q_s = \frac{1}{b}(p_s - a)$$

or

$$q_s = \frac{1}{b}(p_b - tD - a)$$

where,

p_s = the seller's local price;

q_s = the seller's quantity;

p_b = the monopsonist's mill purchase price;

t = the constant freight rate per unit;

D = the buyer's distance from the seller;

and

a and b are positive constants.

Monopsonistic Discriminatory Pricing

$$\pi_d = \int_0^{B_d} (r-p_b)\ \frac{1}{b}(P_s-a)\ \phi(D)\ dD - F$$

where B_d = monopsonist's effective market area

p_b = discriminatory mill prices; and

$P_s = p_b - tD$;

r = constant marginal revenue;

and

F = total fixed cost.

The buyer wishes a function of p_b, defined over D, which maximizes his total profit. Let,

$$p_b = p^* + w\ h(D)$$

where h(D) is an arbitrary function of D.

$$\pi_d = \int_0^{B_d} (r-p^*-w\ h(D))\ \frac{1}{b}(p^* + w\ h(D) - tD - a)\ \phi(D)\ dD - F$$

$$(d\pi_d/dw)_{w=0} = (r-p^*)\ q(B_d)\ \phi(D)\ (dD/dw)_{w=0}$$

$$+ \frac{1}{b}\int_0^{B_d} d[(r-p^*-w\ h(D))(p^*+w\ h(D)-tD-a)]/dp^*$$

$$\cdot\ h(D)\ \phi(D)\ dD.$$

Since $q(B_d) = 0$, the first term above is 0, and

$$(d\pi_d/dw)_{w=0} = \frac{1}{b}\int_0^{B_d} (r-2p^*+tD+a)\ h(D)\ \phi(D)\ dD.$$

Since h(D) is arbitrary, in order for the above to be 0,

$$p^* = (r + tD + a)/2.$$

Optimal discriminatory pricing on the part of a spatial monopsonist involves freight absorption to each seller, just as in the monopolistic case.

Monopsonistic Uniform Mill Pricing

$$\pi = (r - p_b)\, Q_s - F$$

$$Q_s = \int_0^{B_s} \frac{1}{b} (p_b - tD - a) \quad \phi(D) \quad dD,$$

$$\frac{d\pi}{dp_b} = -Q_s + (r - p_b) \frac{dQ_s}{dp_b}$$

$$\frac{dQ_s}{dp_b} = \frac{d\left(\frac{p_b - a}{t}\right)}{dp_b} \cdot \frac{1}{b} (p_b - tB_s - a)\ \phi(B_s)$$

$$+ \int_0^{B_s} \frac{1}{b}\, \phi(D)\ dD,$$

Since $0 = \frac{1}{b} (p_b - tB_s - a)$,

$$\frac{dQ_s}{dp_b} = \int_0^{B_s} \frac{1}{b}\, \phi(D)\ dD$$

and,

$$\frac{d\pi}{dp_b} = -\int_0^{B_s} \frac{1}{b}(p_b - tD - a)\ \phi(D)\ dD$$

$$+ (r - p_b)\left(\frac{1}{b}\right) \int_0^{B_s} \phi(D) \quad dD.$$

Solving for p_b^*,

$$p_b^* = a/2 + r/2 + t\bar{D}/2$$

As in the monopolistic case, the uniform mill pricing monopsonist will set a mill price which reflects absorbing one-half the freight to the average distance supplier.

Monopsonistic Uniform Delivered Pricing

$$\pi = \int_0^{B_d} (r-p_s-tD)\frac{(p_s-a)}{b}\,\phi(D)\,dD$$

at B_d, $r-p_s-tD = 0$, and

$$B_d = \frac{r-p_s}{t}$$

$$\frac{d\pi}{dp_s} = \frac{d\left(\frac{r-p_s}{t}\right)}{dp_s} \cdot (r-p_s-tB_d)\,\frac{(p_s-a)}{b}\,\phi(D)\,dD$$

$$+ \int_0^{B_d} \frac{r-2p_s-tD+a}{b}\,\phi(D)\,dD.$$

Since $r-p_s-tD = 0$,

$$\frac{d\pi}{dp_s} = \int_0^{B_d} \frac{r-2p_s-tD+a}{b}\,\phi(D)\,dD.$$

Solving for p_s^*,

$$p_s^* = a/2 + r/2 - t\bar{D}/2.$$

APPENDIX B

PLANT LOCATIONS AND ASSEMBLY AND DISTRIBUTION MOVEMENTS FOR EACH SPATIAL PRICING SYSTEM

This appendix contains maps showing the plant locations and flows of milk and milk products between points in solutions to selected scenarios for each of the three spatial pricing systems analysed, as well as for the base, cost-minimizing scenario. Assembly and distribution maps for each product class for each scenario are included.

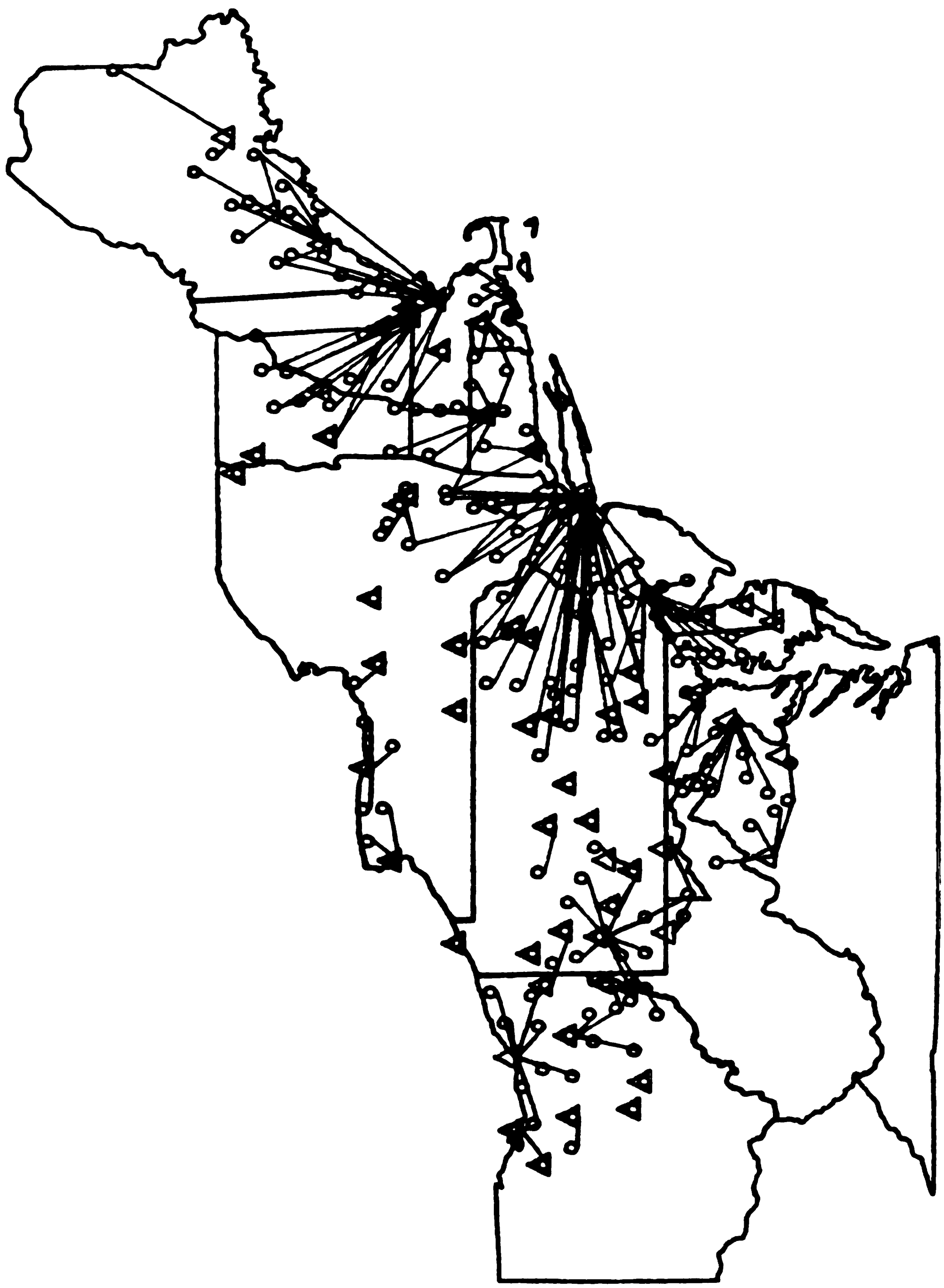

Figure B.1 Class I Assembly Movements: Base

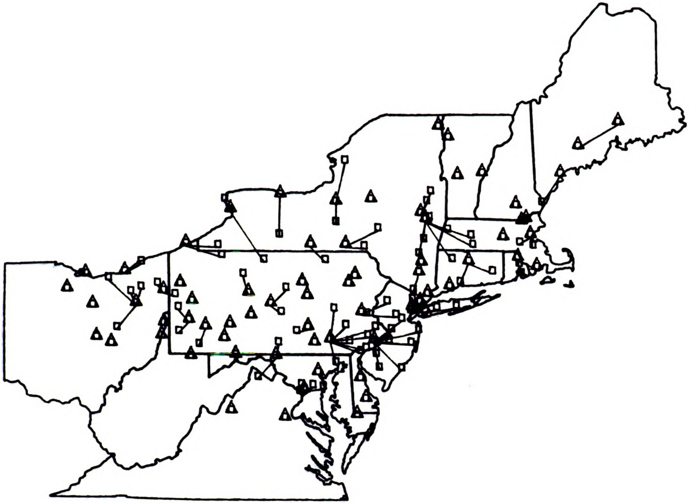

Figure B.2 Class I Distribution Movements: Base

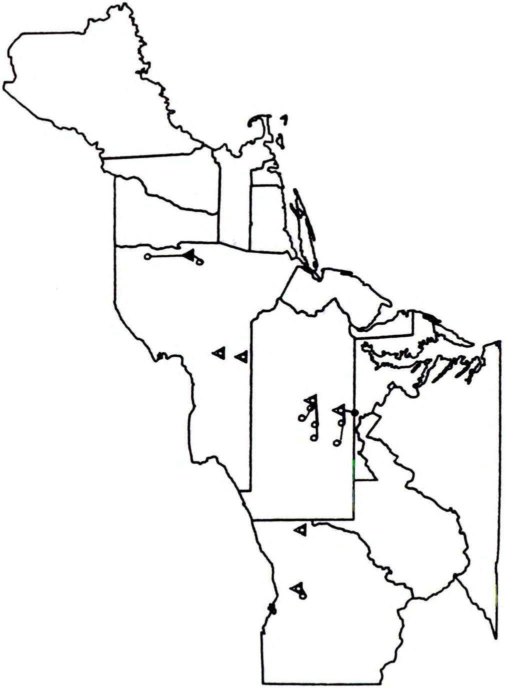

Figure B.3 Class II Assembly Movements: Base

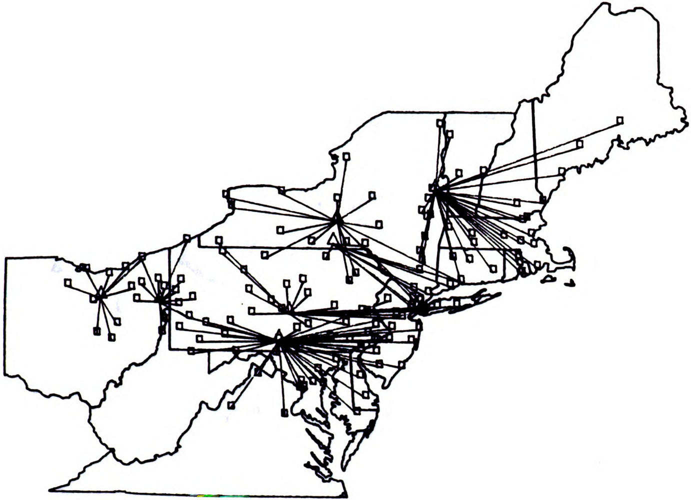

Figure B.4 Class II Distribution Movements: Base

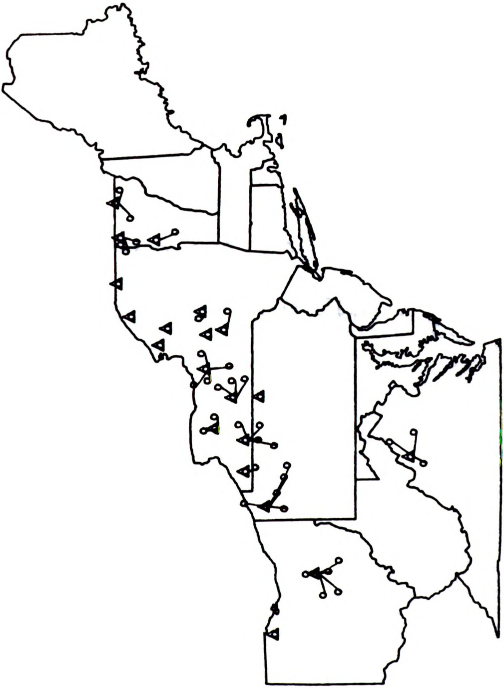

Figure B.5 Class III Assembly Movements: Base

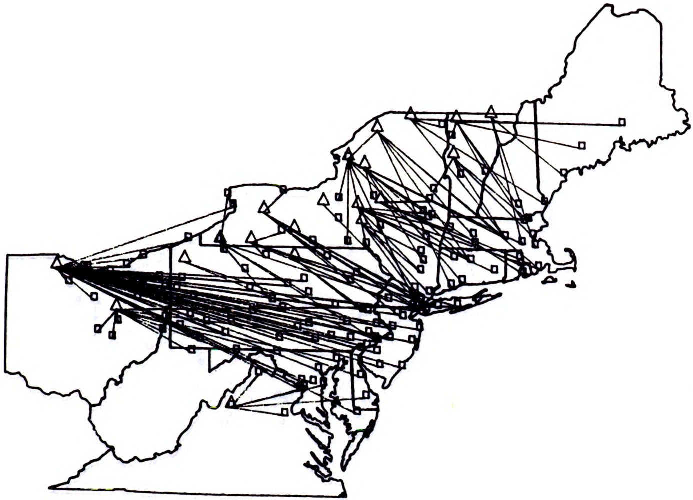

Figure B.6 Class III Distribution Movements: Base

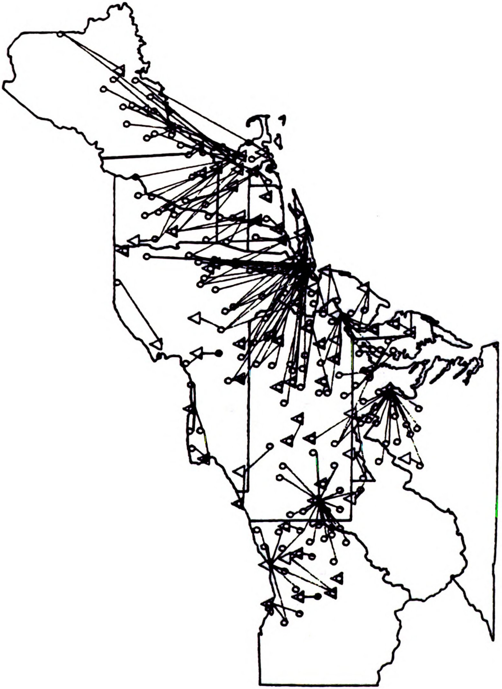

Figure B.7 Class I Assembly Movements: Discriminatory Pricing, 30% Absorption

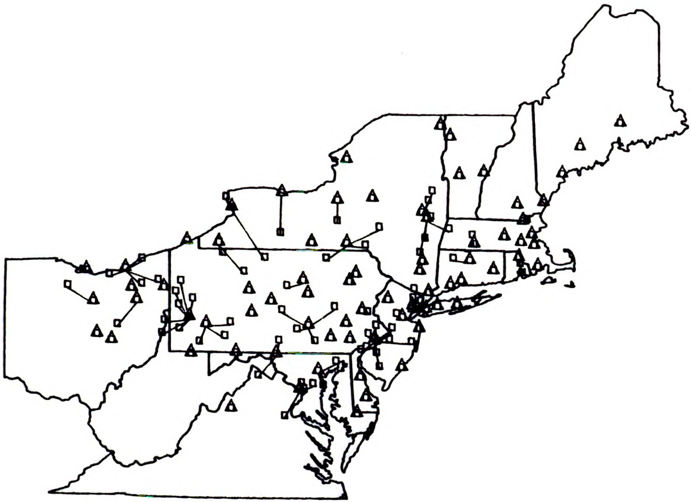

Figure B.8 Class I Distribution Movements: Discriminatory Pricing, 30% Absorption

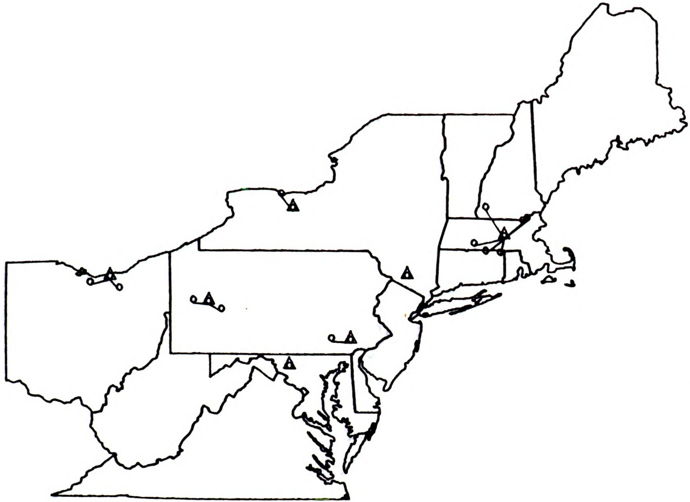

Figure B.9 Class II Assembly Movements: Discriminatory Pricing, 30% Absorption

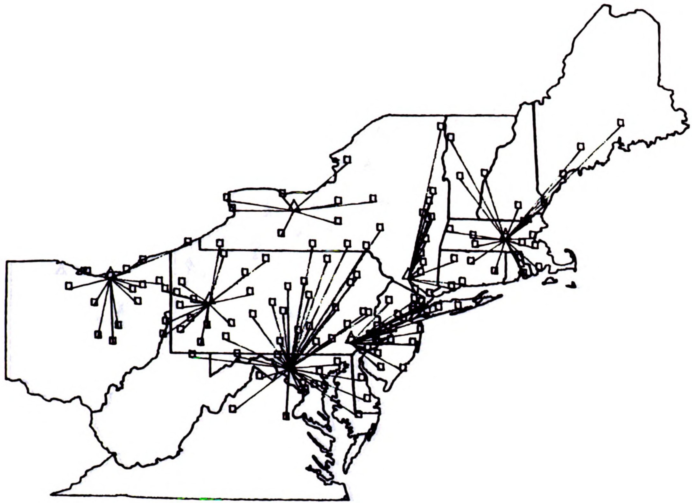

Figure B.10 Class II Distribution Movements: Discriminatory Pricing, 30% Absorption

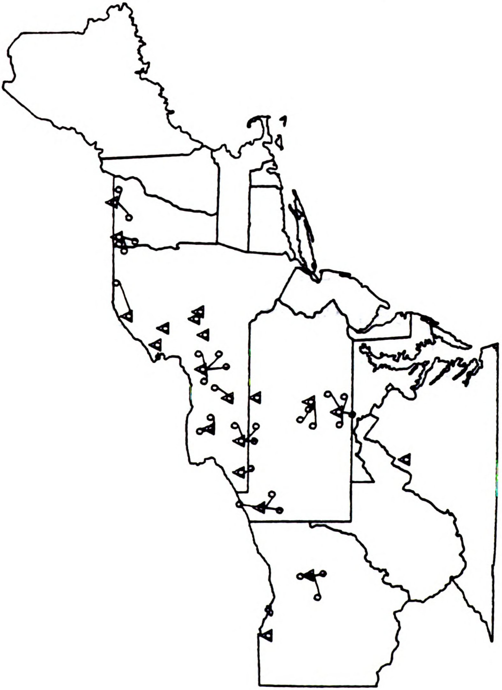

Figure B.11 Class III Assembly Movements: Discriminatory Pricing, 30% Absorption

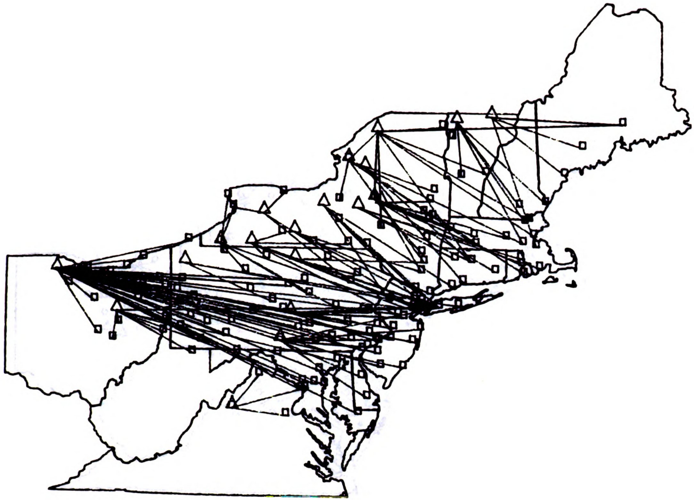

Figure B.12 Class III Distribution Movements: Discriminatory Pricing, 30% Absorption

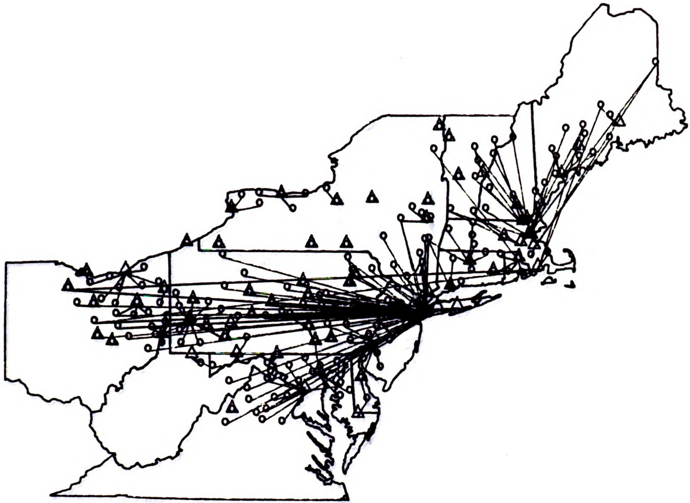

Figure B.13 Class I Assembly Movements: Uniform Mill Pricing, +129¢

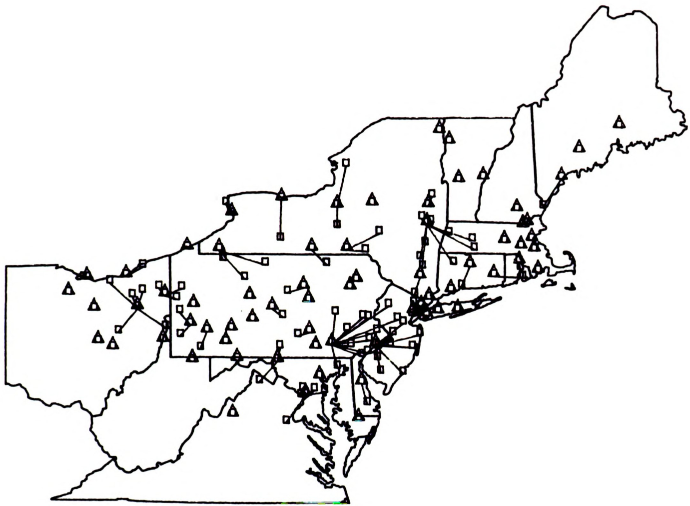

Figure B.14 Class I Distribution Movements: Uniform Mill Pricing, +129¢

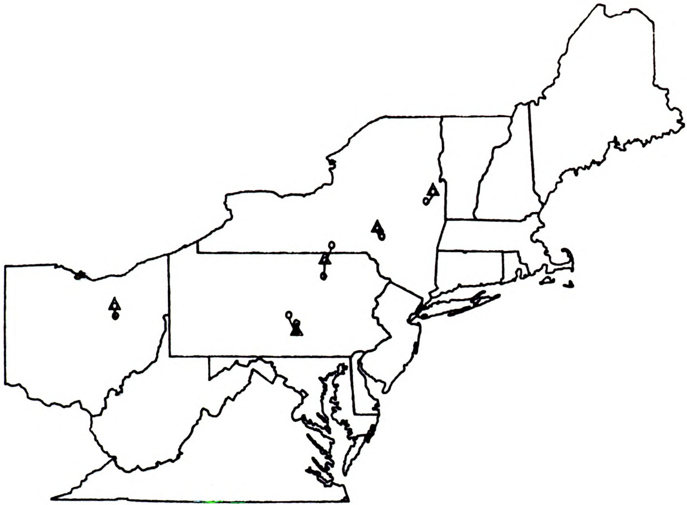

Figure B.15 Class II Assembly Movements: Uniform Mill Pricing, +129¢

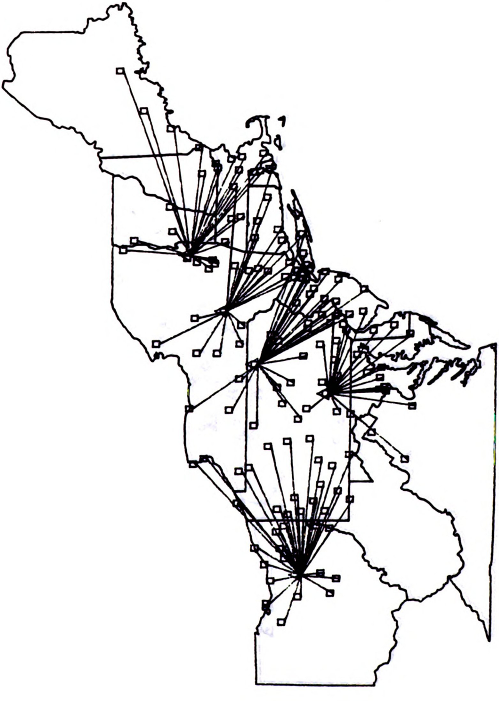

Figure B.16 Class II Distribution Movements: Uniform Mill Pricing, +129¢

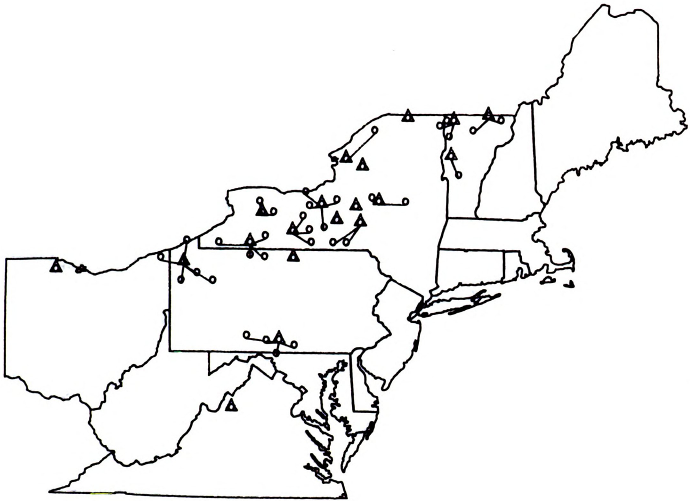

Figure B.17 Class III Assembly Movements: Uniform Mill Pricing, +129¢

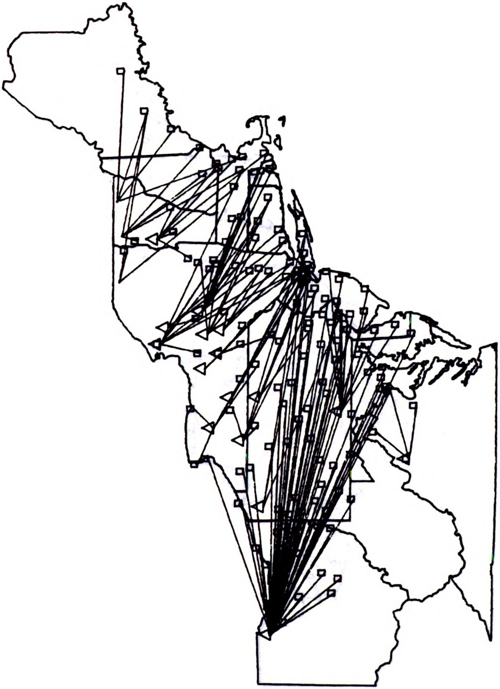

Figure B.18 Class III Distribution Movements: Uniform Mill Pricing, +129¢

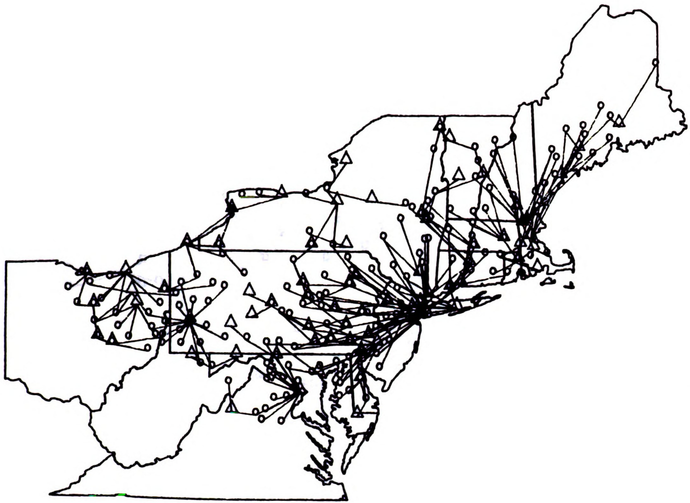

Figure B.19 Class I Assembly Movements: Uniform Delivered Pricing, -60¢

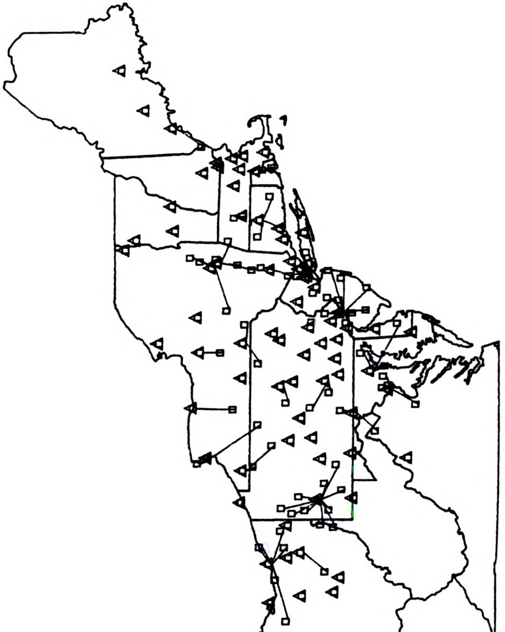

Figure B.20 Class I Distribution Movements: Uniform Delivered Pricing, -60¢

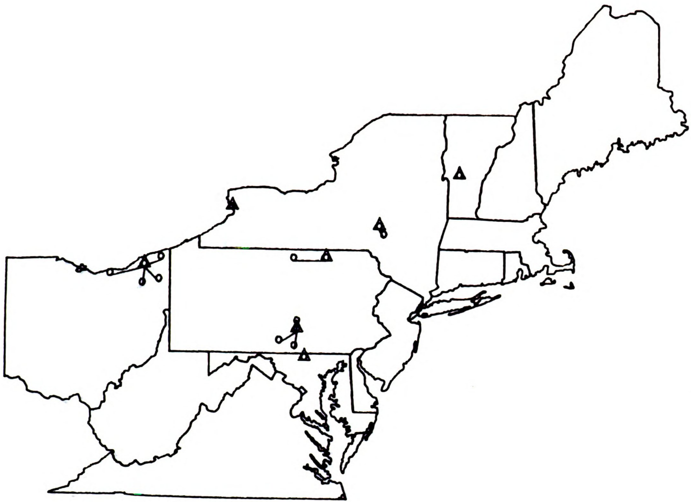

Figure B.21 Class II Assembly Movements: Uniform Delivered Pricing, -60¢

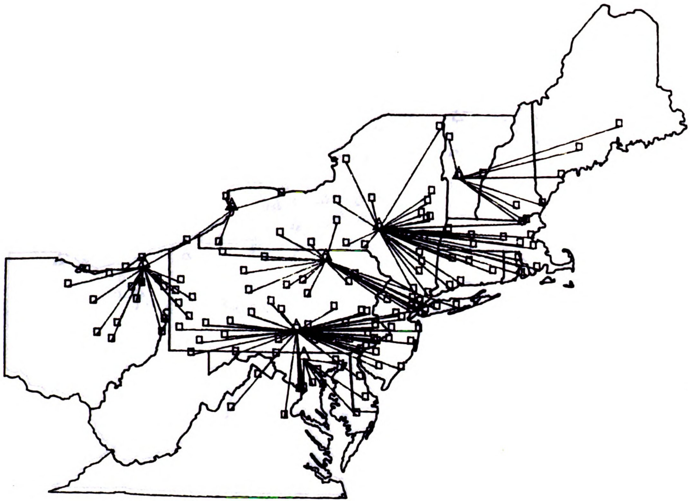

Figure B.22 Class II Distribution Movements: Uniform Delivered Pricing, -60¢

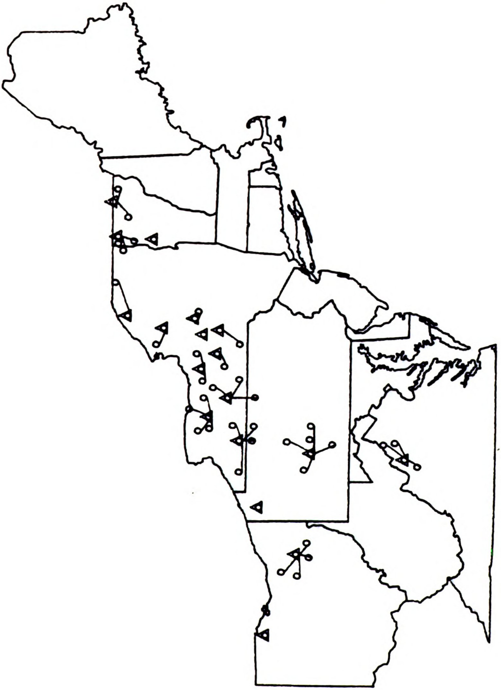

Figure B.23 Class III Assembly Movements: Uniform Delivered Pricing, -60¢

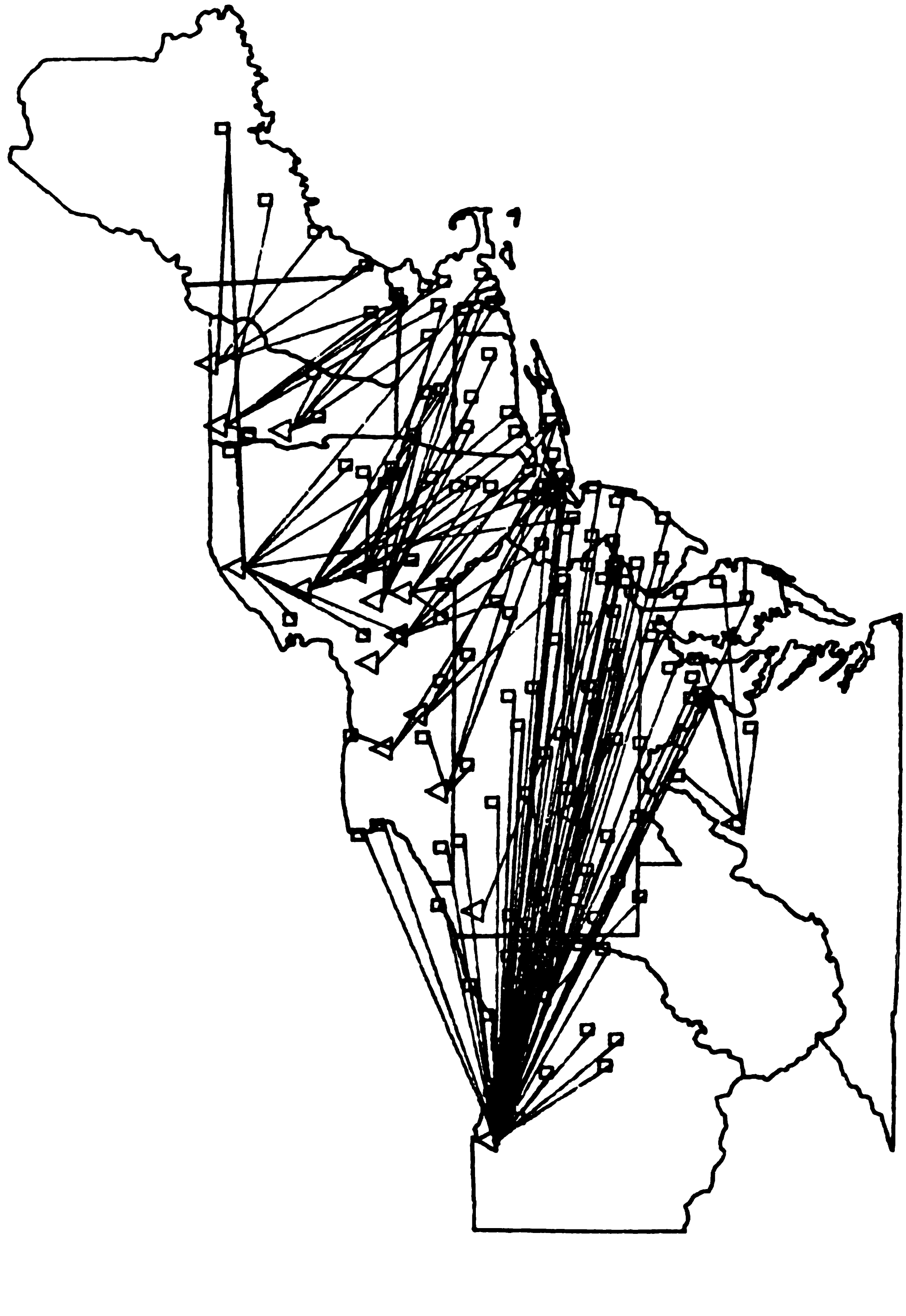

Figure B.24 Class III Distribution Movements: Uniform Delivered Pricing, -60¢

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