A SPATIAL ECONOMIC ANALYSIS OF THE IMPACT OF REVERSE OSMOSIS FILTRATION ON THE GRADE A MILK MARKET

By

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ABSTRACT

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The expanding milk surplus, falling support price, and imminent introduction of productivity boosting technologies have created an environment of increased tension within the U.S. dairy industry. The result has been an intensified effort to identify means for improving economic efficiency and establishing long-run viability. One area of interest has been bulk reduction of fluid milk.

This thesis focuses on the economic feasibility and regional impact of Reverse Osmosis filtration of Grade A milk. For analysis, a short-run spatial equilibrium model was specified. Solutions were generated under a range of pricing and policy scenarios including Class I differential removal and realignment, reduced support price, and increased transportation costs.

Results indicate that fluid milk price would fall with the degree of impact varying by region. As a whole consumers gain while producers lose, yet, for some regions Reverse Osmosis may help minimize the negative impact of certain policy changes.

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ACKNOWLEDGMENTS

This thesis research developed into a far more comprehensive and challenging project than I had originally envisioned. In this sense, naiveté allowed me to achieve something which I otherwise may not have chosen to attempt. Certainly I did not approach this research alone. The fact that it is now sitting completed before you is testimony to the support and guidance which I received throughout. I can not express strongly enough the valuable role which Larry Hamm had as my research advisor and major professor. His guidance and contributions are reflected throughout this thesis -- and will undoubtedly influence future work. Further thanks is gratefully extended to James Oehmke, James Hilker, Ted Ferris and Robert Brunner for their thorough review of various drafts and their valuable suggestions on how to better this project.

Throughout working on this research I have received immeasurable support from people whom I am privileged to call friends. Their support, concern and admirable patience I shall never forget. With them, time spent will never be trivial. Finally, a warm thankyou to my family. Their love has always supported me securely, allowing me the freedom to choose and the opportunity to achieve.

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LIST OF ABBREVIATIONS

AMS	Agricultural Marketing Service
CCC	Commodity Credit Corporation
COP	Cost of Production
cwt	Hundredweight
DMS	Dairy Market Statistics
DAMPS	Dairy Market Policy Simulator
ERS	Economic Research
FEDS	Firm Enterprise Data System
FMOMS	Federal Milk Order Market Statistics
FMMO	Federal Milk Marketing Orders
GTP	Generalized Transportation Problem
M-W	Minnesota-Wisconsin
NASS	National Agricultural Statistics Service
NMPF	National Milk Producers Federation
RO	Reverse Osmosis
UF	Ultrafiltration
UHT	Ultra High Temperature
USDA	United States Department of Agriculture
USDC	United States Department of Commerce
USPHS	United States Public Health Service
VSM	Vector Sandwich Method

CHAPTER ONE

INTRODUCTION

Government efforts to curb milk supply and reduce government expenditures within the dairy industry are forcing the industry towards improved economic efficiency. Producers, finding that they must reduce expenses in order to remain viable, are looking for means by which to maintain revenues and secure their livelihoods. One area of obvious potential for cost reduction is the transportation of bulk fluid milk. In a 1980 National Economics Division staff report, Ed Jesse determined that substantial economic incentives exist in favor of concentrating and then reconstituting whole milk when the distance between production and consumption points exceeds 100 miles. Later studies by Novakovic and Aplin (1981), Novakovic (1982), and Whipple (1983) have substantiated the potential economic incentives in shipping milk in a concentrated form. Although there exist a multitude of methods for removing water from milk, recent technological advancements in reverse osmosis (RO) filtration, a membrane filtration technique, have generated interest by producer organizations. One advantage of RO filtration over other

technologies is that it produces a superior product holding considerable promise for consumer acceptance.

This thesis is designed to determine reverse osmosis filtration's potential for adoption by the Class I (fluid use) milk market under a nonrestrictive policy environment, and to determine what the impact of such adoption would be on a regional and industry-wide basis. It is believed that RO filtration of fluid milk could provide producers in the Upper Midwest with the opportunity to capitalize on their competitive advantage in milk production, by capturing new markets at greater distances. The results obtained from this research prove to be both insightful and, in some cases, rather surprising. For example, no production region is found to benefit from RO filtration to the degree initially hypothesized.

The remainder of this chapter focuses on the current environment under which the industry is operating, reasons for interest in bulk reducing technologies, and the method of analysis utilized in determining the impact of RO filtration upon the market. This will be followed by a statement of research objectives and an overview of the chapters comprising this thesis.

1-1 The Industry Environment

Under the present economic, technological and legislative environment, the dairy industry faces an era of significant change. Recent reductions in the dairy support price have forced many producers to drop out of production while others have enlisted in the government sponsored Dairy Termination Program. Meanwhile, emerging technologies promise to expand production levels to new heights. For example, it has been estimated that bovine somatotropin[1] alone could increase long-run productivity by approximately 15 percent. Such a shift foretells of a major reshuffling within the industry as inefficient producers are forced out and those remaining in production expand their operations in order to capture the benefits of scale economies. The effect of these two opposing forces, the need to decrease supply and the rapid increase in per unit production, has created an atmosphere of increasing tension within the industry.

Clearly new technologies will have a key role in determining the direction and composition of the industry over the next decade. Just as some technologies may impact the industry through increasing supply, others may help producers through this transitional period. Specifically, bulk reduction through membrane filtration techniques has generated considerable attention. This process could potentially allow producers to benefit according to their competitive advantage in production while the industry advances towards improved economic efficiency.

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[1] Bovine somatotropin, commonly refered to as bovine growth homone, is a naturally produced hormone within the animal which, at increased levels, significantly enhances milk productivity.

1.2 Interest in Bulk Reducing Technologies

Fluid milk contains approximately 87 percent water (Wearson and Ginnette, 1970). This water content, due to its bulk and weight, increases transportation, handling, storage, and preservation costs. Clearly then, a natural area for cost reduction within dairy marketing is through reducing the milk's bulk prior to shipping.

The present marketing order structure supports this conclusion. Changes in milk marketing orders have increased the distance which milk is moved within order regions, with distances often exceeding 1,500 miles (Jesse, 1980). Given this order transfer structure, it seems timely to reappraise the current transportation system. One solution to resolving the transportation cost problem would be to transport a concentrated product, which can then be "recombined" into a whole fluid product nearer the point of consumption. The economic advantages of removing some of this water can be actualized only as long as the cost of such removal does not outweigh the savings acquired through reduced bulk and weight.

In the U.S., the majority of regions produce an adequate fluid milk supply to meet regional demand. Importing fluid milk from other regions may be necessary during times of temporary or seasonal shortage. Given the viability of reconstituted milk as an alternative or supplement to local milk production in deficit regions, one would expect to see a reduction in geographic milk price differences among regions. The reason for this is that with Class I differentials based on whole milk transportation costs and transportation costs being positively correlated with weight and volume, removing the water decreases the cost of shipping milk.

For regions such as Michigan which produce a high percentage of fluid grade milk (97 percent of total production) and which have a clear competitive advantage in production over all regions excluding the Upper Midwest, the potential impact of reconstituted milk are particularly attractive (NMPF, 1985). Relatively low cost of production regions could see a rise in export demand leading to an increase in the proportion of production going to Class I use. As a result, producer revenues could increase. Certainly the potential benefits of reducing the bulk and weight of milk appear attractive but the method of concentration remains important, especially in terms of consumer acceptance.

Traditionally, evaporation and spray drying have been employed to remove water from skim milk and more recently the ultra filtration process has gained attention. Liquid foods, however, are very vulnerable to flavor and aroma changes and each of these processes have negative side effects. For example, exposure to high temperatures under spray drying can alter milk's characteristics and ultra filtration may result in the loss of some nutrients present in raw milk.

More recently, reverse osmosis filtration has been applied to the concentration of fluid milk. The advantage of RO filtration over the more traditional forms of reduction lies in its nondependence on heat. A large percentage of water can, therefore, be removed without altering taste and nutrient characteristics; thus, minimizing the impact on consumer demand. It is for this latter reason that the RO filtration process has gained great interest among bulk reduction technologies. With the aid of technological advancements, it appears the process is also becoming an economically feasible alternative. A brief overview of some common bulk reducing alternatives is presented in Figure 1.1.

Clearly, employing RO filtration presents some very exciting possibilities: (1) low cost production regions could benefit from their competitive advantage; (2) the industry could realign its production and shipment patterns, gaining increased economic efficiency; and, (3) consumers could benefit from the reduction in transportation costs as reflected in the retail price of milk. Regionally and intraregionally the impacts would certainly vary. For example, consumers in regions farthest from the source would necessarily see the greatest potential impact. Furthermore, low income consumers, who devote a greater proportion of their income to food purchases, could realize appreciable benefits.

METHOD	COST* (Cents/cwt)	CONCENTRATION (% Solids)	CURRENT USE	DISADVANTAGE	ADVANTAGE
Conventional Evaporation	101.9	27	Condensing skim milk prior to drying	-Unknown stability characteristics	-elmination of heat drying
Thermal Evaporation	56.9	36 to 40	Whole milk concentration for evaporated and UHT milk	-Stability problems -Limited degree ot concentration -Short product life	-Cream separation/ butter manufacturing not needed for reconstitution
Spray Drying	126.9	13	Producing skim milk powder	-Liquid fuel intensive -Significantly alters characteristics -Inferior taste	-acheives the greatest degree of concentration
Ultra Filtration/ Reverse Osmosis	52.4	50	Whey reduction and skim milk concentration	-UF has some loss in nutrient value -High equipment cost	-no heat required
Baseline	30.9	0	Most fresh whole milk marketings	-Bulky -High cost of transportation	-Operates using existing equipment

* Cost of assembly, processing and reconstitution

Figure 1.1. Distringuishing characteristics of the common methods of bulk reduction

Source: Jessee, 1980 and Fenton-May et al., 1972.

This wide range of potential benefits from the adoption of RO filtration technology clearly provides sufficient merit to study its introduction into the fluid milk industry. However, it is recognized that not all technologies will be beneficial to all producers. Given this, it becomes imperative to determine the projected impact of a given technological change at both an industry and regional level.

1.3 Method of Analysis

There are a wide range of economic issues associated with the adoption of RO filtration. Of specific interest to this study is RO filtration's affect on fluid milk markets. The transshipment and regional nature of this question suggests the need to spatially model the national fluid milk market. The basic theory behind spatial price equilibrium illustrates why such analysis is useful.

Spatial theory of pricing suggests that in the absence of market distortions, caused by administered pricing or monopoly presence, the difference in price between geographic regions will be equivalent to the cost of moving the product between regions. Hence, in a trading environment free of barriers, as long as the supply and demand equilibrium price difference between the two regions is not less than the cost of transportation, trade will occur. Milk will be shipped from the surplus (relatively low price) to the deficit (relatively high price) region.

The consequence of a decrease in transportation cost and, hence, a change in the regional price wedge, would be evidenced by an altering of the prices, quantities traded, and distribution patterns within the U.S. fluid milk market. For example, regions which face very high fluid milk prices would expect to see a decrease in price and an increase in consumption. Furthermore, if production costs are relatively higher in the deficit region, a decrease in production could be experienced. On the other hand, a surplus and relatively low cost of production region, like Michigan, might enjoy many benefits arising from RO filtration and reconstitution. Export markets may expand and the blend price increase as surplus fluid grade milk, which would otherwise be "dumped" into less profitable manufactured dairy product use, is allocated to Class I use.

Spatial equilibrium analysis will allow determination of the economic and distributional impacts of introducing RO filtration to the Grade A market. Several spatial models of the dairy industry have been developed (Hallberg et al., 1978; and Novakovic et al., 1980). Although these models are very thorough, they create a limitation simply because of their size -- large mainframe models with extensive data requirements.

For the purposes of this study, a general idea of the market impact of RO filtration can be obtained through the use of a more simplistic spatial equilibrium model run on a

less demanding computer program. Sharples and Holland (1984) and Holland (1985) have developed such a program, the Generalized Transportation Problem (GTP). Although GTP is specified for international trade, spatial price theory remains the same for trade between any spatially separated regions. The program generates trade flow quantities, prices and revenues and has a data requirement commensurate with the detail level of this study. In sum, GTP and spacial equilibrium theory present the necessary tools of analysis for obtaining the research objectives.

1.4 Study Objectives

The objectives of this study are:

(1) To gain a working knowledge of RO filtration, constraints to its adoption, operational parameters and its potential for future use within the Class I milk market.

(2) To understand the fundamental characteristics of the dairy industry; to reaffirm the relative production advantages among states and regions; and, to identify market relationships and policies relevant to the sale of RO filtrated milk.

(3) To incorporate these market characteristics and relationships into the design and specification of a spatial equilibrium model of the Grade A milk market.

(4) To examine the potential Class I market impact of the full scale adoption of RO filtration through analysis of model results run under a range of pricing and policy scenarios.

1.5 Overview of the Study

This study evaluates the economic feasibility of RO filtration through spatially modeling a selected segment of the U.S. Grade A milk market. The modeled area is broken down into nine supply and ten demand regions. The necessary supply and demand data are respecified from state and federal marketing order statistics. Estimated costs of applying RO filtration, transportation cost functions, and supply and demand elasticities are all extracted from previous research. A spatial equilibrium model incorporating this data is specified according to market characteristics and the objectives of this thesis. Results from this model are generated under numerous economic scenarios. The regional impact on distribution, prices and revenues are isolated for cross analysis.

This thesis is divided into six chapters yielding insight into the operation of RO filtration, the industry in which its adoption is being analyzed, and its potential impact on fluid milk markets.

Chapter Two reviews fundamental characteristics of the domestic dairy industry. Areas covered range from the role of government, the pricing mechanisms involved and regional costs of production. Discussion focuses on industry relationships which are tied to the adoption of RO filtration. Additionally, the issues related to reconstituted milk are discussed.

Chapter Three deals exclusively with the technology isolated for study: RO filtration. The general principles of RO filtration are presented and the RO system itself is described

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described. Potential operational constraints to adoption of RO for fluid milk are highlighted.

In Chapter Four the relevant industry characteristics introduced in Chapter Two are placed within the context of a spatial equilibrium model. The general theory of spacial equilibrium and previous modeling research are discussed as well as the specific computer program and solution algorithm employed in this study. Finally, the fully specified model used for analysis is submitted along with its data requirement.

Model results and analysis are presented in Chapter Five. The scenarios under which each solution is generated are described, as well as their incorporation into the model. Additionally, the primary limitations and caveats associated with the model are submitted.

Chapter Six summarizes the study and the results obtained. The achievement of study objectives is discussed as well as what can and can not be inferred from the results. In conclusion, implications of the results are submitted.

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CHAPTER 2

RELEVANT DAIRY INDUSTRY CHARACTERISTICS

The dairy industry, by its nature, poses unique marketing concerns. Fluid milk is a bulky, highly perishable, continuous flow product subject to health contaminants; requiring strict sanitary compliance in production, transportation and processing. Furthermore, supply is highly inelastic in the short-run with producers traditionally being very vulnerable to the market power held by proprietary handlers and processors. These characteristics all pose potential marketing problems.

Milk also has important nutritional qualities. Notably it is high in protein and calcium and is considered an important nutritional item in the nation's diet. It is because of this combination of sensitive marketing conditions and nutritional importance that the dairy industry has been seperated from other agricultural industries in the design of marketing policies. Dairy industry policy is unique in that dairy is the only industry where both government price supports and federal marketing orders exist.

The degree of regulation and the complexity of the pricing mechanisms which have evolved, together with the distinguishing marketing problems associated with milk, make it difficult to transfer general knowledge of agricultural marketing and policy to the specific concerns of the dairy industry. Hence, before one can approach the task of spatially modeling the marketing of fluid milk within the United States, a basic understanding of the industry is essential.

This chapter overviews some of the more prominent dairy industry characteristics, focusing on areas directly tied to this study. An examination of the regional production cost structure upon which the relevance of this study hinges will follow. Finally, a close look at reconstituted milk will be made, including methods of concentration, the role of current regulations, and some previous studies addressing these issues.

2.1 Role of Government Within the Domestic Dairy Industry

The government has intervened in fluid milk markets by creating regulations to reduce inequities, uncertainty, and variability. In general, the government intervenes in commodity markets because there are unsatisfactory conditions within the market. For example, milk's perishability creates the opportunity for gross inequities to develop, resulting in market uncertainty and price and quantity instability within the industry.

Before regulation, processors could shift costs between producers, manufactures and fluid plants, all of which had supply

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had supply level requirements to ensure efficiency. This led to instability in the general milk market and, with marketing power in the hands of processors, inequities developed (USDA, Jan. 1984). Furthermore, to limit variability, reserves needed to be maintained. Private plant operators were unwilling to bear the burden of this expense, as were producers. The fluid milk market was clearly classifiable as disorderly.

Additionally, milk supplies often became contaminated or failed to meet health standards. Incentives were deemed necessary to encourage investment in the costly equipment and facilities required to improve sanitary standards. Such investments would ensure that an adequate supply of safe Grade A milk was always available. Hence, the central objective of many dairy program provisions is to provide price stability and an equitable income to producers, while ensuring a reliable and safe supply of milk for the nation's consumers. Regulation primarily came in the form of federal marketing orders and price support programs.

2.1.1 Federal Milk Marketing Orders

Federal regulation of fluid milk markets began with the establishment of the Federal Milk Marketing Order (FMMO) system in the 1930's. This system was designed to address the chronic problems existing within the market. Federal orders for milk are issued by the Secretary of Agriculture and administered by the Dairy Division of the USDA's

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Agricultural Marketing Service. Each order applies to a specific geographic region where producers have voted for its establishment.

The function of FMMOs differs from those common to fruit and vegetables in that milk marketing orders actually function to establish an institutional structure for pricing. FMMOs regulate all the fluid milk industry indirectly via direct regulation of handlers selling their milk within orders. This is accomplished by setting a minimum price which must be paid by processors to producers for Grade A milk[1]. Processors may then use the milk for any purpose, including manufactured products which only require the lower quality standard Grade B milk.

In the 1930's, when the FMMOs were established, markets were local. Seldom was milk transported between markets; the technology was not advanced enough and the risks were too high. As a result, supply and demand were necessarily met within the market.

Due to transportation costs being greater for fluid than for manufactured dairy products, surplus regions developed large manufactured product industries. These products were marketed on a national scale; fluid markets remained relatively local, within a couple hundred miles. As the technology (transportation and refrigeration) improved, transportation costs and risk decreased. As a result, the

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[1] Only Grade A milk is regulated under federal orders.

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necessity for adequate reserves to be held locally declined and federal orders began to merge.

In 1962 the number of FMMOs peaked at 83. Since then the number has decreased, yet, the amount of milk covered under federal orders has increased. At present, approximately two-thirds of all milk marketed in the U.S. is covered under federal orders. These trends are illustrated in Table 2.1.

Table 2.1. Extent of The Federal Milk Market Order Program, 1960 to 1985

Year	Number of Federal Orders	Volume of Milk Covered Under Orders	Volume as a Percent of U.S. total
	(Number)	(Bil. lbs.)	(Percent)
1960	80	48.8	45.0
1965	73	54.4	48.3
1970	62	65.1	59.6
1975	56	69.2	62.8
1980	47	84.0	67.4
1985	44	97.8	70.0

Source: National Milk Producers Federation, 1984 Dairy Producer Highlights, 1985, p.20 and USDA, Federal Milk Order Statistics: 1985 Annual Summary. 1986.

2.1.2 Price Support Programs

Current government policy intervention in the dairy industry is primarily in the form of price supports which were established in 1949. Acting through it's Commodity Credit Corporation (CCC), the government guarantees purchase of cheese, butter, and nonfat dry milk at a set price. These CCC purchases serve to support the market price of manufactured dairy products and indirectly help to support the price of all milk[2]. While the price support program is not directly tied to the federal order program, it does have a direct impact on federal order marketings.

2.2 Pricing Mechanisms

Price is the primary coordinator of activity at each stage of marketing: production, assembly, processing and distribution. Price also serves as a production incentive and helps to maintain adequate supplies for the various competing sources of demand. Prices for milk and dairy products are partly administered and partly negotiated in the market place.

The current price structure is a result of the combined influence of government regulations and cooperative action as allowed by the Capper-Volstead act. Government regulations directly impact the M-W price through price supports and impact the Class I milk price and the blend price[3] through classified pricing. Producer cooperatives have created over-order premiums, now common in most orders. Each of these pricing mechanisms is discussed below with their mathematical formulations presented in Appendix A.

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2 While Class I milk receives a price equal to the M-W (Grade B milk) price plus a local differential, government purchases supporting the manufactured goods market price indirectly supports the fluid grade market.

3 The blend price is that which the producer receives and is determined by proportion of milk allocated to the alternative Grade A use classes.

2.2.1 M-W Price

The Minnesota-Wisconsin Price Series is a weighted average price paid for non-order (Grade B) milk destined for manufactured use in the states of Minnesota and Wisconsin. Computed on a monthly basis by the USDA, it is designed to reflect a combination of the wholesale product price level and manufacture's profit margin. The former may be partially determined by support prices and the latter is determined in the market place. As a result of this structure, under FMMOs the price of milk destined for storeable manufactured products is set equal to the M-W price.

2.2.2 Classified Pricing

Federal milk marketing orders regulate via establishing a minimum price which handlers must pay and which producers receive for Grade A raw milk. Although handlers buy milk from producers, the price they pay and price producers receive is not the same. Specifically, handlers pay what are termed classified prices.

Classified prices are based on the end use, or Class, to which the milk is put. Depending upon the order, there are either two of three classifications: Class I products comprise fresh fluid products; Class II are soft manufactured products; and Class III are hard manufactured products. Where there is no Class III division, Class II represents all manufactured products.

The Class I price structure differs greatly from that of Class II milk. Class I milk receives a higher price than does milk going to either Class II or III use. This is partly necessitated by the Class I product's nature: more expensive to transport and more vulnerable to spoilage. Regionally, the Class I price will vary according to the Class I differential, as discussed in the following section.

In contrast to the Class I price are the Class II and III price which the USDA indirectly supports through the M-W price. Specifically, a tentative Class II price is announced for the following month based on a formula. This formulation takes the M-W price for the second preceding month and adjusts it via the weighted change in the gross value of milk used to make cheddar cheese and butter/nonfat dry milk. Hence, the Class II price is nearly equivalent to the M-W price and is fairly uniform nationally, while Class I prices vary positively with distance from the Upper Midwest -- the traditional milkshed. This pricing theory is reflected in the observed differential pricing scheme.

2.2.3 Class I Differentials

Federal order Class I milk prices are aligned to Eau Claire, Wisconsin, the milkshed's base point. The Class I differential increases directly with increasing distance from Eau Claire in such a way as to approximate the cost of transporting raw milk from the milkshed. Figure 2.1 illustrates this spatial pricing system: the highest

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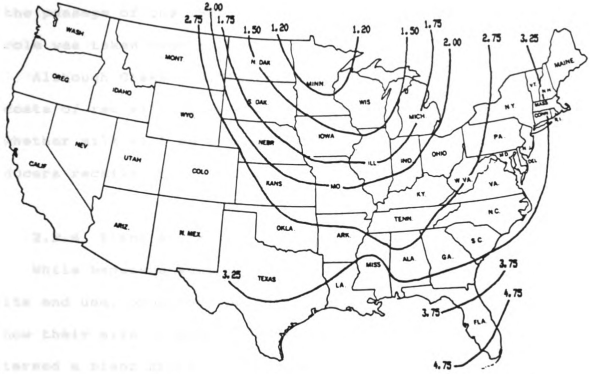

Figure 2.1 1985 Class I differential price surface in dollars per cwt.[4]

Source: Data taken from FMOS, USDA; Contours, estimated.

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[4] Note, this price surface is an approximation derived from Class I price differential data for selected cities. While this figure does provide an illustration of the general case, not all price differentials coincide with this surface.

differentials are in Florida and the lowest in Minnesota. These differentials are tacked onto the base price which handlers must pay for milk going to Class I use. Historically, the USDA has set the Class I differentials. With the passage of the 1985 Food Security Act, this pricing role was taken over by Congress.

Although Class I differentials reflect transportation costs of raw milk, they are not the primary determinant for whether milk will be transported. The price which producers receive, the blend price, serves that function.

2.2.4 Blend Price

While handlers must pay for Grade A milk according to its end use, producers do not receive payment according to how their milk is used. Rather, producers receive what is termed a blend price for their milk.

To preserve equity among producers, regardless of their distance from the fluid milk market, proceeds from both fluid and manufactured sales in a given order are pooled. The proceeds are than distributed to producers at a blended per unit price, with allowances made for location, butterfat and marketing services[5]. Hence, the blend price is

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[5] For example, if 80 percent of the milk sold in an order goes to Class I products and the remaining 20 percent to Class II, then the blend price per unit received by all producers selling in that order is comprised of 80 percent of the Class I price and 20 percent of the Class II price.

determined by the proportion of milk pooled on a given order going to each Class usage.

2.2.5 Over-Order Pricing

One consequence of cooperative growth within the federal order system has been the development of over-order pricing practices. Over-order premiums represent an additional charge instituted by a producer cooperative which the handler must pay. While cooperatives announce the over-order premium for the market in advance, decreasing the uncertainty faced by handlers, these premiums generally have not been negotiated. It should be noted that producers may not receive the full over-order premium. Producer cooperatives often take a proportion of the premium to cover operating expenses. Both the amount of the premium and the amount which the cooperatives withhold varies between regions and over time.

2.2.6 Commodity Exchanges

For two manufactured goods, butter and cheese, formal commodity exchanges have been established at the Chicago Mercantile Exchange and the National Cheese Exchange, respectively. A primary service generated by these exchanges is that they form the basis for formula pricing, location price adjustments, and product characteristic adjustments.

2.3 Role of Producer Cooperatives

The initiation of federal order regulations effectively decreased the power of processors while increasing stability in the market. One consequence of these regulations has been a shift in market power from industry processors to producer cooperatives. These cooperatives began appearing in the late 1960's and have a growing role within the industry.

Cooperatives act to procure, assemble and coordinate the cyclically contrasting supply and demand. Additionally, they may provide services such as quality control, intermarket transfers and surplus management. Presently more than 85 percent of producers in federal orders are cooperative members and more than 75 percent of the nation's milk, is sold through cooperatives (USDA, Jan. 1984). The primary direct impact which cooperative presence will have on this study is through the existence of over-order premiums.

2.4 International Trade in Dairy Products

Dairy is a highly regulated and protected industry in most modern industrialized countries. Domestic dairy programs commonly have led to significant surpluses and, in turn, to the imposition of import barriers and/or heavy export subsidies. In the U.S., imports of dairy products have averaged less than two percent of total U.S. milk production annually (USDA, Jan. 1984). On a world wide scale, trade in dairy products remains fairly steady near five percent of total world milk production (USDA, Jan. 1984). The world trade in dairy products will likely remain relatively small and as such, will not affect the analysis undertaken in this study.

2.5 Market Characteristics of Supply and Demand

Fluid milk markets display unique characteristics in both supply and demand. A fundamental characteristic of the fluid milk market is that seasonal patterns exist in both production and consumption; however, these patterns do not coincide. Production peaks in late spring and troughs in late fall, while consumption is lowest in late spring and highest in early fall. Similarly, consumption shows strong weekly trends. Hence, for demand to be met on any given day of the year necessitates surpluses at other times.

Of particular interest to this study are the supply and demand elasticities for fluid milk. Dairying is characterized by a highly inelastic short-run supply schedule. This is due to high fixed investments in specialized facilities which prevent rapid contraction or expansion. Additionally, there is a lag of two years from birth until a heifer enters the milking herd. As a result, supply is very unresponsive to price over a two year period, becoming more elastic in the long-run. On the demand side, dairy product sales characteristically are not very price responsive in the short-run and may be more responsive in the long-run.

2.6 Regional Costs of Production and Competitive Advantage

The existence of competitive advantage in a free market allows one region to benefit from producing the commodity for which it has a competitive advantage. The questions addressed in this study are relevant only so long as the Upper Midwest really does have a competitive advantage in the production of milk. Of specific interest is Michigan's position relative to states outside of the Upper Midwest region.

2.6.1 Establishing Michigan's Competitive Position

Regional competitive positions in the dairy industry are linked to costs of production. Given this, it is necessary to compare the costs of producing milk in Michigan relative to other regions in order to establish the competitiveness of Michigan's dairy industry.

Average cost of production figures for milk in Michigan can be obtained from two reliable sources, Michigan State University Telfarm reports and the USDA's Firm Enterprise Data System (FEDS) budgets. Telfarm is a Cooperative Extension supported farm accounting project operated by Michigan State University. It generates Michigan farm accounting records by using a voluntary mail-in system. Several hundred dairy farms take part in this project.

Although the data generated may not be representative of all dairy farms in Michigan, given the large sample size, one can be confident that the data does accurately represent commercial Grade A dairies grossing greater than $50,000 annually.

The USDA's cost of production studies were mandated by the federally legislated Agricultural Consumer Protection Act of 1973. This Act requires annual reports to Congress on the costs of producing various commodities, including milk. Although data is originally compiled at the state level, the USDA publishes its cost of production statistics annually in regional form.

A large part of the FEDS technical data used to estimate costs of production is compiled by the Economics Research Service (ERS) and National Agricultural Statistics Service (NASS) through enumerated surveys of farm operators. ERS presents cost of production data in enterprise budget form: a listing of all the costs and returns associated with the production of a specific commodity. State enterprise budgets are generated for each state located in the major production regions for the given commodity. These budgets are then weighted according to production, determining the regional and national average production costs for that commodity. Cash receipts are also weighted in this manner. Opportunity costs for feeds, unpaid labor, and capital are used while costs of machinery and buildings are generated from a data base of those items.

There are two major areas of weakness associated with the USDA generated data. First, the usual problems associated with aggregating data are likely to exist (ie. intraregional variation is masked). Second, the USDA's method of estimating machinery and machinery related expenses has been questioned (Nott, 1985). However, while potential weaknesses do exist, USDA generated data is the most complete available and reasonable conclusions can be drawn from analysis based on this data.

For the purposes of this thesis, the USDA's cost of production statistics will be used rather than any Telfarm data. The reason for this hinges on three points. First, the statistics are gathered at the state level in a consistent fashion. This allows for interregional and even interstate (when the original data is available) comparisons to be made without significant error. Second, using USDA statistics enables easy comparisons to be made with other studies addressing similar issues. Finally, although variation is present between the USDA and the Telfarm statistics, when definitions are standardized between the two sources, total cost of production for milk in Michigan comes within one percent of each other for 1983 data (Nott, 1985).

2.6.2 Cost of Production

The key elements of total cost of production are the fixed and variable expenses. Variable costs will increase as total production rises, while fixed costs will not, *ceteris paribus*. Costs of producing milk vary widely over time from farm to farm and state to state due to differing production levels per cow, climatic conditions, management practices, herd size, feed prices and labor to name a few of the many influences. In general, the Upper Midwest (Michigan, Minnesota, South Dakota, and Wisconsin) has higher fixed costs than other regions because of heavy investment in buildings and harvesting equipment. On the other hand, the Upper Midwest enjoys a lower variable cost than other regions because its dairy farmers produce a large portion of their own feed, utilize more family labor and have a higher average output per cow (due in part to higher quality forage).

Feed costs represent a very important element in differing regional costs. Both Appalacia (Kentucky, North Carolina, Tennessee, and Virginia) and the Southern Plains (Texas) are grain deficit regions and as such face large expenditures on imported feed. Additionally, the forage grown in these two regions is generally of a poorer quality relative to the Upper Midwest, again requiring producers to pay relatively higher feed costs per hundredweight of milk produced. For example, in 1984 the Upper Midwest's feed costs accounted for 41 percent of the region's total variable expenses as compared to 55 and 51 percent for the Southern Plains and Appalacia respectively (USDA, Sept. 1985). Figure 2.2 helps to illustrate this point.

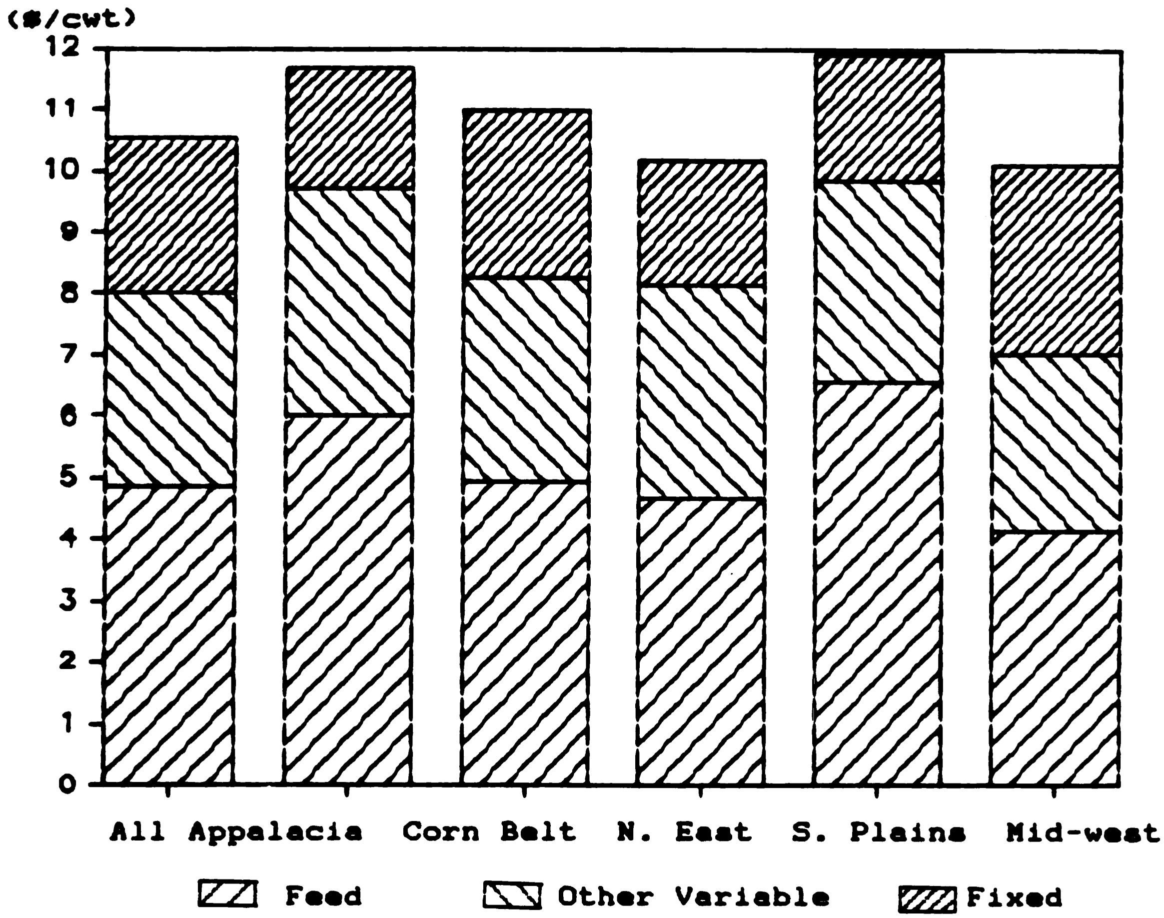

Figure 2.2. Costs of production: variable and fixed, by region for 1984

Source: Economic Indicators of the Farm Sector: Costs of Production. USDA, 1985.

2.6.3 Michigan's Relative Position

In contrast to these high feed cost regions, Michigan producers characteristically produce the majority of their feed requirement in the form of haylage and corn silage. This self sufficiency has the effect of lowering feed costs and, with a slightly higher quality forage, helping to increase production per cow. Together these influences provide Michigan farmers with a lower variable cost per hundredw

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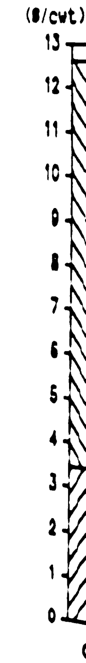
hundredweight than experienced by producers in the South. Compared with the two other primary producing states in the Upper Midwest, Minnesota and Wisconsin, Michigan's variable costs are generally slightly higher. Table 2.2 illustrates the relative costs of production and competitiveness of selected states.

Table 2.2. Cost of Production, Price, and Return to Risk Management for Selected States, 1982 ($/cwt)

State	Fixed Costs	Variable Costs	Total Costs	Price of Milk	Return to Risk Mgt
Georgia	3.46	9.09	12.55	14.40	2.42
Kentucky	3.35	8.14	11.49	13.50	1.32
Michigan	3.61	7.12	10.73	13.60	2.15
Minnesota	4.06	6.42	10.48	12.98	0.25
N Carolina	3.15	9.23	12.38	14.70	1.90
Tennessee	3.03	8.55	11.58	13.60	0.94
Virginia	3.29	8.86	12.14	13.90	1.29
Wisconsin	4.03	6.28	10.30	13.22	0.03

Source: USDA, "Firm Enterprise Data System". Unpublished data for 1982.

Michigan producers do not hold the same clear advantage over Southern states in fixed costs. However, even though Michigan's fixed costs are higher relative to all Southern states, they are not significantly higher. Compared to Minnesota and Wisconsin, Michigan's fixed costs are slightly lower. The lower variable costs provide Michigan with a total cost of production below that of all Southern states, as demonstrated Figure in 2.3.



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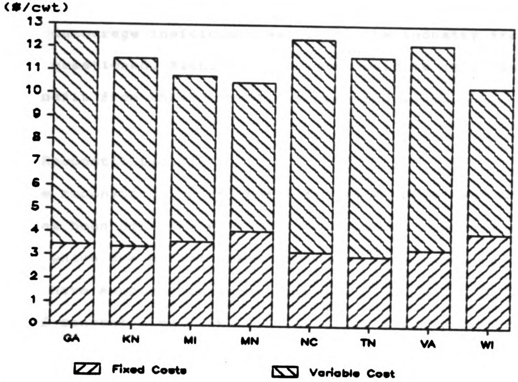

Figure 2.3. Total cost of production: selected states, 1982.

Source: USDA, "Firm Enterprise Data System". Unpublished data for 1982.

Based on the data presented here and the subsequent comparisons made, it can be said with confidence that Michigan holds a competitive advantage over Southern states in milk production. Futhermore, when the difference in total cost of production between Michigan and the rest of the Upper Midwest, specifically the heavy surplus states ofMinnesota and Wisconsin, is coupled with Michigan's relative proximity to the high cost of production deficit states, it appears Michigan may be in a position to establis

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establish itself as a key supplier to Southern states. At a time when technological developments promise large increases in productivity and expensive dairy policies which encourage inefficiencies within the industry are being questioned, Michigan producers could be in a position to benefit from their competitiveness and location.

2.7 Reconstituted Milk

The reconstitution of nonfat dry milk powder and milk fat has been done for many years throughout the world in areas which are either great distances from supplies or which have supply consistency problems. In the U.S. the use of concentrated milk, including dry milk powder, has primarily been limited to the production of cheese, cultured buttermilk and, to a small extent, fluid beverage milk. This latter market is supplied by "reconstituted" milk and has been limited to a single processor in North Carolina marketing a blended milk product[6], and to the state of Alaska, where approximately one third of the fluid milk demand is supplied by reconstituted milk (Hammond, Buxton and Thraen, 1979).

There exist several different methods of concentration which have been applied to fluid milk. With the advent of new and improved technologies the list of potential methods of bulk reduction available has expanded. Specifically,

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[6] A product made from a blend of fresh whole milk, water and nonfat milk powder allowing the area's fluid milk supply to be stretched.

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membrane separation techniques have been gaining interest. This study deals directly with a product which would currently be classified as reconstituted. As such, methods of concentration, use restrictions imposed on concentrated milk forms, and previous research addressing these issues are all of importance. The remainder of this chapter addresses these areas.

2.7.1 Methods of Concentration

Edward Jesse (1980) presented a study which listed several methods of bulk reduction and some of their inherent weaknesses. The more traditional methods, spray drying, conventional evaporation and thermal evaporation, require large amounts of liquid fuel. As a result, the milk undergoes a phase change[7] resulting in substantial variation in the final product.

A somewhat less traditional approach to concentrating milk involves the use of reverse osmosis filtration (RO) either on its own or in conjunction with ultra filtration (UF). Currently, the two-stage UF-RO process is used commercially in the concentration of cheese whey. An advantage of filtration over thermal-evaporation may be in its reduced liquid fuel requirements. Additionally, filtration is less detrimental to the solution's constituents because in the absence of heat, no phase change occurs.

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[7] A phase change occurs when a discrete homogeneous characteristic of the solution is separated from the rest of the solution by some external force.

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To determine the economics of employing these various methods of concentration, they were ranked by Jesse according to their processing shipping and assembly cost. From this a transportation cost surface was developed. The numbers indicated that for distances greater than 100 miles, some form of concentration is economical. Thermal evaporation was found to be the most cost efficient method of concentration for distances up to 900 miles with spray drying to dry ingredients becoming most economical at greater distances. Membrane separation methods were found to be attractive due to their non-reliance on heat and superior taste, however, their cost structure was rather high relative to the more traditional techniques.

Advancements in membrane technology have greatly enhanced the potential for applying membrane filtration techniques to the concentration of whole fluid milk. This thesis deals solely with the use of RO filtration which is discussed in greater detail in the following chapter. The current regulatory environment faced by reconstituted milk products are examined below.

2.7.2 Use Restrictions

Reverse osmosis filtration of fluid milk produces a product which, under current classifications, would be regulated as a reconstituted milk product. As they currently stand, the regulations for reconstituted products would eff

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would effectively eliminate the economic incentive for adopting technologies such as RO filtration.

Under current government regulations, "reconstituted" is a word shrouded by negative connotations. The Grade "A" Pasteurized Milk Ordinance of the U.S. Public Health Service defines reconstituted or recombined milk and milk products as "...milk products...which result from the recombining of milk constituents with potable water" (USPHS, 1965). Given this definition, any blended milk product must be labeled "recombined" regardless of the amount of water which was added to "reconstitute" it.

Allocation provisions, compensatory payments, and pricing provisions impose significant penalties on production of reconstituted milk. Additionally, restrictions on the marketing of reconstituted milk and mandatory pricing provisions for ingredients exist under both state and federal marketing orders. For example, the pricing provisions held by eleven states act to insure that the handler producing reconstituted milk will pay greater than or equal to the local Class I fluid milk price for the ingredients going into reconstituted milk (Hammond, Buxton and Thraen, 1979). Allocation provisions assign reconstituted milk to the lowest use class regardless of its end use. For every quantity down-allocated an equivalent amount must be up-allocated. If there exists insufficient resources to "up-allocate", a compensatory payment equal to the Class I differential is charged to the excess quantity of recon

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of reconstituted milk. In essence then, processors must pay the local Class I price for reconstituted milk made from Class III or Grade B products. Several studies, which have researched the impact of these regulations and have explored some policy alternatives, are discussed below.

Federal milk marketing order price differentials are designed to reflect transportation costs. Charging the manufactured price for the condensed milk or developing a second price differential structure for reconstituted milk would help to eliminate this gap. In a study of these two alternatives it was estimated that reconstituted milk had the potential for capturing over one third of the fluid consumption when ingredients were priced at their manufactured price; the second alternative having a less severe impact on farm prices (Whipple, 1983).

In 1979 Hammond, Buxton and Thraen published the results of their research on the potential impact of reconstituted milk. They investigated what effect restrictions placed on reconstituted milk would have on regional price relationships between fluid and manufactured products, as well as on production, usage, and consumer/producer welfare. Specifically, they looked at two alternatives to the present pricing scheme: 1) alter the differentials while continuing to use the assigned Class I price for fluid and reconstituted milk; and 2) maintain regional differentials between fluid and manufactured prices by way of a Class I price on

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price on fresh fluid milk but remove such pricing for milk used in ingredients for reconstitution.

Their research indicated that under scenario one, reconstituted milk products would have little impact on the price of milk going to manufactured use and the Class I price would decline in three of the eight regions in their study (the Northeast, Southeast and Southcentral). By comparison, under scenario two they found that producer incomes would decrease more and the fall in Class I price would be greater, as would be the change in utilization and production. Furthermore, the manufactured goods' price would increase, producer incomes would decrease and once again purchases by the CCC would be eliminated.

Similar studies were carried out by Novakovic and Aplin (1981) and Novakovic (1982) who employed an economic engineering approach to determine the cost of producing blended and reconstituted milk relative to the standard fresh milk. Their research results indicated that the cost advantage of shipping and reconstituting/blending the milk was sensitive to the Class I price; the advantage being greater in markets with high Class I prices. When FMMO provisions restricting the sale of reconstituted milk were removed, the cost of producing blended milk became less than fresh milk processing costs in many major markets. Hence, in the absence of current restrictive pricing provisions, cost incentives to reconstitution were found to exist virtually everywhere. The estimated retail level cost of t

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cost of these regulations restricting use of reconstituted milk ranged from 3.2 cents in Chicago to a high of 10.8 cents in Boston for the shelf price of a gallon of milk (in 1981 prices). Clearly then, the current FMMO pricing provisions significantly eliminate incentives which would otherwise exist in favor of reconstituted milk.

Recently there have been several economic studies (primarily out of Cornell University) which have looked specifically at the application of UF at central locations as well as at the farm level. With the rapid improvements on the pivotal components of the membrane separation process, interest in these bulk reduction alternatives will remain high. In addition to these studies on reconstituted milk policy issues, several spatial modeling studies have been published which approach these and other policy areas. A discussion of such studies is presented in Chapter Four.

2.8 Summary

The natural characteristics of milk have led to a unique and complex set of institutions designed to provide a safe and secure supply of milk in an orderly fashion. At the center of the FMMO system is the existence of the Upper Midwest's competitive advantage in the production of milk. Examining the production cost structure indicated that Michigan itself holds a competitive advantage over the non-Midwest states with which it would potentially compete.

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Examining the relevant market institutions existing within the dairy industry and establishing Michigan's competitive position in milk production were fundamental first steps in addressing the potential impact of RO filtration of fluid milk. At present, reconstitution appears economically viable in the absence of Federal and State disincentive regulations. If RO filtration is used to concentrate fluid milk, with the concentrate then being "recombined" nearer the point of final sale, transportation, handling, and storage costs will be reduced. Furthermore, RO filtration provides the most likely recombined or reconstituted fluid product for consumer acceptance. However, before such generalized claims of feasibility are made, a more detailed description of the technology is necessary and the effects of RO filtration on the marketing of fluid milk should be considered. Chapters Four and Five address the latter of these issues while the RO filtration process and technology are presented in the following chapter.

CHAPTER 3

REVERSE OSMOSIS FILTRATION

Reverse osmosis (RO) filtration technology was developed in the 1950s. Initial research focused on using RO to produce pure water from sea and brackish waters. In more recent years RO has been used to filter apple concentrates, used in candy manufacturing and, within the dairy industry, it has been used to process whey. Presently within the dairy industry, RO filtration is seen as a reasonable alternative to evaporation, requiring less heat and not involving a phase change. Additionally, RO filtration has the potential for becoming an on farm process. Although under current conditions on farm RO is not economical, given greater specialization, improvements in the technology, and increased hauling charges, on-farm RO could find future use.

This chapter presents the technical aspects of employing RO filtration for the concentration of fluid milk. Throughout all discussion of RO filtration within this study, it is assumed that the whole fluid milk will pass through a separator prior to filtration with the cream then remixed

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remixed before shipping. Hence, the actual filtration will be applied to skim milk.

3.1 Principles of Reverse Osmosis Filtration

The basic principles behind RO filtration are the same regardless of the solution involved. The osmotic process takes place in all organisms where water and a solution are separated by a membrane and the water naturally passes through the membrane to dilute the solution. Hence, all solutes in solution exert an osmotic pressure.

Osmotic pressure is needed to maintain equilibrium between the solution and the water across a membrane, which is permeable to the solvent (i.e. water). The flow of the solvent from its pure state through the membrane and into the solution (i.e. milk) is termed osmosis. Figure 3.1 illustrates this principle. The maximum work involved is that which is against the osmotic pressure. The osmosis process will continue until a state of equilibrium is achieved; hence, the pressures exerted on both sides of the membrane are equal. An example of this process can be illustrated with sea water, which is 3.5 percent salt. Given a strong membrane, the movement of water through the membrane would continue until a column 750 feet high is achieved; equaling the osmotic pressure of the salt (Dunkley, 1971).

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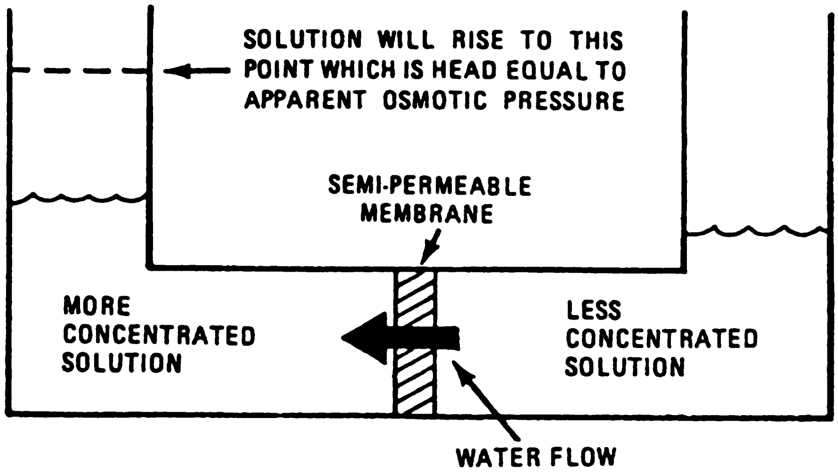

Figure 3.1. The osmosis process

Equilibrium implies reversibility. To reverse the osmosis process, sufficient pressure must be applied until the osmotic pressure of the solution is overcome. Additional pressure must then be applied in order to create an hydraulic flow in the opposite direction. The reverse osmosis process is illustrated in Figure 3.2.

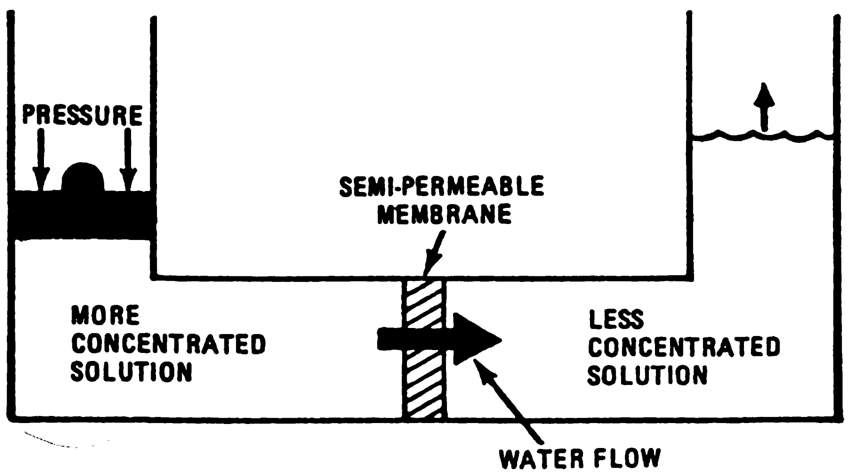

Figure 3.2 The reverse osmosis process

RO filtration can be thought of as a pressure driven membrane process in which substances are fractionated, separated or concentrated without the substance undergoing a phase change. The minimum work for this process is the existing osmotic pressure. Hence, in RO filtration the driving force is the net result of the resistance and osmotic pressure on both sides of the membrane and the applied pressure.

The relevant osmotic pressure involved is not that which is in the bulk of the solution, rather, it is the osmotic pressure at the surface of the membrane. In the filtration of milk, this becomes increasingly important over time. As water passes through the membrane, a layer of continually increasing concentration develops on the membrane surface. This layer, primarily casein, reduces the effectiveness of the membrane[1].

3.2 The Reverse Osmosis System

RO membranes must be mounted in equipment providing the necessary support and flow control. There are four main variations in design with the general principle remaining the same. The most common system involves mounting tubular membranes in a series of porous support tubes connected by headers. A cross section of one of these tubes is illustrated in Figure 3.3 and the general RO system presented in Figure 3.4.

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[1] Casein is the protein component in milk.

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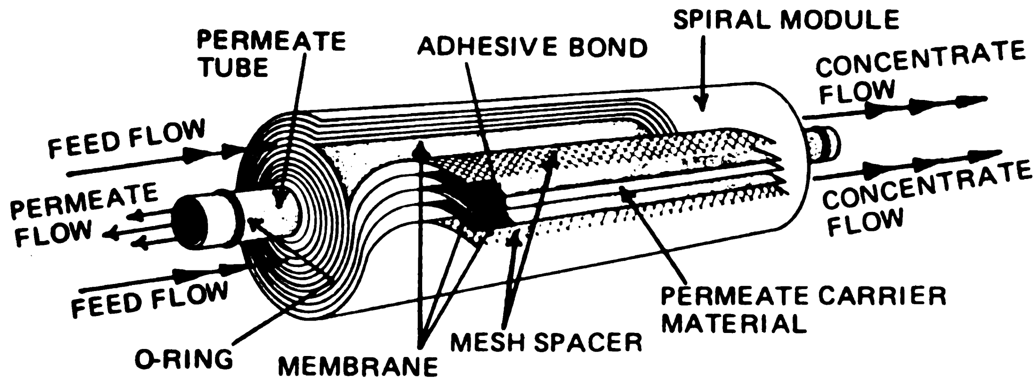

Figure 3.3. Standard membrane module used for reverse osmosis

Source: Osmonics, Inc. Minnetonka, MN.

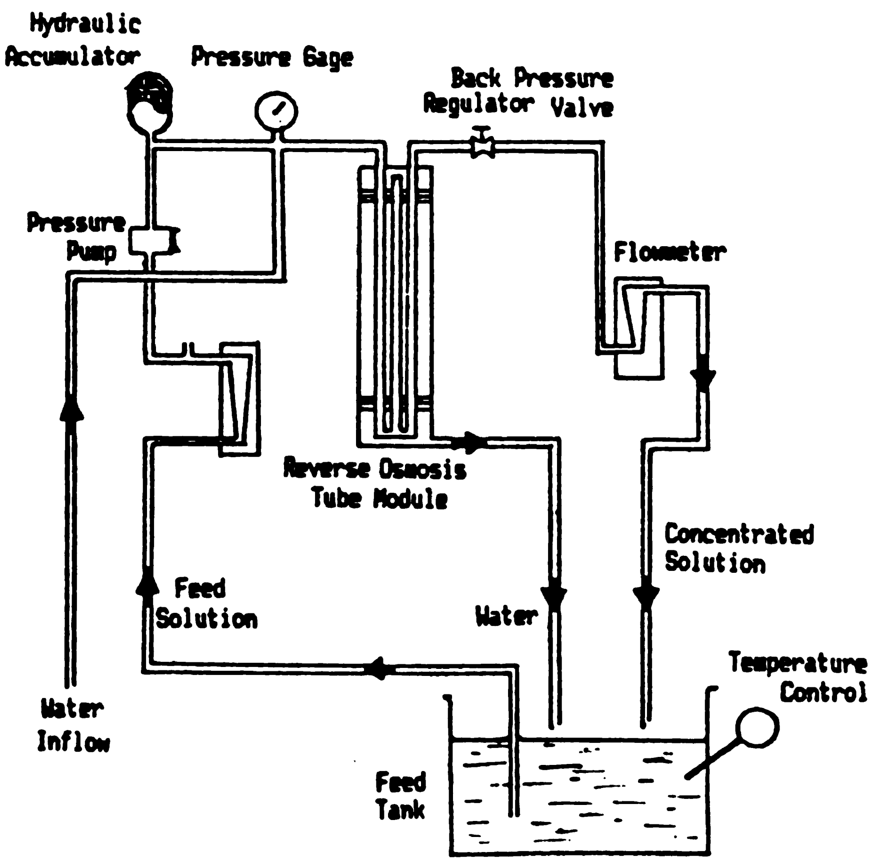

Figure 3.4. The reverse osmosis system

The solution (i.e. milk) to be concentrated passes at high velocity through the tubes where the filtration takes place. The resulting permeate then travels through the membrane before it is collected outside the system of tubes.

A primary requirement for filtration is for the solution to be circulated at very high velocities within the tubes to prevent the concentrated layers from forming on the membrane surface, fouling the system. To achieve the required solution velocity, a pressure pump capable of producing up to 2000/psi throughout the system is required. Additionally, turbulence promoters or volume displacing rods are commonly used to generate increased turbulence near the membrane surface.

3.3 Key Factors Influencing Operation of the RO System

The prevention of the casein build-up on the membrane surface has been one of the major areas for technical improvement in recent years. Both the membranes and the cleaning methods have been improved, significantly enhancing the process's economic feasibility. Thus, the membrane and the flow through the membrane, termed the flux, along with solution velocity, pressure, concentration level and temperature, are all important elements of the system's operation and merit further discussion. Figure 3.5 provides an over view of the key factors influencing the efficient operation of the RO filtration system.

FACTOR	EFFECT (Pos or Neg)	IMPACT OF INCREASING THE FACTOR	RATE OF EFFECT	REQUIREMENTS	ECONOMIC IMPLICATIONS
Velocity	Pos.	-Increases rate of permeation -decreases concentration polarization	Flux rate will increase with velocity up to a threshold level	-Installation of turbulance promoters or volume dis-placing rods	Additional equipment increases fixed operating costs
Pressure	Pos.	-increases flux	Flux rate will increase with pressure up to membranes limit	-Use of pressure to maintain system at approx. 2000psi	The required high pressure increases energy costs
Temperature	Pos.	-Decreases solution concentration -increases flux	A 1 degree rise in temp. will increase flux by 1 to 2%	-Heating the solution to 90 degrees F.	Increased energy requirements increases operating costs
Solution Concen-tration Level	Neg.	-Increases solution's pressure -Increases polarization -decreases flux	A 1% increase in concentration leads to a 2% decrease in solution flux	-Raise velocity, pressure, or temperature to optimal levels -Frequent cleaning of membranes	Implementing these requirements is expensive and is prohibitave at concentration greater than 50%

Figure 3.5. Key factors influencing operation of the RO filtration system and some elements which affect them

Sources: Dunkley, 1971; Fenton-May et al., 1972; McKenna, 1970.

3.3.1 The Membrane

U.S. Government supported research of water purification in the 1950's and 1960's led to increased testing of the various membranes available for use in RO filtration. Research led by Reid and Breton (1959) at the University of Florida found cellulose acetate membranes to be the most effective in retaining salts. Loeb (1962), at the University of California, later developed a special method for preparing these membranes giving them significantly improved properties. Since then, further technological advances have been made on the membranes available; improving the pH and temperature properties in particular.

In general, the membrane used in the RO filtration process is a synthetic polymer made of a cellulose derivative or comparable materials. This membrane can be thought of as a filter capable of working on dissolved solids of molecular size (Horton, 1973). The membrane itself is composed of two layers. One side is a soft porous layer which primarily acts as a support for the other side, the semi-permeable layer. This semi-permeable layer is very thin, less than one micron, and provides the selectivity or rejecting properties of the membrane. It is this selectivity property which is of particular interest, especially in the reverse osmosis process. As Professor W.L. Dunkley of the University of California, Davis explains, "If you are trying to separate salt from water, the difference in size of the two molecules is small, so the separation is not by a sieving mechanism. What happens, apparently, is that water is soluble in the membrane and passes through by a process of solution and diffusion, whereas the salt is not soluble and is rejected by the membrane" (1971, p.48). This same principle applies to fluid milk whose nutrients are not passed through with the water molecules; a key benefit of the RO filtration process.

Most dairy and food processing plants employing reverse osmosis filtration systems use cellulose acetate membranes. These membranes have performed well but have limited temperature and pH capabilities and require expensive neutral pH enzyme detergents for cleaning. More recently, noncellulosic and ceramic membranes have been used for the RO process. These membranes have significantly improved pH, temperature, and pressure resistance characteristics and result in improved separation performance.

Noncellulosic membranes are made by adding a thin film coating to a standard ultra filtration membrane. Although this process makes the noncellulosic membrane more expensive than its cellulose acetate counterpart, the membrane's enhanced characteristics, as mentioned above, more than offset this additional expense (Johnston, undated). Hence, cleaning can be done with the use of caustic and acidic materials, dramatically reducing time and cost. Additionally, they allow pressure to be increased which in turn increases the flux.

3.3.2 Factors Influencing Performance

The rate at which the solution passes through the membrane, termed the flux (expressed in gallons per day per square foot of membrane area), is a primary indication of the RO system's performance. Three closely related factors which influence transmembrane flux are solution concentration, velocity, and temperature. Each, of these are discussed below.

Concentration of the solution. Perhaps the single most important factor influencing operation of RO systems within the dairy industry is the level of solution concentration. Milk's osmotic pressure is chiefly caused by micro solutes, or solids, within the solution. As the proportion of total solids increases, the natural osmotic pressure of the solution will also increase. This, in turn, causes a decrease in the effective drawing force or transmembrane flux. In other words, it becomes increasingly more difficult to squeeze the water through the membrane. If larger molecules or proteins are involved as the solution becomes more concentrated, the phenomenon of concentration polarization at the membrane surface further reduces solution flux. This will be true even though the system's applied hydrostatic pressure is held constant, because both the

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solution's osmotic pressure and viscosity tend to decrease flux rates. This effect is demonstrated in Figure 3.6.

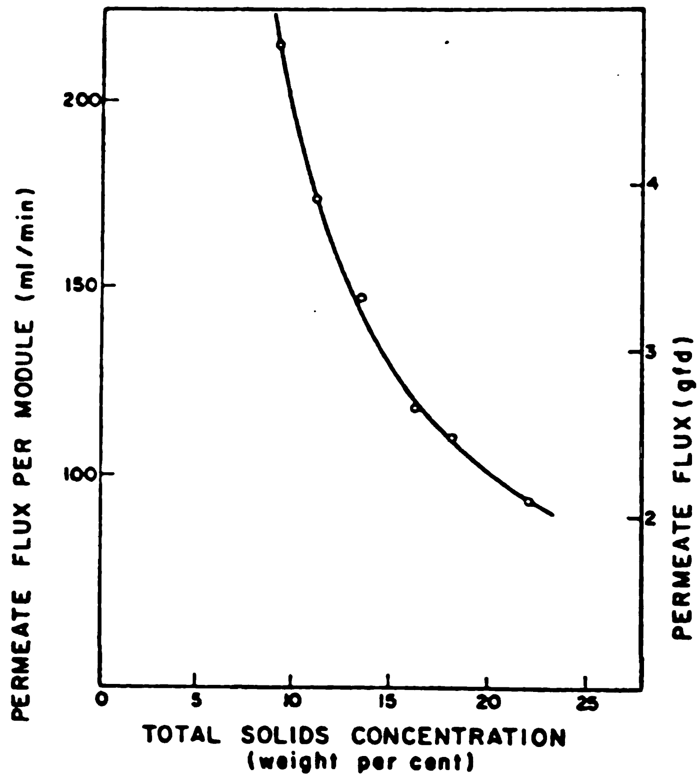

Figure 3.6. Effect of total solids on permeate flux

Source: Fenton-May et al., "Concentration and Fractionation of Skim milk by Reverse Osmosis and Ultrafiltration", Journal of Dairy Science. November 1972, p.1536.

The effect of these conditions is significant. For example, the flux will decrease by a factor of approximately two when a skim milk concentrate, that which has had one half of the original water removed, is being processed. Clearly this problem can have a significant influence on the system's efficient operation.

Velocity and pressure. The velocity of the solution and the pressure applied to it play an important role in reducing fouling. Increasing the rate at which the solution is circulated, the velocity, increases the permeation rate and, in turn, reduces the opportunity for highly concentrated layers to be formed on the membrane surface (Dunkley, 1971). Figure 3.7 illustrates the relationship between solution flux and velocity.

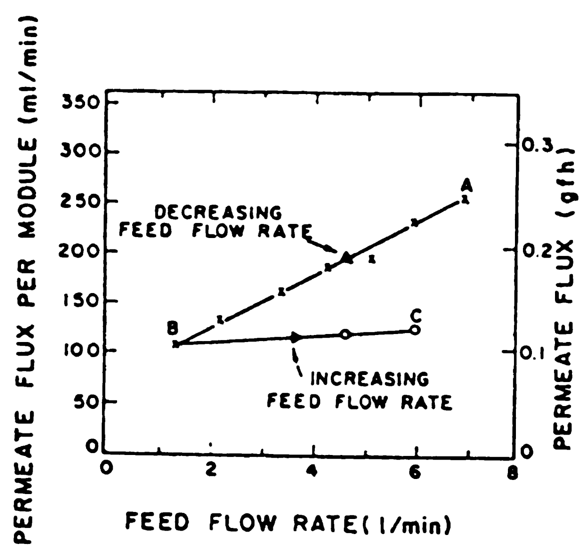

Figure 3.7. Effect of feed flow rate on permeation flux during the concentration of skim milk

Source: Fenton-May et al., op. cit. p.1562.

Once the membrane becomes "clogged", increasing the flow rate has little effect on the transmembrane flux. For example with skim milk, the resistance caused by the deposit is often equal to or greater than that of the reverse osmosis membrane itself (Fenton-May et al., 1972). To help achieve the needed velocity, turbulence promoters or volume displacing rods are often added to the system.

If increased pressure is applied to an increasingly concentrated liquid, the smaller molecules within that liquid will flow through the membrane into the more dilute solutic

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solution (McKenna, 1970). The effect of changes in pressure can be seen in Figure 3.8. In general, the higher the velocity inside the system tube, the higher the flux up to a point where increasing velocity has no effect; raising the pressure normally will enhance the flux rate up to the maximum pressure level which the membrane can withstand. Once this proteinaceous material forms on the membrane surface, increasing the flow rate has little effect on the transmembrane flux.

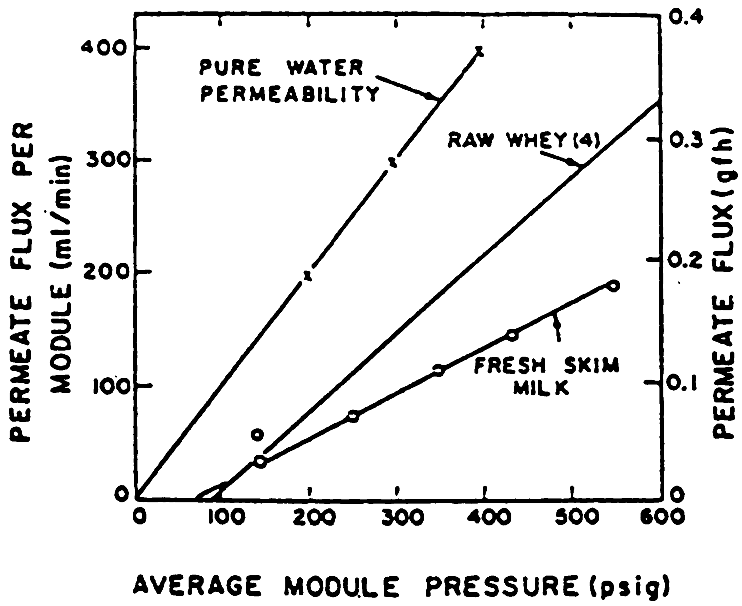

Figure 3.8. Effect of pressure level on permeation flux during skim milk concentration

Source: Fenton-May et al., op. cit., p.1562.

In sum, the permeate flux is linearly dependent upon pressure and partly a function of the thickness of the protein deposit on the membrane surface. The thickness of the deposit is, in turn, a function of the lowest flow rate at which the system has been operated. Once this protein gel forms and consolidates at lower flow rates, it becomes necessary to thoroughly flush and clean the system. This is a time consuming and costly process.

<u>Temperature</u>. The solution temperature level also affects the transmembrane flux. The flux level increases linearly with increasing solution temperature in the range of 10 to 40 degrees centigrade (Fenton-May et al., 1972). In general, raising the temperature 1 degree fahrenheit increases the flux by one to two percent through decreased viscosity (Figure 3.9).

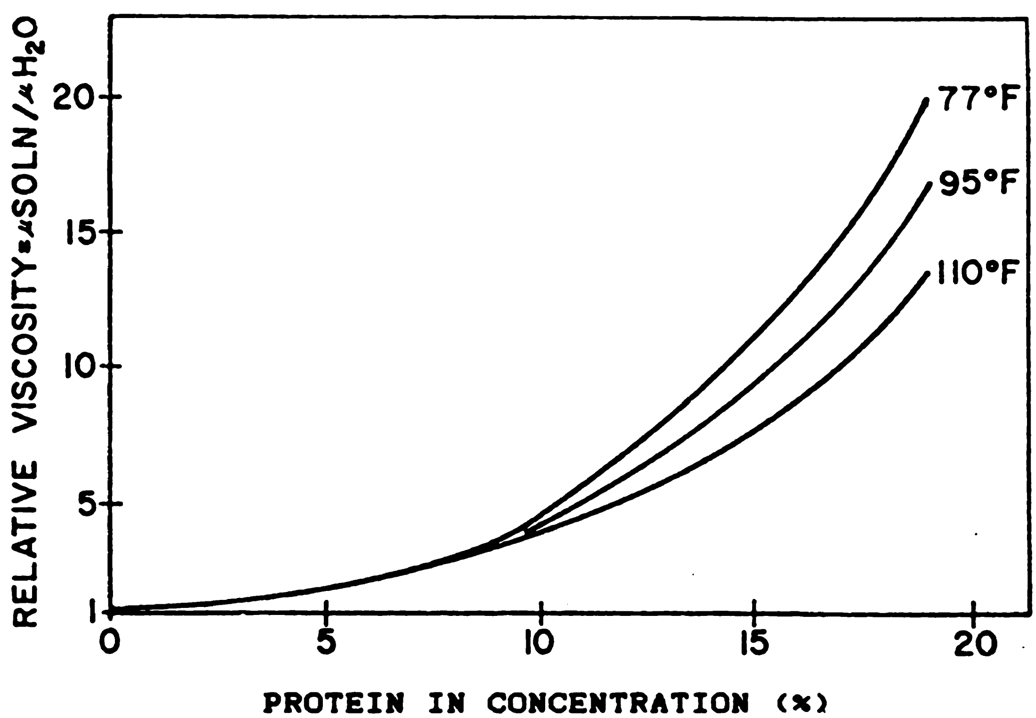

Figure 3.9. Effect of temperature and percent protein on relative viscosity of the concentrate

Source: Goldsmith, et al., "Recovery of Cheese Whey Proteins Through Ultrafiltration." Washington D.C., November 1970, p.4.

An advantage for on-farm RO concentration may exist due to the optimal temperature for RO filtration of milk under some conditions being approximately the same as the temperature of milk coming directly from the cow, 90 degrees fahrenheit (Jesse, 1980). This fact may be important if the location of the RO filtration facilities is questioned: on-farm or in a central processing plant.

3.4 Summary

The dairy industry is going through a period of major adjustment. As specialization continues within agriculture and the average dairy operation increases in scale, production may become more regionalized. This will require economical transfer of a whole milk product for fluid consumption which meets all aspects of consumer demand. RO filtrated milk appears to satisfy these requirements.

Both the RO system design and its membrane are continually being improved to ensure greater operating efficiency. The noncellulosic membranes available today, being more durable, allow more cost effective cleaning methods to be employed and yield a longer life. This helps reduce the overall cost of operation and promotes the RO filtration process to an appealing level. With increased use of RO filtration in the dairy industry, further improvements would likely be made. This, together with consumer acceptance, indicates that RO filtration of milk for fluid consumption could have a futrue role within the dairy industry.

CHAPTER FOUR

THE MODEL

This chapter addresses the application of spatial equilibrium modeling to the dairy industry. A brief discussion of the advance of spatial equilibrium modeling of agricultural commodities is given followed by a description of the specific spatial equilibrium program and solution algorithm used within this study. Additionally, the general model's equilibrium conditions, price linkage function and limitations are set forth. A review of previous economic research in the dairy industry is included and finally, the actual model and data incorporated into this study are presented.

4.1 Spatial Equilibrium Models

Spatial equilibrium modeling provides the appropriate avenue for analyzing the impact of selected changes within the dairy industry. This form of modeling, which endogenize trade flows and market shares, has been used extensively for comparative statics analysis of exogenous variables, such as policy changes. Of specific importance to this thesis, this form of modeling is also efficient at determining the effect on the net positions of trading regions due to changes in transportation costs.

4.1.1 Review of Selected Literature

To obtain spatial equilibrium in the general case, prices must be found which will produce equilibrium quantities and price differentials in and across all markets designated within the model. Samuelson (1952) first approached this problem by maximizing the sum of the areas under the excess demand curves for the importing regions, less the area under the excess supply curve for the exporting regions, less transportation costs. This formulation, designed for objective function maximization, provided a spatially competitive equilibrium solution.

Takayama and Judge (1964 and 1971) were key contributors to this area, applying standard quadratic programming methods to Samuelson's model. Later this model was enhanced to solve across periods (Takayama and Liu, 1975) and to solve optimally for multi-commodity trade (Takayama and Hashimoto, 1976).

Among commodities studied, feed grains have received the most application of the one-commodity, one-period model. Beginning in the mid-sixties, empirical research developed which applied quadratic programming, spatial-price equilibrium models to world agricultural trade (Schmitz, 1968; Chang, 1972; and McGarry, 1968). Linear programming, quadratic programming, and network flow models became standard tools for analysis.

These traditional model formulations have most commonly been used to ascertain optimal freight flows. However, while they have been used extensively, they are subject to several limitations. Primarily, linear programming and network flow models are constrained to having linear objective functions, while quadratic programming models require linear export supply and import demand functions.

More recently, researchers have begun to develop and apply non-linear spatial equilibrium models to trade in agricultural commodities (Warner, 1979; Holland and Pratt, 1980; Holland and Sharples, 1984; Randolf, 1986). Not constrained by the limitation of linearity, these models have generated a great deal of attention. The spatial equilibrium algorithm used in this thesis falls within this class: the Kuhn-MacKinnon Vector Sandwich Method algorithm (discussed in section 4.2.1).

4.1.2 General Spatial Equilibrium Model

Each region in the general trade model represents a market with its unique supply and demand characteristics. In any given period, regions may be in a surplus or deficit standing with respect to the given commodity. It is the existence of surplus and deficit markets which creates trade across regions.

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The cost of transportation is central to the interregional trade problem. Any change in transportation cost necessarily will create a shock to the system (away from the base conditions) resulting in a change in commodity price, trade flows, and regional supply and demand quantities. In a free, open market, theory would suggest that a decrease in the transportation cost per unit of a given commodity would precipitate a price increase of that commodity in the exporting region and a price decrease in the importing region. The overall result being an increase in the quantity traded. In a regulated market one would expect the degree of adjustment to vary directly with both the degree of restrictions imposed on the free flow of the commodity and with the ability of the price mechanisms to adjust price.

The general interregional spatial-price equilibrium model can be formulated as follows:

> The i^{th} source (exporter) is a collection of agents in region i who are willing to supply a quantity Q_i at a per unit price of P_i. In turn, the jth sink (importer) is a collection of economic agents in the j^{th} region who are willing to pay P_i plus a transportation cost of T_{ij} for the quantity they demand at price P_j (where $P_j = P_i + T_{ij}$). Equilibrium between each i region (those which are a net source) and each j region (those which are a net sink) exists when the regional price differential equals the transportation cost, T_{ij}. At that point, equilibrium quantity equals Q^* and equilibrium price equals P^*_i in region i and P^*_j in region j where $P^*_j = P^*_i + T_{ij}$.

Equilibrium across two spatially separated markets is illustrated in Figure 4.1. This figure represents the

single product, two region case in the form of a back-to-back diagram. Region Y's supply and demand curves are plotted on the right side and region X's are on the left side in reversed form. Each region's excess supply curve is derived from regional supply and demand schedules, representing the amount by which the quantity offered exceeds (or falls short of) the quantity demanded.

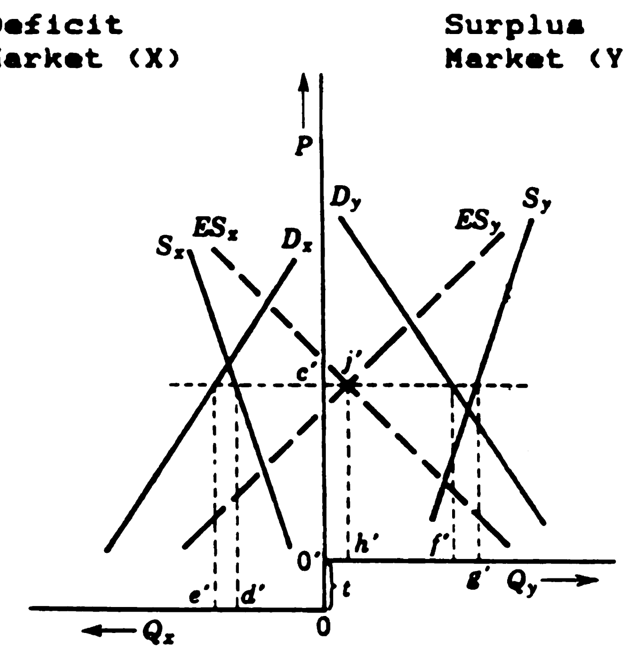

Figure 4.1 Impact of transfer costs, OO', on prices and trade between two spatially separated markets[2]

Source: Raymond G. Bressler Jr. and Richard A. King, Markets, Prices, and Interregional Trade. 1978, p.91.

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[2] Where ES_x = excess supply in region X; ESy = excess supply in region Y; S_x = supply in region X; Sy = supply in region Y; D_x = demand in region X; Dy = demand in region Y; Q_x = quantity supplied/demanded in region X; Qy = quantity supplied/demanded in region Y; P = price; t = per unit transportation cost.

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Equilibrium price occurs at the level where the excess supply curve for market X, ES_x, intersects the excess supply curve for market Y, ESy. Note that the equilibrium price in the two markets differs exactly by the per unit cost, OO′, of shipping the good from the excess supply market, Y, to the excess demand market, X. Furthermore, equilibrium at each price level ensures that the quantity of good Q exported from region Y, f′g′, is exactly equal to that imported by region X, e′d′.

4.2 Generalized Transportation Problem

Holland and Sharples (1984; Holland, 1985) put the above general formulation into a form useable for inter-regional trade analysis. They developed a micro computer program, Generalized Transportation Problem (GTP), which solves the spatial equilibrium problem via the Kuhn-MacKinnon algorithm in the international trade setting. The solution algorithm utilized in GTP is briefly discussed below, followed by a more comprehensive look at GTP itself.

4.2.1 Vector Sandwich Method Solution Algorithm

The Vector Sandwich Method (VSM) spatial equilibrium algorithm, developed by Kuhn and MacKinnon (1975) and MacKinnon (1975), solves via a fixed-point, or complementary-pivoting algorithm approach. A primary benefit of the VSM formulation over the traditional method of solving spatial equilibrium problems is that VSM is not bound by the restriction of linear excess schedules. It can handle non-linear demand and supply relationships and can even accommodate non-smooth (first derivative discontinuous) functions.

VSM solves by searching directly for equilibrium prices and quantities which will satisfy a specified set of equilibrium conditions. The process involves dividing the total solution space into a set of several simplicies. Then, using a sophisticated search procedure, it generates a "path" which leads to an equilibrium point. In this way VSM yields the equilibrium conditions for the general interregional trade model.

4.2.2 GTP Equilibrium Conditions

GTP is not capable of producing an exact solution, rather, it generates a solution to a piecewise linear approximation of the system of equations defining the original problem. While it is true that the solution generated is not exact, estimated to eight decimal places, it is satisfactorily accurate. GTP's solution procedure is based on a set of equilibrium conditions which are subject to a set of constraints -- some innate to the program and others which may be manually specified by the operator.

The model's general equilibrium conditions (items 1, 2 and 3) and constraints (items 4, 5, and 6) can be stated as follows:

(1) For each region the amount supplied of the commodity is defined by the quantity dependent excess supply schedule and must equal total out-shipments.

(2) For each region the amount demanded of the commodity is defined by quantity dependent excess demand schedule and must equal the total in-shipments.

(3) The amount in total which is supplied across all regions must equal the total demand.

(4) Supply and demand schedules define convex, non-empty feasible solution sets in non-negative price-quantity space.

(5) Assumption of free disposal applies, ensuring that the equilibrium price will be non-negative.

(6) Total excess demand will become negative if the sum of prices is sufficiently large.

Conditions (4) and (5) are implicitly in the model while condition (6) is explicitly in the model as part of VSM.

4.2.3 Price Linkage Mechanism

Within GTP there exists the ability to account for regional price differences through the specification of a price linkage function. This function acts to incorporate the relationship between exporter price and importer price via a combination of potential price wedges such as tariffs (ad valorem and specific), exchange rates and transportation costs. Hence, when no tariffs exist and the same currency is used in each region, in equilibrium the difference in price of the traded good between regions is exactly equal to the cost of transportation.

The price linkage function can be specified as follows for trade between the i^{th} exporter and the j^{th} importer:

$$L_j(P_i) = (((P_i*(V_i + 1) + U_i)*E_i + T_{ij})*(V_j + 1)/E_j) + U_j)$$

where: $L_j(P_i)$ = the linkage between the price in regions i and j where P_j plus this value equals P_i,

P_i = price in region i,

V_i = ad valorem tariff imposed by the i^{th} exporter,

U_i = specific tariff (in domestic currency units) imposed by the i^{th} exporter,

E_i = exchange rate (base relative to domestic currency) for the i^{th} exporter,

T_{ij} = transportation cost (in base currency units) from the i^{th} exporter to the j^{th} importer,

V_j = ad valorem tariff imposed by the j^{th} importer,

U_j = specific tariff (in the domestic currency units) imposed by the j^{th} importer, and

E_j = exchange rate (base relative to domestic currency) for the j^{th} importer.

In the final model solution, the price linkage function is the equivalent of the first order condition for the surplus maximization formulation of the problem (Holland, 1985).

4.2.4 Limitations of the GTP Program

There are several potential problem areas associated with this program. While most can be circumvented through careful model specification, others may actually be limitations to specification. Two relevant areas, functional form and regional specification, are discussed below.

The GTP program requires that supply and demand schedules take on a specific functional form, $Q = \alpha + \beta(P)^{\tau}$. This form will accommodate constant, linear, and constant elasticity excess supply and demand schedules but it will not allow perfectly inelastic functions. This limitation on the functional form of the excess schedules implicitly restricts the form of the underlying regional supply and demand schedules. In other words, these underlying functions must generate excess schedules which conform to the form stated above. Additionally, under the given functional form demand is limited to a single explanatory variable, price. Therefore, one can not include cross price variables and must assume that cross price variables have a minimal impact on the model. This limitation could be serious and should be considered.

Through GTP, regions are defined by their excess schedules. Hence, each must be specified either as an export or import region. This assumes prior knowledge of whether a given region will be an excess supplier or demander in the final equilibrium solution. An alternative approach would be to represent each region as an export and import sub-region; allowing direct use of each region's supply and demand schedules. This alternative may, however, create a size problem as the model would then be limited to ten regions.

4.3 Modeling the Dairy Industry

This thesis presents a short run spatial equilibrium model of a selected portion of the U.S. Grade A milk market. Review of previous research of this nature influenced both specification and application of the model. A brief summary of selected dairy modeling research is presented below, followed by specification of the model and the incorporated variables.

4.3.1 Previous Models of the Dairy Industry

Economic research and modeling in the dairy industry can be classified as falling into three general categories of study: supply and demand relationships, optimal plant location, and impact analysis of alternative policies. The first category is discussed later in this chapter (section 4.4.5h) while the latter two are briefly discussed below.

Optimal plant number, size and location studies have been applied to many areas within the dairy industry. Primary research has been conducted by Kloth and Blakley (1971), Thomas and DeHaven (1977), Buccola and Conner (1979), and Beck and Goodin (1980). More recently researchers have studied and modeled the spatial organization in the Northeast dairy industry (Pratt, Novakovic, Elterich, Hahn, Smith and Criner, 1986). Their model has been used to determine the optimal location of Class I, Class II and Class III processing plants within the Northeast region (Pratt, 1986). Results from such a model can then be compared to the plant locations which have evolved under the existing FMMO system. In this way, the spatial efficiency of processing plants can be examined.

To properly determine the full impact of a policy change, one must first have a model which accurately reflects the initial market structure and product flow. Given the complicated nature of the institutions and restrictions under which the dairy industry operates, modeling and isolating specific impacts has provided a dynamic challenge for researchers. Development of major dairy industry and policy analysis models began in the late 1960's (Ruane and Hallberg, 1967). The first complete models designed to analyze the impact of policy changes emerged in the mid-seventies (Hallberg and Fallert, 1976; Hallberg, Hahn, Stammer, Elterich, and Fife, 1978). During this same period, Riley and Blakley (1975) and Novakovic, Babb, Martella and Pratt (1980) developed models for static analysis of alternative FMMO policies. Figure 4.2 provides a brief overview of scenarios modeled in selected studies. These spatial models have been used extensively to determine the market impact of altering the Class I price differentials, merging federal orders, and increasing the number of base pricing points.

Policy Scenario	Author(s) and Date
Establish single national order	Graff and Jacobson (1973) Hallberg et al. (1978)
Merge regional orders	Graff and Jacobson (1973) Hallberg et al. (1978) Hallberg and Fallert (1976)
Alternative Class I pricing scenarios	Babb and Mindon (1971) Blakley (1967) Hallberg et al. (1978) Novakovic et al. (1980) Riley and Blakley (1976)
Multiple base pricing points	Hallberg et al. (1978) Novakovic et al. (1980)
Reconstituted milk shipments	Hallberg et al. (1978) Hammond et al. (1979) Novakovic (1982) Novakovic and Aplin (1981) Novakovic et al. (1980) Whipple (1983)

Figure 4.2. Selected spatial studies of dairy marketing and scenarios analyzed

This thesis utilizes a less comprehensive model, yet, one which will adequately allow analysis of the specific questions addressed. Proper specification of the model remains of paramount importance to providing useful and accurate results. Such specification requires careful application of the market forces and relationships reviewed in Chapter Two.

4.3.2 Model Specification

The market relationships put forth in Chapter Two reflect the price mechanisms at work within the industry; however, not all of these mechanisms or relationships are actually needed to analyze the impact of reverse osmosis filtration on shipments of fluid milk. Neither Class II demand or price, nor blend price are necessary for this analysis. The justification for their elimination is discussed below.

<u>Elimination of Class II Milk</u>. Although some federal orders have three classifications for Grade A milk's end use, many do not. In this study Class I is only Class I while "Class III" encompasses Class II and Class III, where it exists. Where there is a Class III price it is nearly equivalent to the M-W price. Due to government regulations, the Class II price, P^{II}, is approximately the same in all regions. Hence, $P^{II}_i = P^{II}_j$.

As long as the modeled area's Class III price shadows the M-W price and it remains "equal" between regions, no reason exists for transporting RO filtrated milk for manufactured use. It need not be included in the model as an influence upon shipments of reverse osmosis filtrated milk. However, Class III milk demand does enter the model within a balancing role and is incorporated through region ten. This is explained in a section 4.3.6b.

<u>Elimination of Blend Price</u>. The blend price is calculated based on a use ratio, or weighted price: $P^B = U^I * P^I + U^{III} * P^{III}$. There is no characteristic relationship between regional blend prices, i.e. $P^B_j \neq f[(P^B_i) + T_{ij}]$ in

equilibrium. Furthermore, while only the $U^I P^I$ part of the relationship varies between regions, there is no characteristic relationship between utilization ratios among regions. Thus, the focus is returned to the Class I price as the drawing force for Grade A milk shippments.

4.3.3 Price Linkage Mechanism

As discussed in section 4.1.2, before region j will import from region i or i will export to j, $P_j \geq P_i + T_{ij}$. This condition for equilibrium holds for all regions. What remains then is to link the Class I price between source and sink regions; regional Class I price being a function of the over-order premium and fluid differential within the region. GTP accommodates this through its price linkage function.

This linkage mechanism was originally designed to accommodate tariffs (subsidies), quotas, exchange rates, and transportation costs. With the fundamental principles of interregional trade being identical to those of international trade, the price linkage function allows the regional price differences, as manifested in over-order pricing and the Class I differential, to be incorporated into the model with ease. The appropriately specified price linkage function can be expressed as follows:

$$L_j(P_i) = P_i + U_j + T_{ij} \qquad \text{where } U_j = D_j + O_j$$

Where D_j = fluid differential in j^{th} importing region less the fluid differential in the i^{th} exporting region.

O_j = Average over-order premium in the j^{th} importing region less the average over-order premium in the i^{th} exporting region.

T_{ij} = transportation cost per hundredweight from the i^{th} exporter to the j^{th} importer

[Note: the cost of RO filtration is incorporated into the transportation cost function, as discussed in the following two sections.]

4.3.4 Cost of Reverse Osmosis Filtration

The cost of operating the kind of RO filtration system assumed in this study is far from exacting. No large scale RO plants are known to be operating for the concentration of whole milk. The most probable application of RO filtration for fluid milk would entail putting the whole milk through a separator, concentrating the skim milk and then remixing the cream and skim milk concentrate. The cost of operating a separator is minimal; the cost of concentrating skim milk via RO is not documented, and the cost of reconstitution has been estimated at five cents per hundredweight (Hammond, Buxton and Thraen, 1979).

This lack of data is understandable. Current application of RO within the dairy industry is almost exclusively limited to the concentration of whey. The advance in technology has the potential to change this, but as of yet, there is little cost data to go by.

Two applicable sources for the estimated cost of RO were reviewed for this study. The first represents estimated operating costs generated by Jesse (1980). He estimated the on farm application of RO filtration to be $.32/cwt for a 1000 cow dairy. Within this thesis, it is assumed that RO filtration is applied at the processor level so as to capture scale economies in operation. Given this, the estimated data for on-farm filtration for a 1000 cow dairy should be higher than would exist for filtration at a central location.

Jesse estimates the cost of filtration by a central processor for the combined UF-RO process. This cost is estimated to be $.279/cwt. Unfortunately, the dual UF-RO process is not addressed in this study. Furthermore, since the publication of Jesse's study in 1980, membrane technology and RO equipment improvements should have led to a significant decrease in operating costs. Thus, Jesse's unadjusted on-farm RO filtration estimate appears to fall closest to the conditions set forth in this study.

The second source appears to be somewhat arbitrary, yet, not necessarily inaccurate. It is the present "rule-of-thumb" estimate assumed within the industry. In general, plant economists are said to estimate the cost of employing RO filtration techniques to be approximately two cents per pound for whey and 1.5 to 1.7 cents per pound for skim milk[3] (Ottem, 1986).

The corresponding difference between the two estimates is noticeably substantial. In light of the wide range of cost estimates for the application of RO filtration, the model is run under three cost alternatives. An adjusted figure based on Jesse's estimate represents the low end of the range, the industry estimate represents the high, and an estimate of $.90/cwt represents a middle ground alternative. Each RO filtration estimate is incorporated into the transportation cost function, as developed in the following section.

4.3.5 Transportation Costs

The cost of transporting milk is of fundemental importance to the determination of distribution flows. With each market being at least partially supplied by local production, this becomes particularly true when great distances are involved. The extent to which RO filtrated milk will be shipped is dependent upon the difference between the additional cost to using RO filtration versus the savings of shipping a reduced bulk and weight product, and upon the per unit cost of transportation. The trans-

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[3] Although concentration of whole milk is not standardly considered, Ottem (1986) estimates that the cost would be approximately 1.7 to 1.9 cents per pound. The 1.5 to 1.7 cents per pound for skim milk should cover the cost of passing the whole milk through the separation unit prior to filtration.

portation cost function employed in this study is discussed below.

In spatially modeling the fluid milk industry, researchers have generally adopted previously developed transportation functions. Lough (1977), McBride and Boynton (1976), and Moede (1979) all estimated transportation costs for bulk milk by drawing information from milk trucking companies and equipment dealers. These estimated cost functions were then updated through an inflation differential and incorporated into spatial models (Hallberg, Hahn, Stammer, Elterich, and Fife, 1978; and Jesse, 1980).

For the purposes of this study, transportation costs are estimated based on two functions. For local hauling, less than 100 one-way miles, the function developed by David Hahn (1983) using 1983 data to estimate fixed and variable costs is used. For longer hauls, an updated version of Lough's 1977 transportation cost function is employed. Each of these functions is presented below.

4.3.5a Short Haul Function

For short hauls, Hahn estimated a transportation cost function based on a standard three axle diesel tractor pulling a 36 foot refrigerated trailer with a 25,000 pound capacity[4]. Costs were based on round trip mileage for

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[4] The tractor trailor rig's gross weight is 65,000 pounds yeilding a net weight of 25,000 pounds.

6,000 gallon shipments. The total transportation cost function, representing fixed and variable cost components, is given as follows:

$$\text{Total Costs (\$/cwt/day)} = 41.68 + .8320M \qquad (4.3a)$$

where M = round trip mileage.

Although actual transportation cost functions will vary according to local economic conditions and equipment used, this function provides a reasonable estimate of the short haul transportation cost under 1983 conditions.

Since 1983, the U.S. has experienced a decline in fuel costs as well as inflation. In general, expenses have increased at a lower rate from 1983 to 1985 than from 1981 to 1983[5]. It is also believed that efficiency (equipment and management) has risen slightly over this period. Although the total cost of transporting a given quantity of milk most likely increased from 1983 to 1985, the change is expected to be relatively minimal. Given this, attempting to re-estimate a total cost increase for 1985 could not insure a sufficient level of improved accuracy to warrant such an undertaking. Furthermore, using the 1983 transportation cost function, as estimated by Hahn, will likely provide equal or greater accuracy as obtained in previous spatial equilibrium studies for which older functions were updated by a fixed inflation index.

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[5] The inflation rate over the period 1981 to 1983 averaged 4.77 percent annually as compared to 4 percent for the period 1983 to 1985.

4.3.5b Long Haul Function

The transportation cost function used for one-way distances greater than 100 miles was developed by Lough (1977). This function is based on a dual tanker rig, with a 47,500 pound capacity, and allows for multiple drivers. Although Lough's function was originally estimated for 1976 data, it can be updated to approximate 1985 prices in a manner analogous to that used in previous studies. Specifically, the eight year percentage increase in costs used by Hahn to update his 1975 data was applied to Lough's function. Thus, variable costs are said to have increased 98 percent and fixed costs 115 percent. Although this provides only an estimate of the true increase, it yields a reasonably accurate function. The updated long haul function can be stated as follows:

$$\text{Cost } (\$/\text{cwt}) = .16491 + .00432M \qquad (4.3b)$$

where M = one-way miles

To apply the above cost function to this thesis, two simplifying assumptions are made. First, it is assumed that by reducing the bulk and weight by 50 percent, the variable costs of transporting the milk are also reduced by that margin. It is further assumed that the backhaul costs are incorporated into these estimates. To place this adjustment into the context of the cost function, the fixed and variable cost terms have been halved.

Second, it is assumed that milk will only undergo the RO filtration process when being shipped distances greater than 100 miles; hence, no adjustment to the cost components is made to Hahn's function. This assumption helps to create a realistic scenario wherein production is first used to supply the local market and RO filtration is applied to milk shipped greater distances.

The following set of long haul Total Cost (TC) functions result:

No RO applied:	$TC = .16491 + .00432M$	(4.3b)
Cost of RO = \$.30/cwt:	$TC = .38245 + .00216M$	(4.3c)
Cost of RO = \$.90/cwt:	$TC = .98245 + .00216M$	(4.3d)
Cost of RO =\$1.75/cwt:	$TC = 1.83245 + .00216M$	(4.3e)

4.3.5c Break Even Mileages

Applying the defined transportation cost functions to the model requires determination of the point at which the cost of shipping unfiltrated milk equals the cost of shipping RO milk. For long haul distances below this break even point equation 4.3b would be used. For distances above that point the appropriate RO function, 4.3c through 4.3e, would be used. In all cases, for distances less than 100 miles the short haul equation, 4.3a, is applied.

Break even points have been calculated for each of the alternative costs of RO filtration and are presented in Table 4.1. As expected, the break even mileage increases faster than the increase in cost of RO filtration.

Table 4.1. Break Even Cost Distances for Three Alternative RO Filtration Cost Levels, One-Way Miles

Cost of RO	Break even Distance	Cost Function Sequence	
		M < 100	(4.3a)
None	100 miles	M > 100	(4.3b)
		M < 100	(4.3a)
$.30/cwt	100 miles	M > 100	(4.3c)
		M < 100	(4.3a)
		100 > M > 378	(4.3b)
$.90/cwt	378 miles	M > 378	(4.3d)
		M < 100	(4.3a)
		100 > M > 772	(4.3b)
$1.75/cwt	772 miles	M > 772	(4.3e)

The break even distance function for increasing costs of RO filtration is presented in Figure 4.3. The function indicates that for distances greater than 100 miles, application of RO filtration is profitable. Analogously, for any cost of RO less than $.30/cwt, RO filtration is profitable at any long haul mileage.

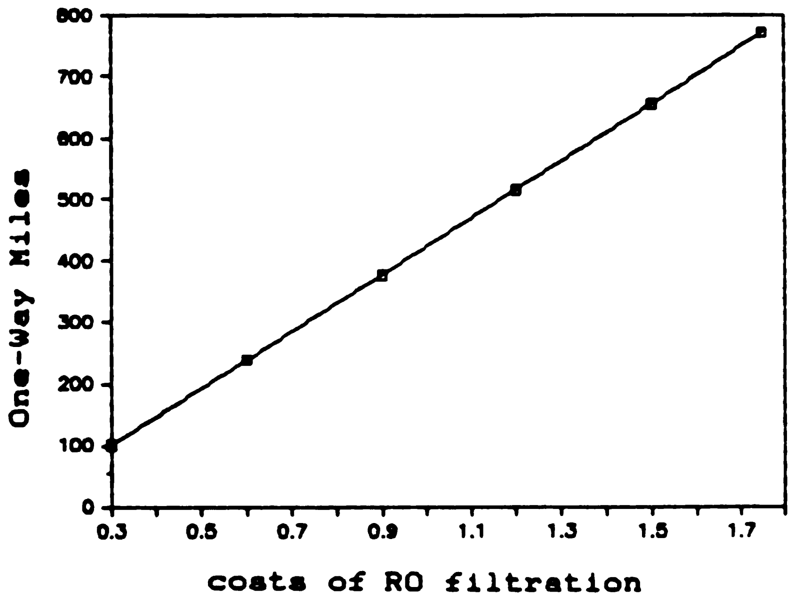

Figure 4.3. Break even mileage function under normal costs

4.3.6 Data Requirement

The data required to run the model is dependent upon how the various parameters are defined. Efficiency, ease of operation, consistency with previous studies, and coincidence with research goals were the primary criteria used when defining model parameters. Each parameter is discussed below with its data requirement and sources outlined.

4.3.6a Regions

GTP is limited to ten exporting (source) and twenty-five importing (sink) regions. For the purposes of this study, each region is included as both a source and a sink, except for the tenth sink region which has been reserved as the non-Class I sink. Hence, a maximum of nine Class I regions is possible.

Regions for this study were defined along state borders. The joining together of states to create regions was based on regional importance in the study, each state's juxtaposition to its major export destination(s) and/or import source(s), compatibility with previous studies, and data considerations. In all, 29 federal orders and 33 states are incorporated into nine regions. The primary data source used in defining these regions was the FMMO, State of Origin statistics for Class I milk pooled under federal orders (USDA, FMOMS, March, 1986). A map of the regional boundaries is presented in Figure 4.4.

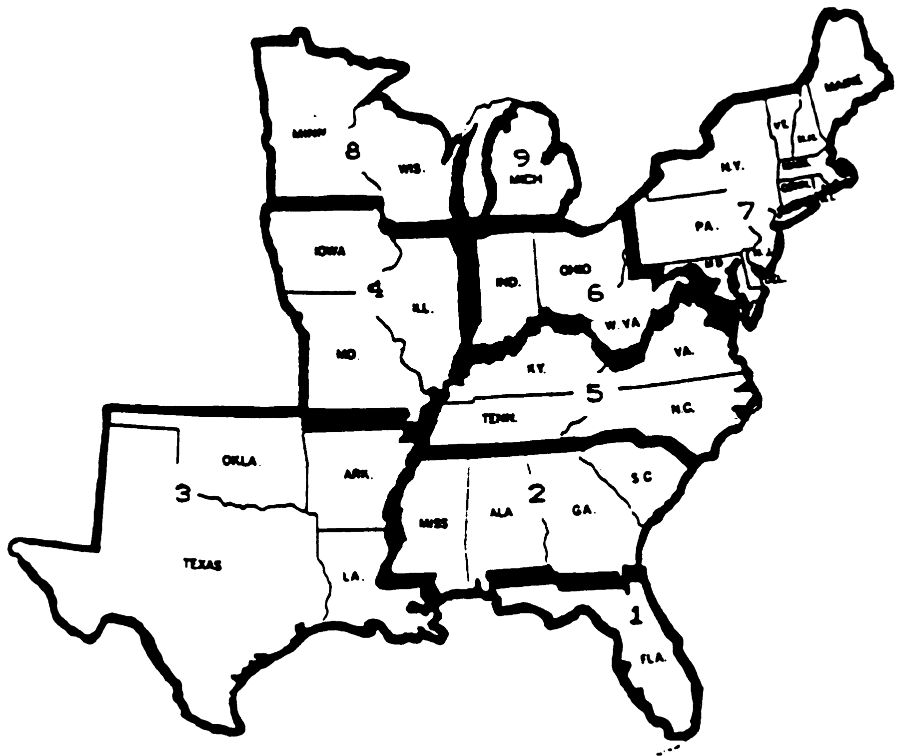

Figure 4.4. Delineation of regions used in this study

4.3.6b The Tenth Region

While Supply data is available for Grade A milk, only a portion of Grade A milk goes to Class I use. If the model were run with this Grade A data, yet only Class I demand, the excess supply of Grade A over Class I demand would swamp the market forcing the equilibrium price down. In this sense, Class III demand must be incorporated into the model within a balancing role. The tenth region serves this role. Specifically, it is given a near infinite demand elasticity for Grade A milk at the M-W price. In this way, Grade A milk in excess of fluid demand is allocated to Class III use.

In contrast to the other regions, region ten does not have a specific location; rather, it is assumed that every region has a Class III market which is located at each region's supply center. Hence, the transportation cost from each demand center to region ten is set at zero. Such a specification further ensures that milk bound for Class III use will neither be imported nor condensed through reverse osmosis.

4.3.6c Regional Centers

A market supply and demand center has been designated for each region. This center serves as the base point for demand/supply, price, and shipment costs between regions. Regional market demand centers were designated as the closest major city to the estimated center of population for the region. Population data for 1980 was used to estimate the market demand centers (USDC, 1983).

Regional supply centers were determined by looking at a milk cow numbers map and selecting the closest city to the estimated center of milk cow population. Data and maps on milk cow numbers were taken from the 1982 Census of Agriculture (USDC, 1985). Regional supply and demand centers are listed in Figure 4.5.

Region	States Encompassed	Demand Center	Supply Center
1	Florida	Lake Wales, FL	Lakeland, FL
2	Alabama Georgia Mississippi South Carolina	Macon, GA	Newnan, GA
3	Arkansas Louisiana Oklahoma Texas	Lufkin, TX	Greenville,TX
4	Illinois Iowa Missouri	Galesberg, IL	Ottumwa, IA
5	Kentucky North Carolina Tennessee Virginia	Mount Airy, NC	Hazard, KY
6	Indiana Ohio West Virginia	Newark, OH	Mansfield, OH
7	Connecticut Delaware Maine Maryland Massachusetts New Hampshire New Jersey New York Pennsylvania Rhode Island Vermont	Port Jarvis, NY	Oneonta, NY
8	Minnesota Wisconsin	Eau Claire, WI	Eau Claire, WI
9	Michigan	Highland, MI	Lansing, MI
10	All of above	All of above	------

Figure 4.5. States encompassed within regions, regional demand and regional supply centers

4.3.6d Length of Run

Each variation of run in this study is based on a one period, annual model. In dairying this is effectively a short-run period: neither producers nor consumers would fully adjust to a change in price during that time span. Furthermore, this length of time yields results based on the average market conditions throughout the year. Such an average must be considered for the implementation of reverse osmosis filtration technology. Additionally, market data is conveniently available in annual form.

4.3.6e Base Period

The base period selected is 1985. This represents the most recent year for which all necessary data is available and provides base data which reflects the current macro economic conditions as closely as possible. Two major influences on 1985's data should be mentioned. First the dairy diversion program, initiated in September of 1984 and extending through February of 1985, effected the prices in some markets. Second, the St.Louis-Ozarks order was terminated in April, 1985. The termination of this order impacted the data only slightly. The data was adjusted where possible to reflect these changes and the regionalization and one year length of run should effectively mask their impact. Also masked are other year to year variations in base-excess plans, direct delivery differentials or other similar adjustments within FMMOs.

4.3.6f Bounds

GTP allows the operator to set upper and lower trade bounds for each region. This restriction helps to mimic actual market conditions and ensure realistic results. Given the low price elasticity of supply and demand in dairying, little variation in supply or demand is likely over one period. No regional trade quantity bounds are set for Class I use. However, it is assumed that in each market a minimum amount of supply goes towards Class III use. For each region this lower trade flow bound is set at ten percent of 1985 supply levels. This forced allocation to the Class III sink is designed to reflect the combined effect of local production of Class II products and the natural loss of Class I quality milk which occurs during marketing. Thus, this trade level restriction serves the purpose of ensuring a more realistic equilibrium price.

4.3.6g Prices

The actual 1985 price for each region was calculated as the sum of the average base Class I price, regional Class I differential, and regional over-order premium. The calculated regional prices and regional elasticities were used to generate supply and demand schedules. Additionally, the Class I fluid differentials were directly incorporated into the price linkage function. Class I price differentials remained unchanged for each region throughout the base year.

Class I differentials were not necessarily uniform across all marketing orders within a region. In such cases the region's differential was estimated by weighting the separate differentials according to the amount of milk pooled in each order. Price differential data and data on milk pooled under FMMOs was taken from Federal Milk Order Marketing Statistics (USDA, May 1986; August 1986). Regional over-order premiums were generated in an analogous manner from data on over-order premiums for selected cities from Dairy Market Statistics, (USDA, Maarch 1986). The error involved in estimating regional prices in this fashion is believed to have an insignificant impact on model results.

4.3.6h Demand and Supply Schedules

Rather than specifying each region as being either in a state of excess supply or excess demand, separate supply and demand functions are used for each region. This has the advantage of directly setting the supply and demand functions from the available data and reducing the restrictions on excess schedule form. Furthermore, predetermination of a region's final trade status is not required.

For this study supply and demand schedules are entered under the constant elasticity format. By using this form, the schedules are easily derived from available data for each region. The elasticities employed were obtained from other studies. Specifically, three main sources of short-run supply elasticities were available.

Hallberg, Hahn, Stammer, Elterich and Fife (1978) derived short-run supply elasticities from a report by Hallberg and Fallert (1976) for nine regions nationally. For the latter study, regional short-run farm level demand elasticities were derived primarily from retail level studies by Boehm (1976) and George and King (1971)[6]. Later Hammond, Buxton and Thraen (1979) used short-run and long-run supply elasticities as generated by Hammond (1974) and long-run demand elasticities as developed by Fallert and Buxton (1978).

Supply and demand elasticities available for fluid milk generally have not been exacting. It is not unusual for different supply schedule functional forms to be used for different regions, as well as inconsistent data sources, time periods, or method of adjustment across variables. Recently Huy (1986), has attempted to eliminate some of this variability by using a duality approach to estimating short-run supply elasticities[7]. This methodology avoids the characteristic over estimation found with elasticities

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[6] The farm level elasticities were derived by scaling up the retail level elasticities by an assumed elasticity of price transmission of .5. Reference to this proceedure is found in George and King (1971).

[7] Specifically, the method Huy employes is a profit function approach to duality theory using Zellner's similarly unrelated regression. This entails developing one function from which the other functions are derived; regionalization is achieved through use of dummy variables.

generated by linear programming (Cilley, 1985). Additionally, Huy's elasticities cover twenty-nine states on an annual basis from 1981 to 1985 allowing for more freedom in region specification.

For the purposes of this study, short-run demand and supply elasticities will be taken from Hallberg et al. and Huy respectively. While the long-run demand elasticities estimated by Hallberg et al. are all less than those obtained by Hammond, proportionately they are the same between regions[8]. These elasticities were generated for the larger USDA regions, but are not expected to vary significantly within those regions. Hence, they can be transferred to the regions used within this study with acceptable confidence.

Huy's initial short-run elasticities are used because of their current nature, more exacting estimation procedure, and their availability on a state and regional level. It should be noted that proportionately Huy's and Hallberg's elasticities appear to be very similar. Furthermore, comparison of model results generated using the two sets of elasticities indicated that the model is relatively insensitive to a switch between the two. This is discussed in section 5.7.2.

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[8] Hallberg et al. suggest long-run demand elasticities will be 1.5 times greater then their estimated short-run demand elasticities. Hammond's elasticities are uniformly approximately 2.16 times greater than Hallberg's short-run elasticities.

To fully develop regional supply and demand schedules, the function's slope, β, and intercept, α, terms are also needed. Each region's α and β terms are generated from the price and quantity values existing during the base year for each state within the defined regions (USDA, FMOMS, May 1986 pp. 40-43). The α and β values associated with the regional supply and demand schedules are listed in Table 4.2.

Table 4.2 Regional Supply and Demand Schedule Slope and Intercept Values

	Supply		Demand	
Region	Intercept	Slope	Intercept	Slope
1	3.820	.959	25.710	-.153
2	5.431	1.423	37.994	-.219
3	-7.196	4.829	63.867	-.363
4	29.834	2.747	54.396	-.277
5	10.886	5.841	48.330	-.269
6	27.531	2.695	49.049	-.248
7	78.003	11.207	127.668	-.625
8	173.040	5.374	24.554	-.096
9	37.890	.999	24.990	-.130
10	---	---	42499.000	-3572.00

The required data was incorporated into the model presented in this chapter. This fully specified model provides the tool of analysis through which study objectives can be achieved. Chapter Five presents the model results and analysis of them.

CHAPTER FIVE

ANALYSIS OF RESULTS

The model specified in the previous chapter was used to analyze the Class I market impact of RO filtration under several pricing and policy scenarios. Each of the major scenarios, and the results generated from them, are discussed in this chapter. Figure 5.1 provides a reference to the various model runs and Figure 5.2 presents a diagram of their incorporation. The primary questions asked under each alternative case are how supply and demand quantities are affected, how the distributional pattern is altered, and what is the resultant impact on costs and revenues.

Results are discussed primarily in terms of all regions as a whole with five regions, 1, 2, 7, 8, and 9, being isolated for cross analysis. Any other regions significantly impacted by a particular parameter change will be mentioned as warranted. Model generated prices, quantities and trade flows for all regions under all runs are presented in Appendix C. To prevent any confusion in terms of scale, comparisons are made on a percentage change basis. Any change of less than one percent is considered insignificant in terms of the model's sensitivity to minor changes.

Run Title	Description
BASE	Initial annual run serving as the standard for comparisons. 1985 market conditions with no RO applied.
BRO3	BASE specification with RO incorporated at a cost of $.30/cwt.
BRO9	BASE specification with RO incorporated at a cost of $.90/cwt.
BRO175	BASE specification with RO incorporated at a cost of $1.75/cwt.
SEPT	Model run generated based on September 1985 market conditions. Serves as a base upon which RO feasibility during month when shipments are high. No RO applied.
SRO3	SEPT specification with RO incorporated at a cost of $.30/cwt.
SRO9	SEPT specification with RO incorporated at a cost of $.90/cwt.
SRO175	SEPT specification with RO incorporated at a cost of $1.75/cwt.
CCC	BASE model adjusted for reduced CCC purchases. An import quota was placed on Class III milk, reducing purchased by 444 million pounds.
CCCRO9	CCC specification with RO incorporated at a cost of $.90/cwt.
ND	BASE model adjusted for the full removal of Class I differentials. No RO applied.
D86	BASE model with 1986 Class I differentials substituted for the 1985 levels. No RO applied.
D86RO9	D86 specification with RO incorporated at a cost of $.90/cwt.
TC2	BASE model with a fifty percent increase in transportation costs incorporated. No RO applied.
TC2RO9	TC2 specification with RO incorporated at a cost of $.90/cwt.

Figure 5.1. Reference of model scenario titles and descriptions

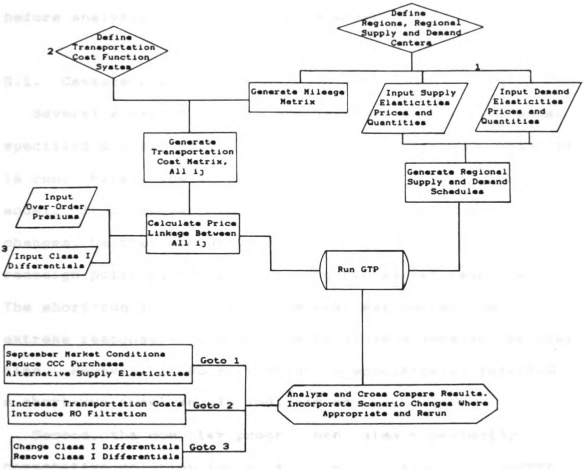

Figure 5.2. Flow diagram of the incorporation of various scenarios into the model

Although great effort was taken to reproduce actual industry characteristics, many aspects of the dynamic, Grade A milk market could not adequately be captured within this model. A brief reminder of some of the inherent limitations associated with this model will be discussed before analysis of the results is made.

5.1. Caveats and Limitations

Several areas of caution are inherent to both the model specified and the spatial equilibrium program upon which it is run. First, the model is specified as a short-run model. It produces rather sudden shifts to parameter changes, neither accounting for the industry's ability to redesign policies nor for the long-run market response. The short-run solution provides what may perhaps be an extreme response in the absence of dynamic interaction over time. However, if RO filtration is economically feasible, a short-run model should indicate so.

Second, the computer program generates a perfectly competitive solution for an admittedly "imperfect" market environment. One would expect then that the solutions generated may deviate from those actually produced by a complex and dynamic market. There is no way to determine where along the spectrum of economic markets the Class I market would eventually find equilibrium under the parameter changes discussed within this chapter. Hence, within this study the perfectly competitive solution, found at one end of that spectrum, will be used as the basis for comparison. The actual market position would likely be more liberal as producer cooperatives exercise their market position and negotiation is utilized.

Third, separating the area studied into only nine regions restricts analysis. One can not look at model generated regional results with making comparisons to a specific marketing order in mind. For example, not all shipments into or out of a given region must originate from or arrive at the region's market center. While in reality sales along order boundaries may represent a significant proportion of a region's trade, when restricted to shipments between market centers, these sales may not continue. Given this understanding, the distributional patterns generated by the model should be viewed as guides to changing flow patterns.

Fourth, the vast shifts in Class I production levels occurring under some scenarios do not reflect the local market phenomenon nor the ability for producer cooperatives to control markets and/or negotiate prices above the level generated by a theoretical model. Although this thesis does not address these factors, they do exist and significantly impact Class I marketings (USDA, January 1984).

Fifth, the greater the restrictions imposed, or the larger the alteration made to model parameters, the farther the model is stretched and the less confidence one can have in any given result. This is to say that given that supply and demand schedules were generated from point elasticities, the further the solution is forced away from the equilibrium point at which the elasticities were applied, the less confidence one can have in the results. However, even though the model may not exactly parallel actual industry reaction to the conditions imposed, a sound theoretical indication can be garnered by comparing alternative scenario solutions to the BASE solution.

Stating these obvious limitations is not meant to detract from the results generated nor the analysis submitted; rather, it is meant to serve as a reminder of the inherent limitations of such modeling. No perfect data sets exist nor is there a perfect theory through which to apply them. Given these limitations, the results and analysis from this study should be viewed as intended: as providing a useful indication of the possible impact of certain technological and policy changes, given the industry as modeled.

5.2 Base Run

The model was run under 1985 data and market conditions with the results generated serving two key purposes. First, the results were directly compared to actual 1985 market levels. This comparison served as a test of the model's performance under normal conditions and it allowed the model's specification to be recalibrated. This process led to the model as described in the previous chapter.

The model generated a base solution, BASE, with supply, demand and price levels very close to those calculated for 1985. Table 5.1 lists these levels and the percentage change between the actual and generated values. In general the model generated values remaining within +/- 2 percent of actual levels; the exception being regions 4 and 8 for which the model generated prices 6.4 and 5.9 percent, respectively, less than the actual prices. While the model generated highly acceptable results statistically, one should not overlook the potential impact of even a minor change in variable levels.

Table 5.1. Comparison Between Actual and Model Generated Supply Price and Quantity Levels

	Price ($/cwt)			Quantity (mil. cwt)		
Region	Actual	Model	% Change	Actual	Model	% Change
1	17.09	17.08	-0.06	20.21	20.20	-0.05
2	15.75	15.72	-0.19	27.85	27.81	-0.14
3	14.68	14.86	1.23	63.69	64.56	1.37
4	14.22	13.31	-6.40	68.69	66.46	-3.25
5	14.68	14.83	1.02	52.59	53.03	0.84
6	14.34	14.06	-1.95	66.18	65.42	-1.15
7	14.79	14.57	-1.49	243.76	241.32	-1.00
8	13.80	12.98	-5.94	247.20	242.81	-1.78
9	13.88	13.67	-1.51	51.76	51.55	-0.41

The accuracy of distributional patterns for 1985 is not as easily determined. A comparison between the source of each region's 1985 supply and the model's results match fairly well for major shipment levels (over 10 million hundredweight). The exceptions being model shipments from regions 6 and 9 to region 7, which did not actually occur in 1985, and the omission of shipments from region 4 to region 8, which did occur. At lower minimum trade levels, the number of "wrong-way" shipments (going south to north) increased. This is not surprising given the role of negotiation and the presence of overlap between states and marketing orders.

The overlap between regions and marketing orders accounts for a large proportion of the difference between actual 1985 distribution patterns and those generated by the model. Region 4's shipments to region 8 are an example of this overlap effect. In 1985 Illinois shipped approximately 11 million hundredweight of milk to the Chicago Regional order. Presumedly, the majority of this milk served the Chicago metropolitan area. Chicago is in Illinois which is part of region 4 but the Chicago Regional order is considered within region 8; hence, the large shipments appearing to go north in 1985.

When comparisons were made between actual interregional trade quantities and those generated by the model, concern arose over trade flow levels for region 7. During 1985, region 7 imported approximately 9 million hundredweight, yet, the model generated an import level of 35 million hundredweight. Either due to boundary overlap or not capturing some aspect of region 7's market environment, region 7 appears somewhat "worse-off" in the model. This is likely carried through all runs. It was not apparent what form of adjustment should be made based on theory and understanding that market; hence, rather than guessing at how the specification should be altered, if at all, region 7 was left as is. Interpretation of results tied to that region should be made with greater care. In all, however, the generated distributional patterns do capture the major flows and will provide useful insights as to what the true distributional patterns would be. Figure 5.3 provides an illustration of distributional patterns under the BASE run.

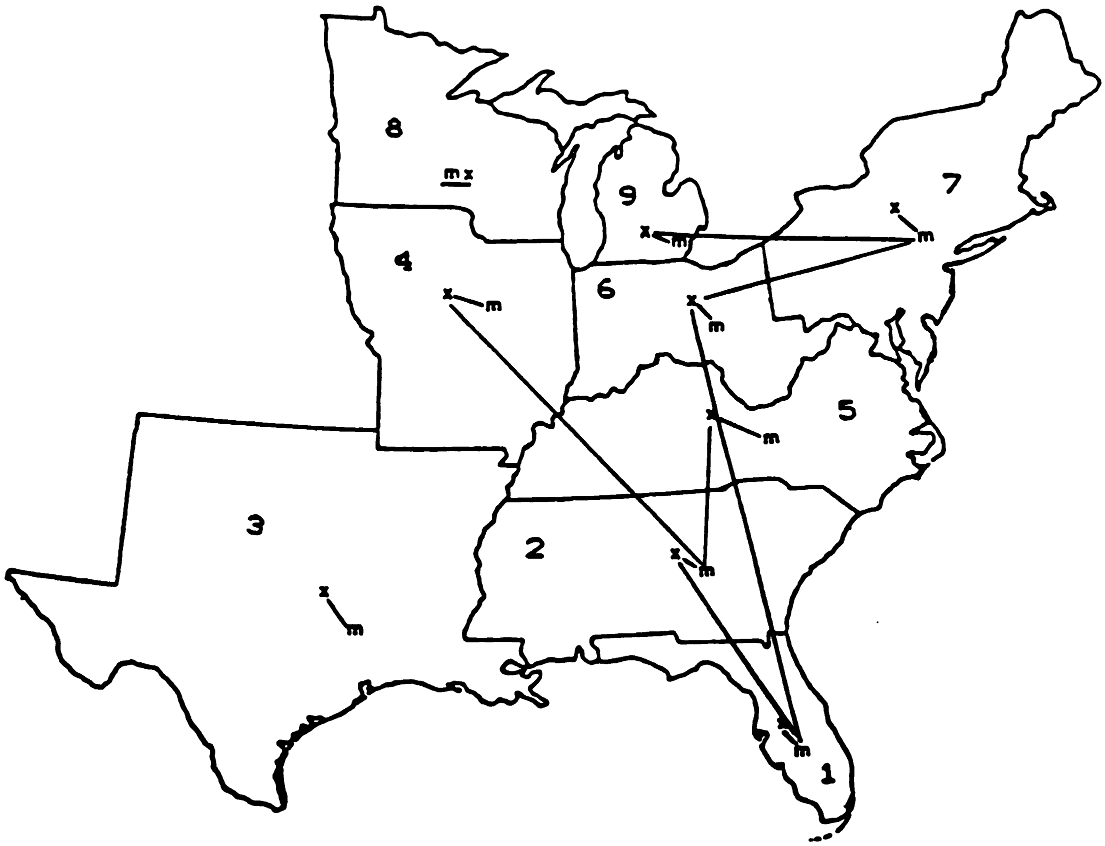

Figure 5.3. Distributional pattern under 1985 market conditions, (BASE)

The second purpose for the 1985 run was to provide a bench mark upon which solutions from alternative runs could be compared. Given the models good performance relative to actual 1985 levels, one can feel confident that the 1985 base solution adequately serves as a basis for comparison.

5.3 Impact of RO Filtration

The regional impact of RO filtration on the fluid milk industry is determined by comparing the model generated RO solutions to the BASE solution. As discussed in the previous chapter, the exact cost of full scale operation of an RO filtration unit for whole milk is unknown. To determine the range of possible impacts of RO filtration on the industry, three widely varying cost estimates were employed, $.30, $.90, and $1.75 per cwt. In addition to creating a range of possible impacts, such varied cost levels provide an indication of how sensitive the model is to increasing the fixed cost component of the transportation cost function.

5.3.1 Applying RO Filtration at $.30/cwt

When use of RO filtration is priced at $.30/cwt, distribution patterns, production levels and Class I allocations change significantly. Table 5.2 provides a reference to the percentage changes occurring under this scenario, BRO3. It should be noted that in regard to changes in exporter revenues, the focus should remain on total rather than Class I revenues. The reason for this being that producers receive a blend price, not just the Class I price. Total revenues were calculated as a weighted average of Class I and Class III revenues.

Across all regions Class I sales increase negligibly, .56 percent, but regionally, the impact is highly skewed.

The availability of essentially half-priced transportation allows region 8 to capture significant gains due to its relatively lower costs of production and Class I differential. While total exports remain nearly the same, Class I exports in region 8 increase 824 percent as it becomes the sole supplier to regions 1, 2, and 4 and the primary supplier to region 7.

Table 5.2. Market Impact Under 1985 Conditions with RO Applied at $.30/cwt, (BRO3)

		Regions				
Variable	All	1	2	7	8	9
(Numbers are as a percentage change of BASE values)						
Exports						
Total		-10.74	-7.44	0.02	0.01	-0.14
Class I	0.56	-100.00	-100.00	-100.00	824.12	-0.15
Class III		792.13	824.17	52.51	-87.50	0.00
Price	-6.95	-13.24	-9.25	0.03	0.03	-0.51
Revenues						
Total		-6.44	-28.84	-7.52	8.02	0.60
Class I	-6.42	-100.00	-100.00	-100.00	824.42	-0.66
Imports						
Total		1.78	1.29	0.62	.00	0.04
Costs	-6.26	-15.44	-12.25	-7.69	0.03	-0.49

No other region experienced a gain in sales. In fact, regions 1, 2, 3 and 7 no longer compete in the Class I market, to an accountable level, and region 4 experiences a 93 percent drop in Class I sales. The BRO3 distributional pattern is illustrated in Figure 5.4. A visual comparison of the BASE and BRO3 distribution pattern demonstrates how the shift in distribution favors region 8.

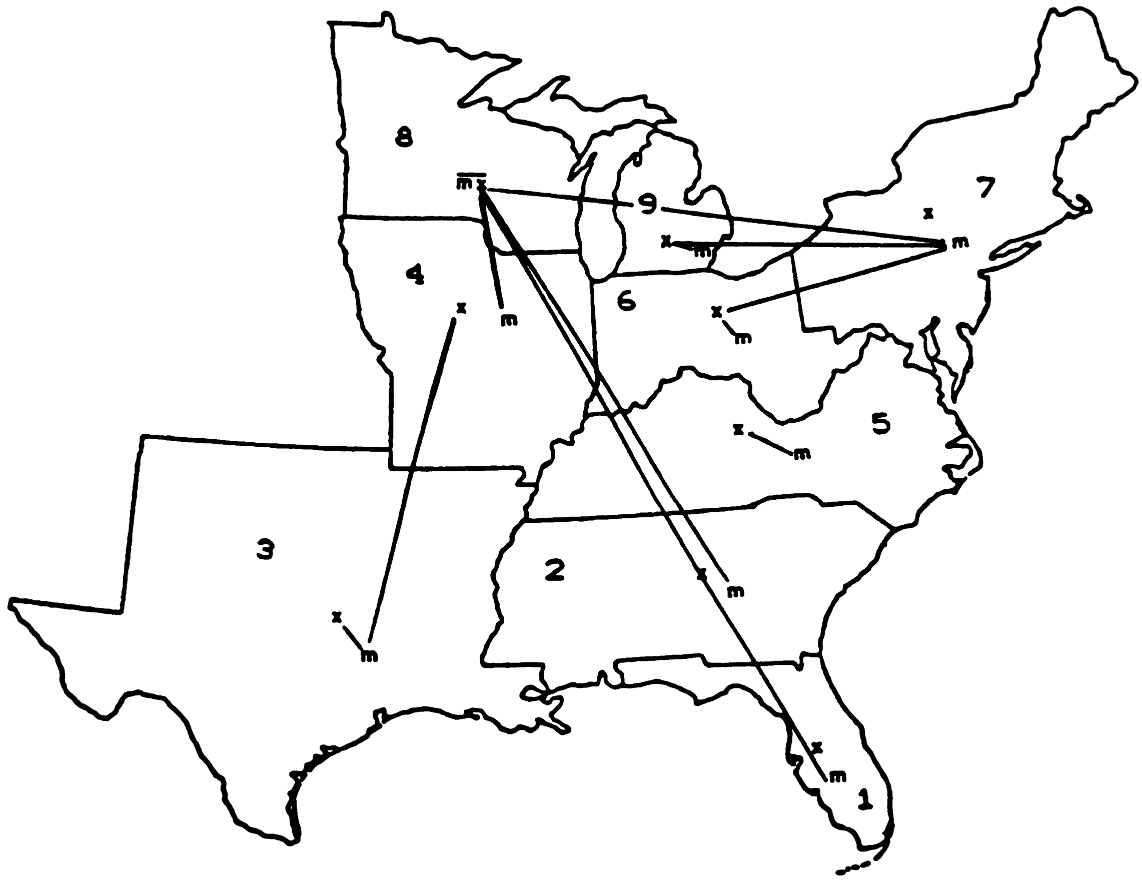

Figure 5.4. Distributional pattern under 1985 market conditions with RO applied at $.30/cwt, (BRO3)

In terms of new Grade A production levels, it is unclear exactly how much milk would continue to be produced solely for Class III use within regions no longer competitive in the Class I market. It is fairly safe to say that some localized production for Class I use would continue. Production for Class III would depend upon local demand and the producer's ability to remain in operation at the government supported Class III price.

As specified, the model dumps excess Class I supply into the Class III sink. With a government set minimum Class III price of 11.78, and aggregate regional costs of production in regions 1, 2, 3, 4, and 7 above that level, the livelihood in those regions is uncertain. However, with the model solutions being generated from annual data and supply and demand quantities listed in millions of hundredweight, no steadfast assessment should be made.

This dramatic shift in distribution is tied to the alteration in regional export prices. Across all regions a 6.9 percent decrease in export price occurs. Region 1 experiences the largest drop, over 13 percent. The resulting withdrawal of region 1 from the Class I market suggests that a 13 percent fall in Class I price would not only put producers in that region at a significant market disadvantage but also it may force many out of production.

The possibility of producers dropping out of the market is further strengthened by the impact on regional Class I revenues. Producer Class I revenues are dependent upon total sales and market prices. Regions which fall out of the Class I market will see a 100 percent decline in Class I revenues; likewise, region 8 enjoys a revenue increase on the same proportion as sales, 824 percent.

The more representative total revenues do not shift as dramatically. Region 8, gains 8 percent, while all other regions lose in total revenues. The actual decrease for regions 1, 2, 4 and 7 remains dependent on how many producers can remain in operation at the Class III price. The large regional boundaries, quantity units and the short-run characteristic of the model make determination impossible.

On the consumer side, the import price falls 6.23 percent. Even with this substantial fall in price, the inelastic nature of milk demand leads to a mere .56 percent increase in consumption. Regionally, consumers in the south enjoy the greatest savings as import prices fall up to 15 percent.

5.3.2 Applying RO Filtration at $.90/cwt

When the cost of applying RO filtration is tripled to $.90/cwt, model results are again significantly altered, albeit not as dramatically. Figure 5.5 illustrates the new interregional flow pattern and Table 5.3 presents the percentage changes associated with this run, BRO9.

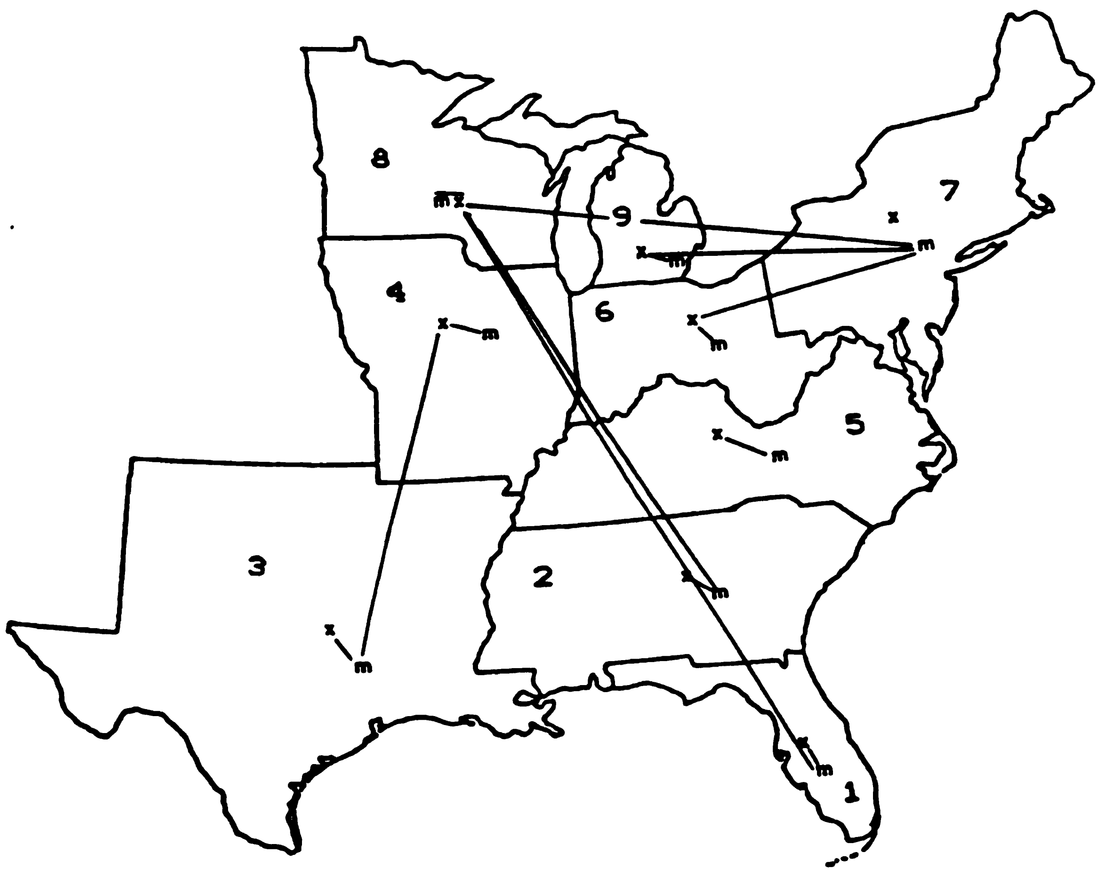

Figure 5.5. Distributional pattern under 1985 market conditions with RO applied at $.90/cwt, (BRO9)

Table 5.3. Market Impact Under 1985 Conditions with RO Applied at $.90/cwt, (BRO9)

		Regions				
Variable	All	1	2	7	8	9
(Numbers are as a percentage change of BASE values)						
Exports						
Total		-9.96	-7.25	0.01	0.01	-0.14
Class I	0.35	-11.06	-8.06	-100.00	436.59	-0.15
Class III		0.00	0.00	52.20	-46.35	0.00
Price	-5.11	-12.27	-9.01	0.02	0.02	-0.52
Revenues						
Total		-20.41	-15.09	-7.52	4.25	-.061
Class I	-4.78	-21.98	-16.35	-100.00	436.72	-.067
Imports						
Total		1.39	0.90	0.30	0.00	0.50
Cost	-3.86	-12.02	-8.61	-3.77	0.02	-0.50

The stair-step effect found under the base solution disappears. Region 8 again captures markets in the two southernmost regions shipping 15 percent of its Class I sales, which corresponds to 51 percent and 45 percent of region 1 and 2's demand, respectively. Additionally, region 8 supplies 70 percent of region 7's Class I requirement. Region 7 is the only region under this scenario which ceases production at the new equilibrium price level. Region 4 experiences a shift of up to 13 percent of Class I production either out of production or into the Class III market.

Across all regions, the Class I price falls 5.11 percent. As expected, the greatest impact occurs in regions 1 and 2 where prices decline 12.27 and 9.01 percent. In contrast, regions 7 and 9 see no significant change in their Class I export price.

The inevitable impact of declining producer prices in the absence of an equivalent rise in sales leads to a drop in revenues. Revenues from Class I sales fall 4.78 percent across all regions. Excluding region 7, regions 1 and 2 record the largest falls, 21.98 percent and 16.35 percent respectively. As in the previous case, only producers in region 8 appear to capture gains in Class I sales and Class I revenues (436 percent each).

Consumers remain significant gainers under this scenario. Across all regions the import price falls 3.85 percent, ranging from a high of 12 percent in region 1 to virtually no change in regions 8 and 9. The overall impact on demand of a lower Class I price remains negligible.

5.3.3 Applying RO Filtration at $1.75/cwt

When RO filtration is priced at $1.75/cwt the market impact is relatively minimal on the whole, as indicated by Table 5.4 and Figure 5.6. Intuitively this makes sense given a one-way break even mileage of 772 miles under this scenario. With export prices falling 1.3 percent, total Class I exports remain unchanged and the regional distribution pattern begins to resemble that of the BASE solution.

Table 5.4. Market Impact Under 1985 Market Conditions with RO applied at $1.75/cwt, (BRO175)

Variable	All	1	2	7	8	9
			Regions			
(Numbers are as a percentage change of BASE values)						
Exports						
Total		-5.93	-2.91	0.01	0.00	0.00
Class I	0.12	-6.58	-3.24	-1.84	62.64	0.00
Class III		0.00	0.00	0.01	0.01	0.01
Price	-1.30	-7.31	-3.62	0.01	0.01	0.01
Revenues						
Total		-12.45	-6.22	-0.13	0.61	0.01
Class I	-1.19	-13.41	-6.74	-1.83	62.62	0.01
Imports						
Total		0.82	0.36	0.00	0.00	0.00
Cost	-1.21	-7.15	-3.46	0.01	0.01	0.01

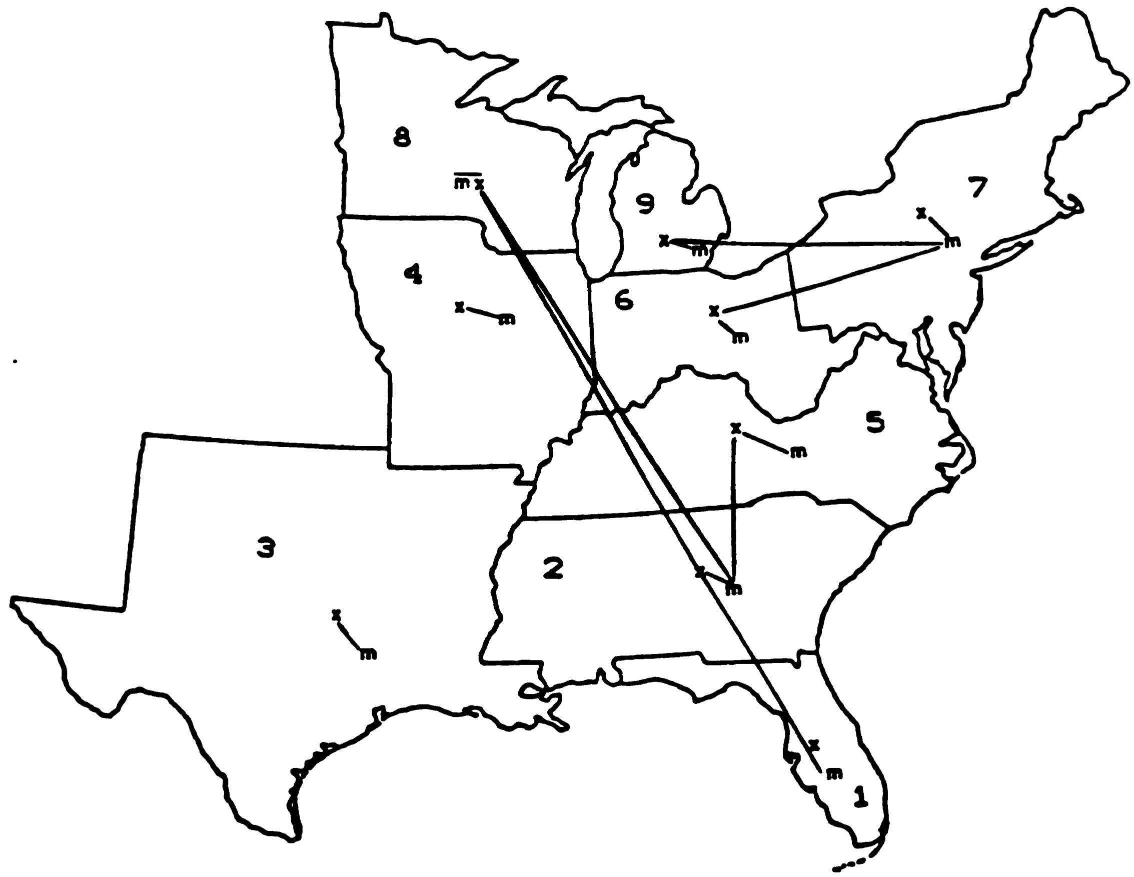

Figure 5.6. Distributional pattern under 1985 market conditions with RO applied at $1.75/cwt, (BRO175)

Of significant change is the opening of new markets for region 8. As in the previous two cases region 8 exports to regions 1 and 2 when RO filtration is adopted. These shipments replace those made by regions 2, 4, and 6 under the BASE run. Also of importance is the re-entry of region 7 into the Class I market. In fact, region 7 experiences only a 1.84 percent decline in Class I sales. This suggests that region 7's sensitivity to the change in market variables, arising when RO is applied, is more likely a result of its relatively high Class I differential than due to its relative cost of production.

Reductions in Class I sales occur as in the previous cases. Regions 1 (6.57 percent) and 2 (3.24 percent) experience significant declines while once again region 8 gains substantially (62 percent). In addition, export prices fall by 7.3 percent in region 1 and 3.6 percent in region 2 with all other regions experiencing insignificant changes.

Total producer revenues for Class I sales fall 1.19 percent with the brunt of this decline again being borne by producers in regions 1 and 2 (13.4 and 6.7 percent). In contrast, region 8 enjoys increased Class I revenues of more than 62 percent. It is again, however, difficult to determine the impact on total revenues.

5.3.4 Interpretation of Annual RO Results

Within the perfectly competitive, short-run, spatial equilibrium framework applied through this model, RO filtration would provide no real benefit to producers as a whole, even when priced at its lowest level. The net effect of full scale adoption of RO filtration is a significant loss in total revenues to the industry, under all RO cost scenarios. In fact, only region 8 stands to gain and only under the RO equals \$.30/cwt and \$.90/cwt scenarios. Additionally, while the possibility exists for some regions to capture new markets, without significantly increased levels of demand, any market gained by one region will represent a loss to another. Such is the case within the three scenarios described in this section.

It should be noted that the results are unclear as to exactly how much milk would continue to be produced in regions no longer competitive in the Class I market. It is fairly safe to say that some very localized production of milk for Class I and Class III use would continue to the extent which local demand warrants and producers can remain viable at the government supported Class III price. Hence, these vast shifts in Class I production levels do not reflect local market phenomenon nor the ability for producer cooperatives to control markets and/or negotiate prices above the level generated by a theoretical equilibrium model. This caveat holds true for all the model generated solutions in this study.

Considering the large number of RO facilities which would likely be operated by producer cooperatives, it is unforeseeable that those cooperatives would voluntarily adopt any technology which would result in lost revenues for their producers. However, recognizing the important role of negotiation and the acquired market power which exists within certain markets, it may be possible for some of the benefit gained by consumers in the theoretical case to be usurped by producers. Under BASE scenario conditions with RO filtration priced at $.90/cwt, this represents a possible average gain of around 4 percent. In an industry where profit margins are slim and producers are struggling to remain viable, this represents a significant increase. How much of that gain could be negotiated away from consumers and how it would be distributed regionally among producers is not clear.

In sum, the future for RO filtration under BASE conditions does not look politically promising. In the theoretical case, sufficient benefits must be created to compensate the losers. Given the lopsided nature of the costs and benefits generated by the model and, more importantly, considering the underlying costs associated with the necessary policy changes and transfers of benefits, it is doubtful that RO filtration would find use under these conditions.

5.4 September Conditions

When modeling the Class I milk market using annual data, the inherently strong seasonality of supply and demand is lost through averaging. In attempting to determine the market feasibility of a technology such as RO filtration, which directly impacts the transportation component of fluid milk shipments, it would then seem of obvious interest to analyze the technology's impact during the time when shipments are naturally highest. Running the model for the month of September serves this purpose; demand is near its peak, supply is approaching its trough, and inter-regional shipments are at their annual high. If this shipment hypothesis is correct, one would expect to see the benefits of RO filtration to be greatest during September. Once again, however, this modeling exercise should be viewed given the limitations of the model. Specifically, the following points should be considered.

First, the model was designed for, built upon and calibrated for annual data. To define short-run as one month stretches the accuracy of the underlying short-run supply and demand elasticities. However, given the model's relative insensitivity to elasticity changes, as discussed in a later section, this should not present a significant problem and no attempt has been made to re-specify the existing annual model for monthly data.

Secondly, what can be easily averaged out on an annual basis can not necessarily be disregarded on a monthly basis. For example, the existence of sustained call provisions in New York made it necessary to force a set quantity of region 7's September supply to the Class I market. This should not create any problems.

Third, no adjustments are made to the estimated costs of RO filtration. It is assumed, therefore, that RO filtration is employed during September at a cost analogous to that used under annual conditions. Given that September test runs were made for the $.30 to $1.75/cwt range of RO costs, the true average cost for any number of use conditions is presumably covered.

While these points of caution exist, none is overwhelming. It is believed that the results presented in this section do serve the purpose for which they were intended: to gain insight into the possible impact of RO filtration on distribution flows, prices and revenues during September market conditions.

5.4.1 September Base Run

Under the base September run (SEPT), the model generated regional supply and demand levels averaged within +/-1.4 percent of actual levels. While prices generated are higher than actual prices, the more important relative alignment of prices regionally remains intact.

Distributional flow patterns for SEPT do not reveal much in and of themselves (Figure 5.7). Comparison to the actual pattern is not possible given the lack of

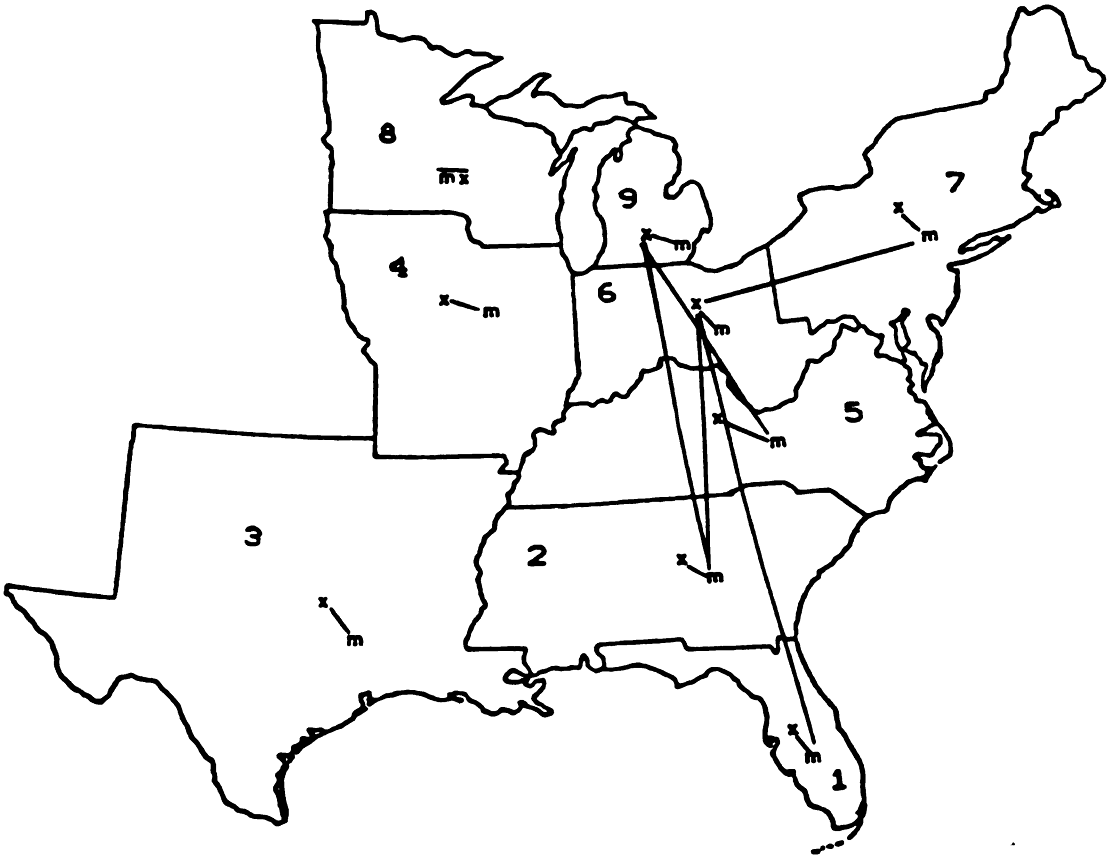

Figure 5.7. Distributional pattern under September market conditions, no RO applied, (SEPT)

appropriate data. It is worth noting that while regions 4 and 8 do not show shipments for September in addition to their annual average, regions 6 and 9 have each increased their export markets. This satisfies the belief that regions with large excess annual Class I supplies are more likely to make September shipments to regions whose annual supply and demand quantities are more in line -- suggesting September supply shortages.

All in all, the base September run indicates that substituting September data into the fully specified annual model does provide a reasonably accurate solution upon which comparisons can be made. Runs were generated for the three alternative RO scenarios (SRO3, SRO9, and SRO175) with the percentage changes listed in Tables 5.5, 5.6 and 5.7. The following discussion of these results focuses on the RO filtration scenario in which cost is set at $.90/cwt, SRO9.

Table 5.5. Market Impact Under September Conditions with RO Applied at $.30/cwt, (SRO3)

		Regions				
Variable	All	1	2	7	8	9
(Numbers are as a percentage change of SEPT values)						
Exports						
Total		-10.14	-7.23	0.03	0.01	0.01
Class I	0.64	-100.00	-100.00	0.64	482.91	-31.44
Class III		782.05	817.75	-0.58	-52.37	58.42
Price	-5.22	-12.54	-9.00	0.04	0.04	0.04
Revenues						
Total		-32.50	-25.04	0.10	2.11	-1.49
Class I	-4.62	-100.00	-100.00	0.68	483.16	-31.41
Imports						
Total		1.65	1.23	0.66	0.00	0.00
Costs	-4.85	-14.53	-11.79	-0.38	0.04	0.04

Table 5.6. Market Impact Under September Conditions with RO Applied at $.90/cwt, (SRO9)

		Regions				
Variable	All	1	2	7	8	9
(Numbers are as a percentage change of SEPT values)						
Exports						
Total		-9.23	-6.71	0.02	0.01	0.01
Class I	0.42	-10.28	-7.46	0.64	76.62	-31.44
Class III		0.00	0.00	-0.60	-8.30	58.41
Price	-3.07	-11.42	-8.36	0.02	0.02	0.02
Revenues						
Total		-18.95	-13.95	0.08	0.34	-1.50
Class I	-2.66	-20.52	-15.19	0.67	76.66	-31.42
Imports						
Total		1.27	0.83	0.47	0.00	0.00
Costs	-3.01	-11.17	-7.96	0.03	0.02	0.02

Table 5.7. Market Impact Under September Conditions with RO Applied at $1.75/cwt, (SRO175)

		Regions				
Variable	All	1	2	7	8	9
(Numbers are as a percentage change of SEPT values)						
Exports						
Total		-4.98	-2.14	0.01	0.00	0.00
Class I	0.23	-5.55	-2.38	0.64	60.96	-30.89
Class III		0.00	0.00	-0.62	-6.61	57.38
Price	-1.17	-6.17	-2.66	0.01	0.01	0.01
Revenues						
Total		-10.50	-4.57	0.06	0.27	-1.49
Class I	-0.94	-11.37	-4.98	0.65	60.98	-30.89
Imports						
Total		0.69	0.26	0.47	0.00	0.00
Cost	-1.07	-6.03	-2.54	0.01	0.01	0.01

5.4.2 Application of RO Filtration

The impact of RO filtration on fluid milk marketing under September market conditions is substantial. All scenarios follow the percentage change pattern outlined under the annual scenarios. This is to say that when RO filtration is priced at $.30/cwt (SRO3) the most significant change occurred; when priced at $1.75/cwt (SRO175), the impact was substantially less. For example, under SRO3 export prices fell by 5.2 percent across all regions with the largest decrease hitting southern regions and with greatest gain in Class I sales captured by region 8 (483 percent). The significance of these shifts diminishes under SRO175: the market wide export price increases 1.2 percent and region 8's Class I exports increase 61 percent.

When RO is introduced at a cost of $.90/cwt, the impact on the industry is significant. The application of

RO filtration leads to a 3 percent overall decrease in the export price. As expected, the burden of this decrease to producers and the benefit to consumers falls heaviest in the two southernmost regions. Total revenue loss for regions 1 and 2 is 19 and 14 percent respectively.

Comparison of Figures 5.7 (SEPT) and 5.8 (SR09) illustrates how the distribution pattern of Class I milk shifts. Specifically, region 8 becomes a competitive supplier of Class I milk to regions 2 and 5, and region 4 ships south to region 3. In contrast to these market gains, however, several regions find markets once open to them during September, now served by alternate sources. For example, both region 6 and 9 lose two export markets.

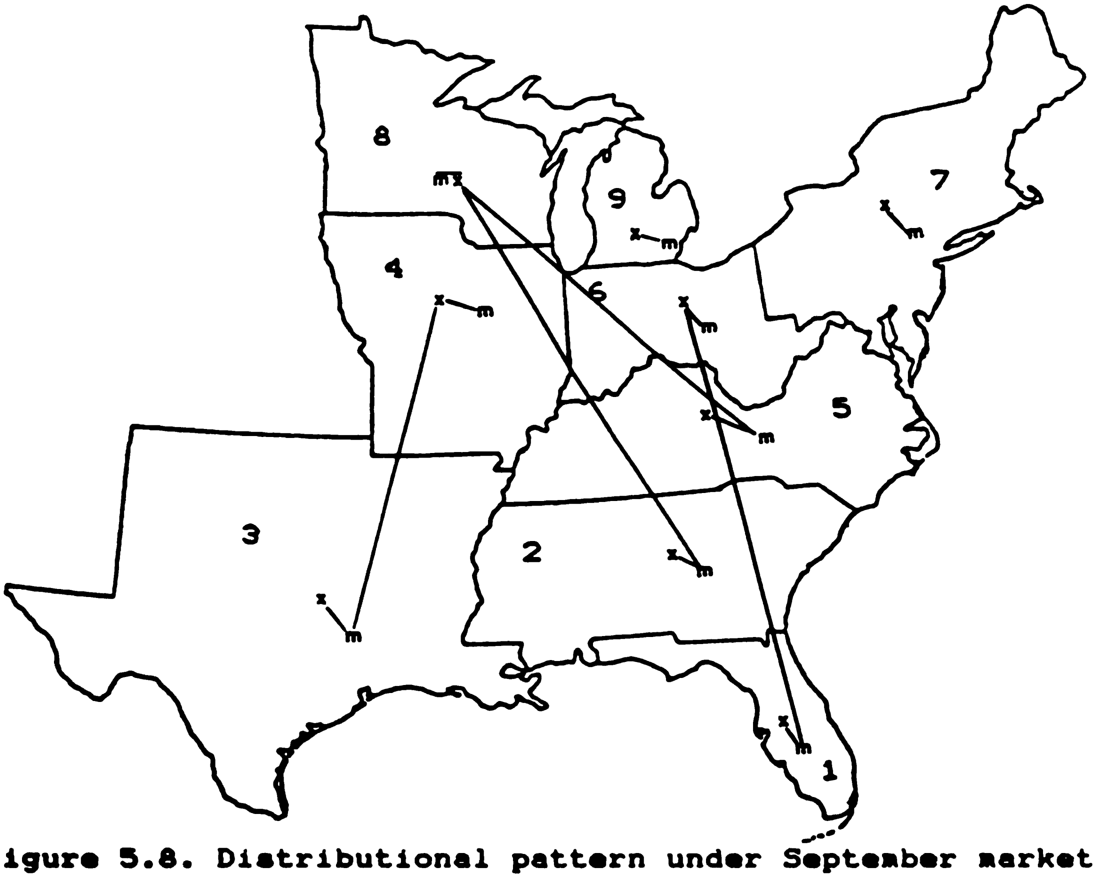

Figure 5.8. Distributional pattern under September market conditions with RO Applied at $.90/cwt, (SR09)

The magnitude of this shift presents itself in Table 5.6. It is interesting to see how application of RO filtration reduces the price gap once existing between regions 8 and 9 due to distance. Figure 5.8 suggests that region 9 may loose its market directly to region 8. This may suggest that under this scenario, the application of RO filtration eliminates enough of the mileage disadvantage faced by region 8 to allow it to capitalize on its relative competitive advantage in milk production. Furthermore, while regions 7, 8, and 9 do not see a significant change in their export price, only region 9 suffers a fall in Class I exports, 31 percent, as its exports shift from Class I markets to Class III. If region 9's total production does remain unchanged, the total revenue loss is limited to 1.5 percent.

In sum, given that the net impact to all producers remains negative, even under September market conditions, RO technology would not likely be adopted under a market environment described by the model. It is worth noting however, that the "negative" impact to producers under September conditions is less than that found under the annual case. From the point of view of an "imperfect" market, this would suggest that for any constant percentage of benefits negotiated at an annual level, a higher percent of the consumer's gains could possibly be transferred to producers during September.

5.5 Cut in CCC Purchases

At present the dairy industry is operating during an era in which government is looking for areas to trim its budget and agricultural enterprises are buckling under both heavy debt and a competitively fueled push for increased efficiency. Under this environment, government expenditures on manufactured dairy products have become highly visible and open to increased public criticism. Without judging the merits of either U.S. dairy policy or criticisms of CCC operations, the model was run under a scenario of reduced CCC purchases.

The volume of 1985 CCC purchases was roughly equivalent to 13.2 billion pounds. An estimated national decrease of 8.2 billion pounds would be necessary to achieve a purchase level approximately at equilibrium with government demand. It was determined that approximately 63 percent of 1985 CCC purchases came from the area covered in this study (DMS, 1985, Table 7). Hence, 4.44 billion pounds of the reduction must be met within the model.

The cut in CCC purchases was incorporated into the model by setting an upper limit on Class III imports. Subtracting 44.4 million hundredweight from the total quantity of Class III shipments in the BASE equilibrium solution produced the proper Class III import quota level. Such a quota should, and in fact does, force more milk onto the Class I market. This, in turn, precipitates a price decrease across all regions. Results from the reduced CCC purchases run (CCC), presented in Table 5.8 support this chain of events.

Table 5.8. Market Impact Under 1985 Conditions with CCC Purchases Reduced, (CCC)

		Regions				
Variable	All	1	2	7	8	9
(Numbers are as a percentage change of BASE values)						
Exports						
Total		-6.92	-6.88	-6.77	-3.23	-2.83
Class I	0.70	-7.69	-7.65	24.20	0.60	-3.14
Class III		0.00	0.00	-23.02	-3.63	0.00
Price	-8.67	-8.53	-8.55	-10.00	-11.22	-10.66
Revenues						
Total		-15.34	-15.30	-15.09	-15.04	-13.37
Class I	-8.04	-15.57	-15.54	11.78	-10.69	-13.47
Imports						
Total		0.96	0.86	0.77	0.60	0.82
Cost	-8.23	-8.35	-8.17	-9.53	-11.22	-10.26

Under limited CCC purchases, the weighted average price of exports falls 8.7 percent and the weighted average import price falls 8.2 percent. The new Class III price drops approximately 12.4 percent to a level of $10.32.

Of the 4.44 million hundredweight removed from Class III use within the model, only 6.7 percent is absorbed as additional Class I sales. The remaining 93.3 percent represents a decrease in total supply. This would follow the hypothesis that under a significant price decrease, producers operating near the margin will be forced to discontinue production. Regionally, those producers in the relatively high cost of production regions would be expected to absorb the greatest impact of the reduction, which they appear to do. Regions 1 and 2 decrease total supply by about 6.9 percent each while regions 8 and 9 see total supply fall by 3.2 and 2.8 percent respectively.

In regard to lost sales, all of the southern regions' loss comes from Class I sales. This is also the case with region 9. Only region 7 sees significant increases in Class I sales, 24 percent; but, no region experiences an increase in total revenues.

Across all regions, producer revenues fall an estimated 14 percent. The distribution of this lost revenue, however, is not as clear cut north to south as under previous scenarios. Specifically, regions 7 and 8 join regions 1 and 2 in suffering above average losses, over 15 percent, while region 9 suffers less of a loss, 13 percent.

The new distribution pattern is presented in Figure 5.9. Region 4 begins shipping a small amount of its supply to region 3, region 2 looses its region 1 Class I market and both region 6 and 9 gain markets. It is the addition of new markets which helps to limit revenue losses in these regions to below the industry average.

The impact to the consumer of lower CCC purchases and, hence, a lower Class I support price, is examined by looking at the new import price. Across all regions the price of imports falls 8.2 percent; however, in contrast to previous scenarios, no longer is the greatest drop in prices, either import or export, found in the south. Rather, the greatest percentage change is found in region 8, 11.2 percent.

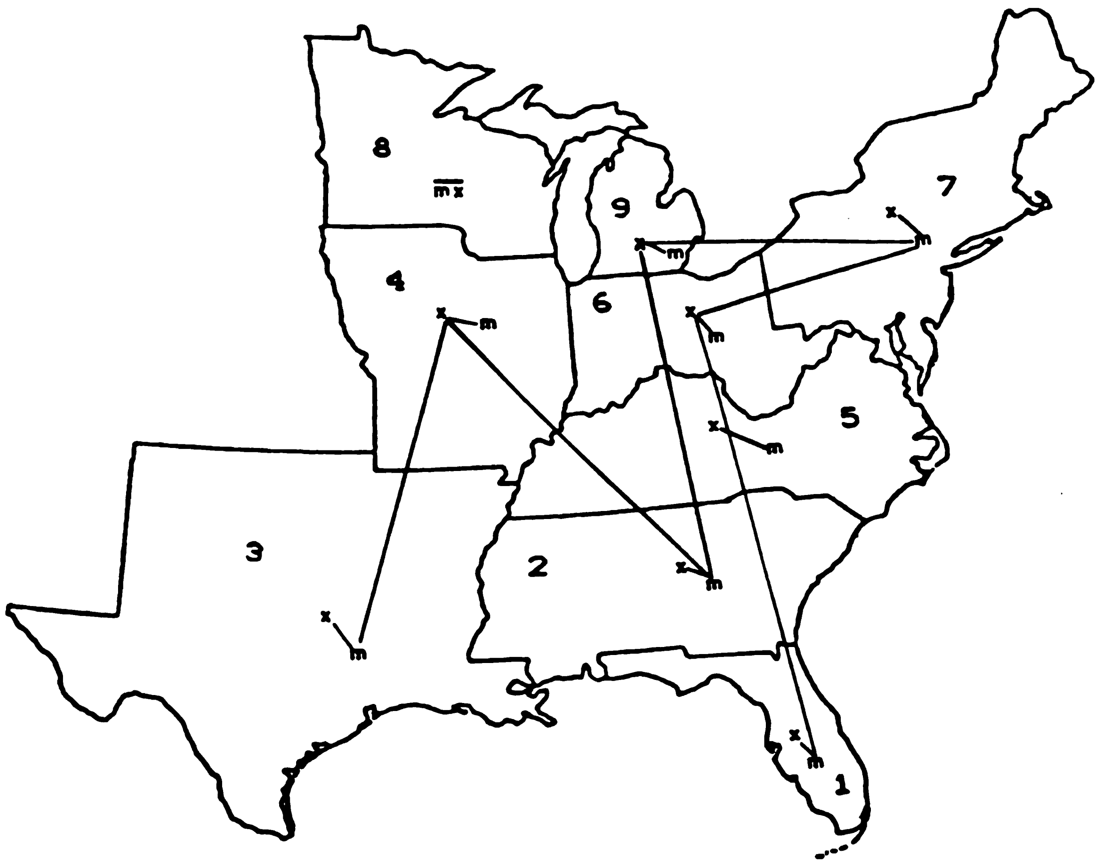

Figure 5.9. Distribution pattern under 1985 market conditions with CCC purchases reduced, (CCC)

5.5.1 Applying RO Filtration at $.90/cwt

The industry impact of both RO filtration and a significant drop in the M-W price is not uniform. Results presented in Table 5.9 and Figure 5.10 (from run CCCRO9) indicate that application of $.90/cwt RO filtration benefits regions with relatively low Class I differentials. These are some of the same regions which suffered the greatest relative burden from the initial decrease in M-W price. For example, application of RO filtration cuts the loss in total revenues experienced by producers in regions 8 and 9 from approximately 15 and 13.4 percent to

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Table 5.9. Market Impact Under 1985, Reduced CCC Conditions with RO Applied at $.90/cwt, (CCCRO9)

		Regions				
Variable	All	1	2	7	8	9
(Numbers are as a percentage change of BASE values)						
Exports						
Total		-14.75	-12.42	-4.67	-2.23	-2.10
Class I	0.88	-16.39	-13.80	-100.00	475.21	-2.46
Class III		0.00	0.00	45.35	-52.93	0.00
Price	-11.90	-18.19	-15.44	-6.90	-7.75	-7.90
Revenues						
Total		-30.22	-25.97	-22.76	-7.49	-10.25
Class I	-11.12	-31.60	-27.11	-100.00	430.64	-10.17
Imports						
Total		2.06	1.55	0.84	0.41	0.61
Cost	-10.02	-17.80	-14.74	-10.38	-7.75	-7.61

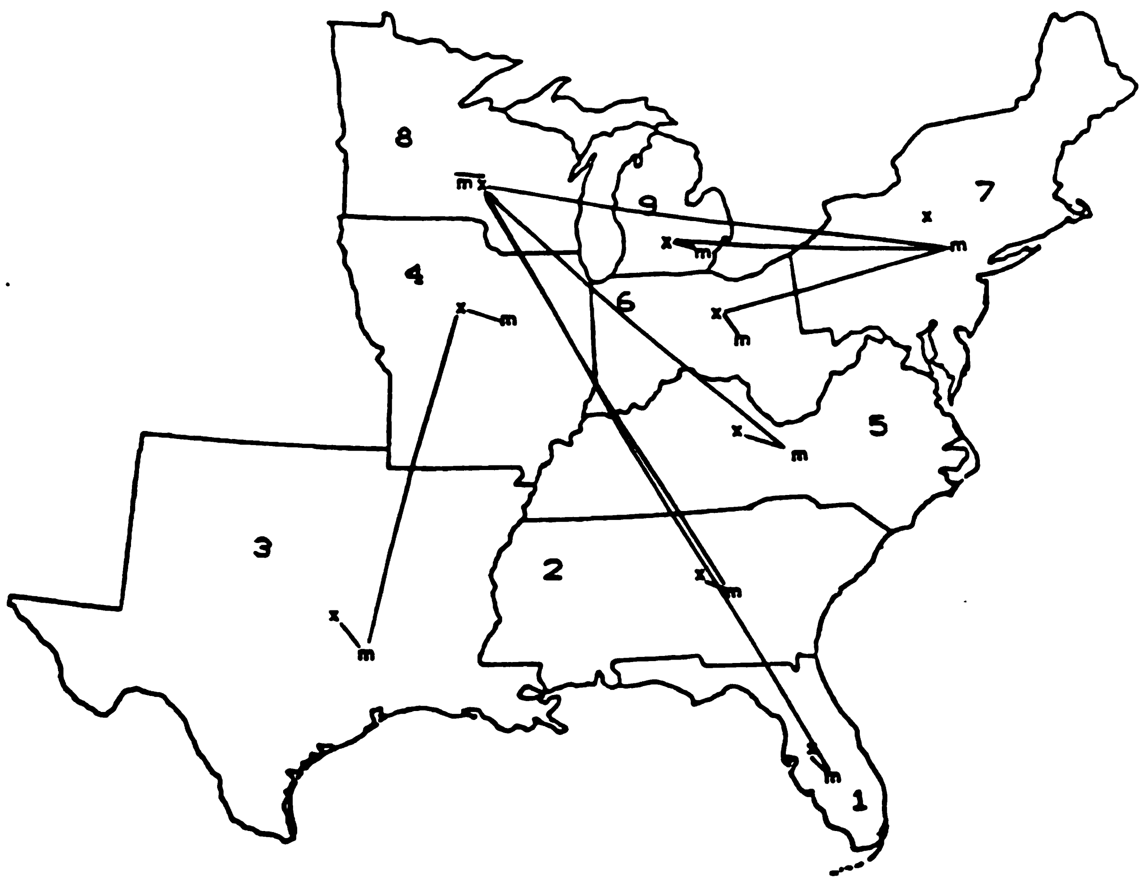

Figure 5.10. Distribution pattern under 1985, reduced CCC purchases market conditions with RO applied at $.90/cwt, (CCCRO9)

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7.5 and 10.3 percent respectively. (When viewed as implementing RO filtration after the cut in M-W price this corresponds to an actual increase in revenue of 8.9 and 3.6 percent for a price increase of 4 and 3 percent in regions 8 and 9 respectively). The net effect of a cut in CCC purchases and application of RO filtration is for the burden of a lower M-W price to shift away from regions 8 and 9 towards regions 1, 2, and 7.

In contrast to the benefits enjoyed by regions 8 and 9, RO filtration causes producers in the relatively high differential regions, such as 1, 2 and 7, to sustain compound negative impacts. First, the cut in CCC causes them to suffer substantial revenue loses, as discussed previously. Second, RO filtration forces an additional lowering of prices and Class I sales, forcing revenues even further down in these relatively high cost of production regions.

5.5.2 Interpretations of Results

The market impact of a 8.2 billion pound reduction in CCC purchases is significant. As CCC purchases decrease supplies previously allocated to government purchases now serve to flood the Grade A market. This, in turn, forces prices down. With the M-W price set at $10.32, it is unclear how many producers can remain competitive. Clearly all dairy operations producing at costs above that level will be forced out of production over time. This is true

both within and across regions. The exact number of producers withdrawing from the market is unclear. The model generates a short-run solution while reduced CCC purchases would have a long-run effect.

The results suggest that in the face of a significant reduction of the M-W price, to maintain regional production at levels analogous to current levels, the Class I differentials would have to be increased. Interestingly, this appears to have happened with the 1985 Food Security Act. The Class I differentials was increased while the M-W price fell nearly two dollars over the previous five years.

The net effect of a decrease in CCC purchases and the adoption of RO filtration is to leave relatively low cost of production regions relatively better off than other regions. Specifically, regions 8 and 9 may capitalize on both their comparative advantage in production and their relatively low Class I differentials. Once again, policy changes, i.e. adjusting the Class I differentials, would be necessary in order to preserve the status quo.

5.6 Altering the Class I Differentials

One of the barriers commonly cited to full scale adoption of bulk reducing technologies is the Class I differential system. Given this, it should prove interesting to explore the impact which both removing and realigning these differentials would have on model solutions. This section discusses each of these policy scenarios.

5.6.1 Removal of Class I Differentials

With Class I differentials removed from the price linkage function, the base model was rerun. The new solution, ND, was than compared to the original BASE solution. Figure 5.11 illustrates the shifts in shipment patterns which occur while Table 5.10 highlights the market changes which lead to these shifts.

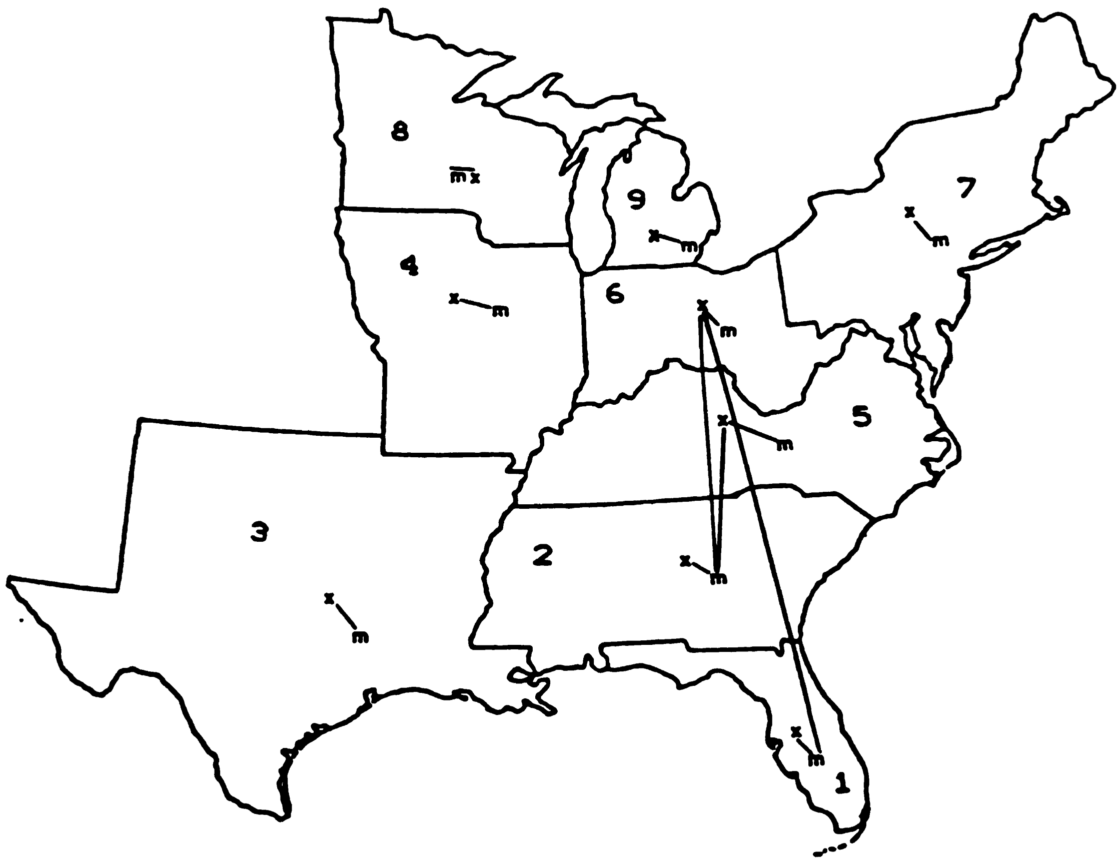

Figure 5.11. Distribution patterns under 1985 market conditions with Class I differentials removed, (ND)

Table 5.10. Market Impact Under 1985 Market Conditions with Class I Differentials Removed, (ND)

Variable	All	Regions 1	2	7	8	9
(Numbers are as a percentage change of BASE values)						
Exports						
Total		11.91	6.66	-0.24	-0.17	-0.67
Class I	0.15	13.23	7.40	42.13	0.03	-50.01
Class III		0.00	0.00	-22.47	-0.19	441.42
Price	-13.65	-5.42	-8.59	-19.15	-9.24	-13.79
Revenues						
Total		6.59	-1.68	-7.75	-1.14	-13.17
Class I	-13.78	7.09	-1.82	14.92	-9.21	-56.91
Imports						
Total		-1.70	-0.92	-0.06	0.03	0.17
Cost	-13.55	-5.31	-8.20	-18.25	-9.24	-13.27

An interesting impact under this scenario is on distribution patterns. One purpose of setting differentials at levels increasing with distance from the base pricing point was to ensure a steady supply of milk at the local level. This was accomplished by the differentials ability to support production in high cost of production regions via raising the minimum price. If the differentials are properly set, their relative level should off-set transportation costs. Given this, removal of differentials should have little effect. If they are improperly aligned, one would expect that their removal would alter prices and increase interregional shipments as the market realigns itself to costs of production.

When the differentials were removed from the model, interregional distribution of Class I milk actually decreases. The Class I price across all regions falls substantially (over 13 percent) with the relative regional export price roughly increasing the larger the region's cost of production is to its Class I differential.

Corresponding to the price fall is a 13 percent drop in Class I revenues. Perhaps surprisingly, the greatest weight of this burden appears to be borne by producers in region 9. In contrast, region 1 sees the lowest fall in export price. Furthermore, region 1 actually increases its total value of exports by increasing production by a greater percentage than the fall in price. The only sure gainers are the importers of Class I milk, the consumers.

An additional run was made under which industry wide application of $.90/cwt RO filtration was instituted after the removal of Class I differentials. While prices did change, no shift in the distribution pattern occurred. This is as would be expected when an unconstrained market in equilibrium receives an equal decrease in transportation costs across all regions.

If these results are at all indicative of how the industry would actually react under elimination of Class I differentials, it appears that the 1985 differentials not only serve to maintain production at the local level but they also provide the incentive behind a large proportion of interregional shipments. As long as these shipments are made to help balance local Class I supply with Class I demand, they serve a beneficial role. However, it appears that in some regions they may actually decrease the proportion of Grade A milk going to Class I use due to the effective subsidization of exports from other regions.

5.6.2 Realigning Class I Differentials

Testing the impact of alternative Class I differentials became necessary with passage of the 1985 Food Security Act. This legislation set new Class I differentials for all regions. On average these differentials, increase at an increasing rate from the base pricing point. To determine how model results would be altered under this legislation, new regional differentials were calculated based on the 1986 levels and incorporated into the BASE model. It quickly became evident that relative changes in regional differentials have a significant impact on model results.

5.6.2a Impact on Base Run

Initial distribution patterns, as illustrated in Figure 5.12, show a rather mild impact of the new differentials (run D86). Region 6 looses one market and region 8 replaces region 4 as an exporter to region 2. In terms of regional Class I prices and revenues, however, the impact is significant. Table 5.11 provides a reference to the degree of change resulting from the new differentials.

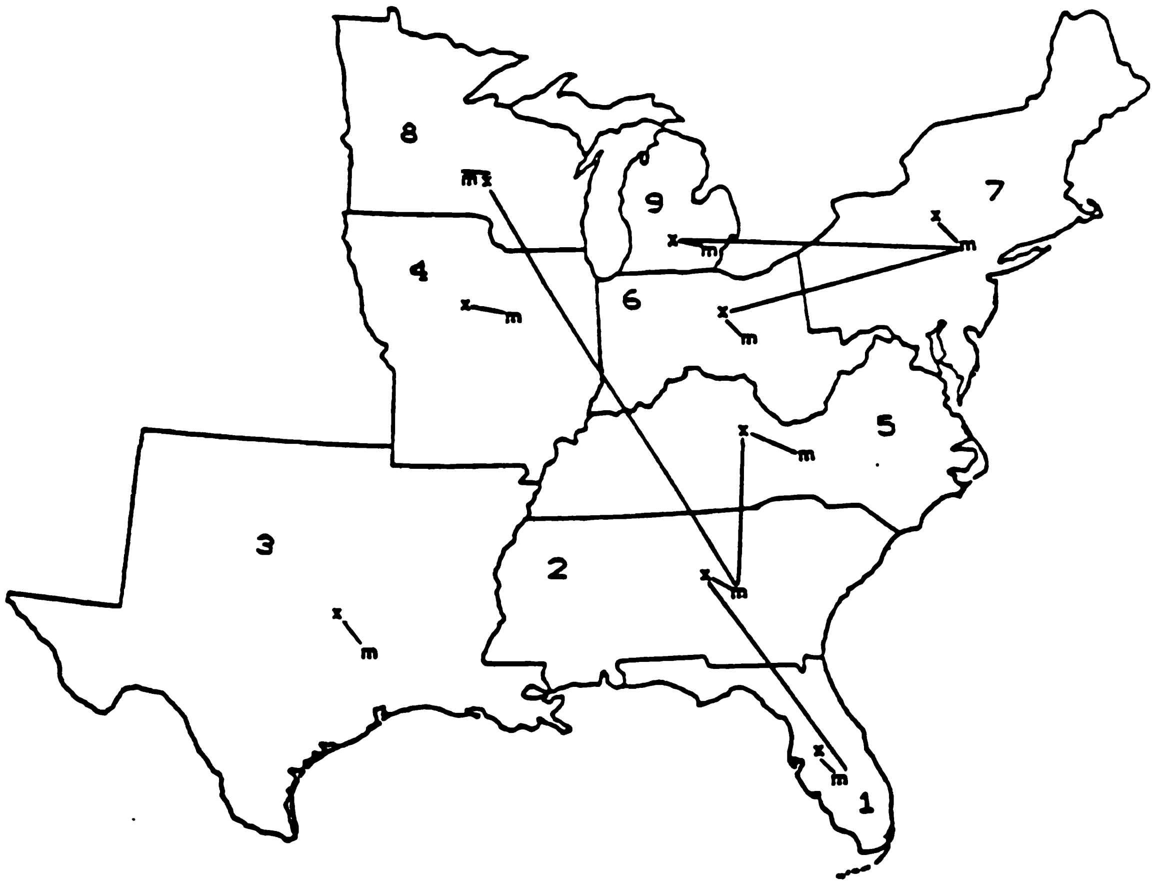

Figure 5.12. Distribution patterns under 1985 market conditions and 1986 Class I differentials, (D86)

Table 5.11. Market Impact Under 1985 Market Conditions and 1986 Class I Differentials, (D86)

		Regions				
Variable	All	1	2	7	8	9
(Numbers are as a percentage change of BASE values)						
Exports						
Total		-4.30	-2.48	1.20	0.24	0.72
Class I	0.00	-4.78	-2.75	-3.13	56.02	0.80
Class III		0.00	0.00	3.48	-5.68	0.00
Price	0.18	-5.29	-3.08	1.78	0.85	2.70
Revenues						
Total		-9.11	-5.30	1.56	0.92	3.21
Class I	0.18	-9.82	-5.75	-1.41	57.35	3.52
Imports						
Total		0.60	0.31	-0.14	-0.05	-0.21
Cost	0.15	-5.18	-2.94	1.69	0.85	2.60

Across all regions the export price and revenue from Class I sales remain unchanged. Regionally, variation exists. The Class I export price in region 9 shows the greatest gain, 2.7 percent, with region 1 receiving the greatest loss, 5.3 percent. In terms of revenues, region 8 stands to gain substantially with an increase of 57.3 percent; region 9 follows with a 3.5 percent gain. On the consumer side, regions 7 and 9 appear to feel the greatest impact as their import prices increase 1.7 and 2.6 percent respectively.

The changes described above all indicate that the disproportional increase in Class I differentials tends to favor producers in regions 8 and 9. This unbalanced effect is further illustrated by model results when RO filtration is introduced. Highlights of these results are discussed below.

5.6.2b Applying RO Filtration at $.90/cwt

The industry wide application of RO filtration, given 1986 differential levels, appears to emphasize the apparent imbalance caused by the new Class I differentials. Percentage changes between this scenario, D86RO9, and D86 are listed in Table 5.12. Figure 5.13 portrays a radical change in distribution patterns both relative to the BASE (Figure 5.3) and BRO9 (Figure 5.5) patterns. The most obvious change is the new role of region 8. It becomes a key supplier of Class I milk to three regions and the sole

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Table 5.12. Market Impact Under 1985 Conditions and 1986 Class I Differentials with RO Applied at $.90/cwt, (D86RO9)

		Regions				
Variable	All	1	2	7	8	9
(Numbers are as a percentage change of D86 values)						
Exports						
Total		-4.87	-3.27	1.20	1.26	0.87
Class I	0.19	-100.00	-100.00	-100.00	848.84	0.96
Class III		850.77	865.82	54.31	-88.74	0.00
Price	-4.01	-6.01	-4.06	1.78	4.40	3.27
Revenues						
Total		-32.27	-25.64	-6.42	13.84	3.89
Class I	-3.84	-100.00	-100.00	-100.00	890.59	4.26
Imports						
Total		1.76	0.99	0.09	-0.24	-0.25
Cost	-1.80	-15.24	-9.47	-1.11	4.40	3.15

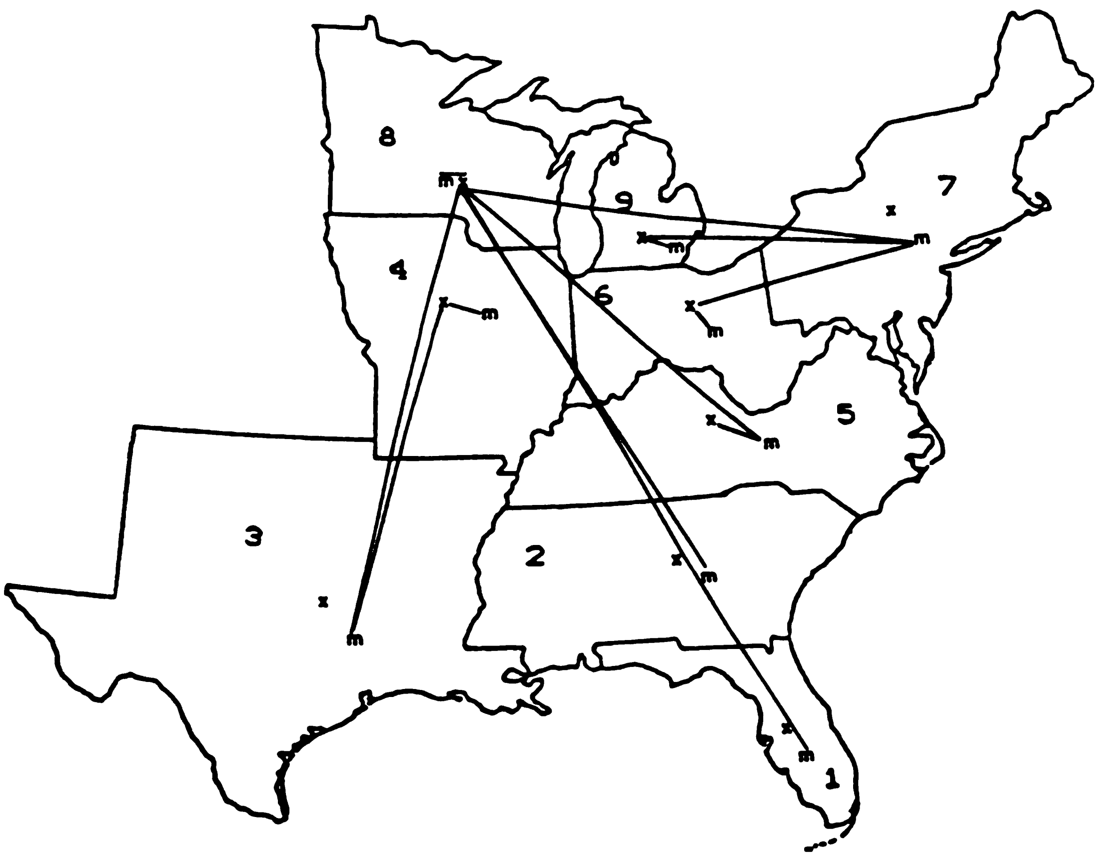

Figure 5.13. Distribution pattern under 1985 market conditions and 1986 Class I differentials with RO applied at $.90/cwt, (D86RO9)

supplier to two. Region 8's Class I sales increase dramatically, over 500 percent, as regions 1, 2, 3 and 7 fall out of the Class I market. Region 9 also benefits significantly form the adoption of RO filtration under these market conditions. It's level of total revenue increases nearly 4 percent as market price raises.

5.6.2c Interpretation of Results

The results from these runs tend to demonstrate two important points. First is the ability of a relative change in the differential level to alter the existing balance within the industry. Any marketing activity operating near the margin is easily influenced by such a change. Within a spatial equilibrium context, any significant alteration to one region's market will be felt across all regions. Such is the case with implementation of new Class I differentials. As relative prices change, marketings and revenues change.

Second is the choice presented by the availability of RO filtration: to allow increases in some forms of market efficiency versus maintaining the status quo. The introduction of RO filtration does allow for increased efficiency in the sense of comparative advantage and trade theory; however, the burdens and benefits of transition to such a market do not fall evenly. There is no Pareto optimal solution.

5.7 Additional Runs

After running the model under a range of alternative scenarios, two main areas of question remain to be discussed. Specifically, how does the model react to a significant increase in the cost of transportation and, how do results change when the underlying supply and demand elasticities are altered. Each of these areas will be discussed below with comparisons made where feasible.

5.7.1 Increasing Transportation Costs

In recent years the transportation industry has seen significant increases in operation costs. In an effort to yield insight into the variability of model results under conditions of significantly increased shipment costs, each component within the transportation cost function was increased by 50 percent. The following set of transportation cost (TC) functions result for one-way mileage:

Short Haul:	TC = .25008 + .00998M	(5.7a)
No RO applied:	TC = .24737 + .00648M	(5.7b)
Cost of RO = \$.30/cwt:	TC = .42368 + .00324M	(5.7c)
Cost of RO = \$.90/cwt:	TC =1.02368 + .00324M	(4.3d)
Cost of RO =\$1.75/cwt:	TC =1.87368 + .00324M	(4.3e)

Table 5.13 presents the revised long haul break even distances and Figure 5.14 illustrates the cost versus mileage relationship under these increased costs and the original transportation costs. Using these new functions,

the BASE and BRO9 scenarios were regenerated as TC2 and TC2RO9. Results from these runs are presented in the following section.

Table 5.13. Long Haul Break Even Cost Distances Under 50 Percent Increased Transportation Costs

Cost of RO	Break Even Distance	Cost Function Sequence	
		M < 100	(5.7a)
None	----	M > 100	(5.7b)
		M < 100	(5.7a)
$.30/cwt	54 miles	M > 100	(5.7c)
		M < 100	(5.7a)
		100 > M > 240	(5.7b)
$.90/cwt	240 miles	M > 240	(5.7d)
		M < 100	(5.7a)
		100 > M > 502	(5.7b)
$1.75/cwt	502 miles	M > 502	(5.7e)

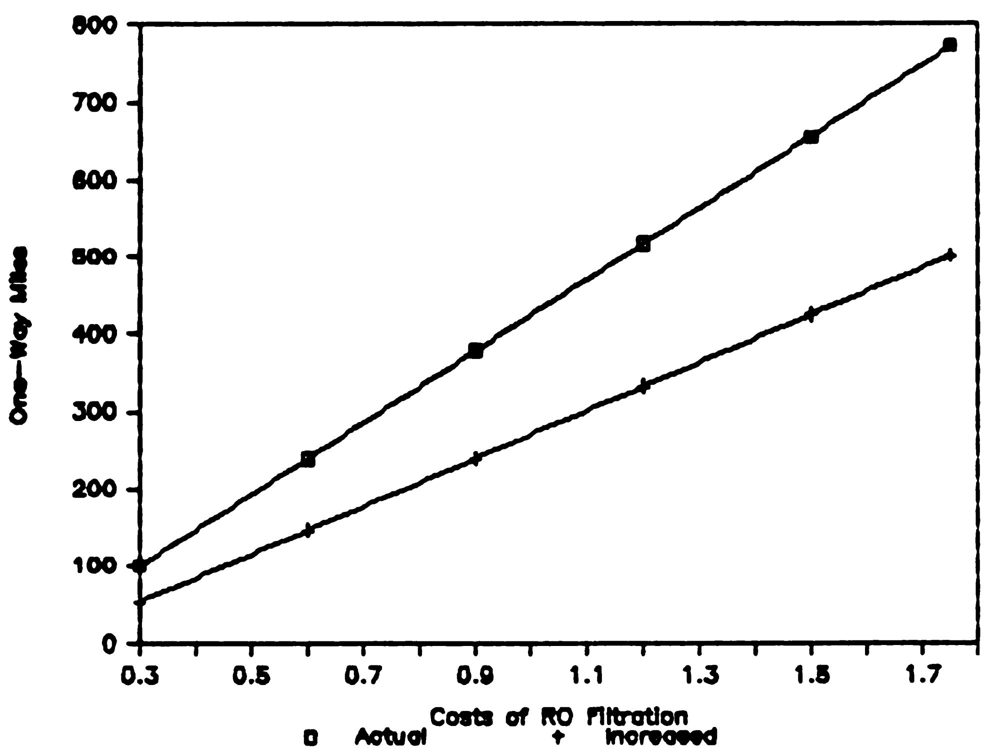

Figure 5.14. Break even mileage of RO filtration under unadjusted and fifty percent increased transportation costs

5.7.1a Impact on Base Run

One would expect a 50 percent increase in transportation costs to result in both a reduction in interregional Class I milk shipments and an increase in intraregional Class I sales, especially within newly "isolated" markets. Indeed, this is the case. Figure 5.15 illustrates an obvious reduction in shipments when compared to Figure 5.3. For example, region 1 becomes self sufficient while region 2 draws its additional supply from a closer source (region 5 versus region 4).

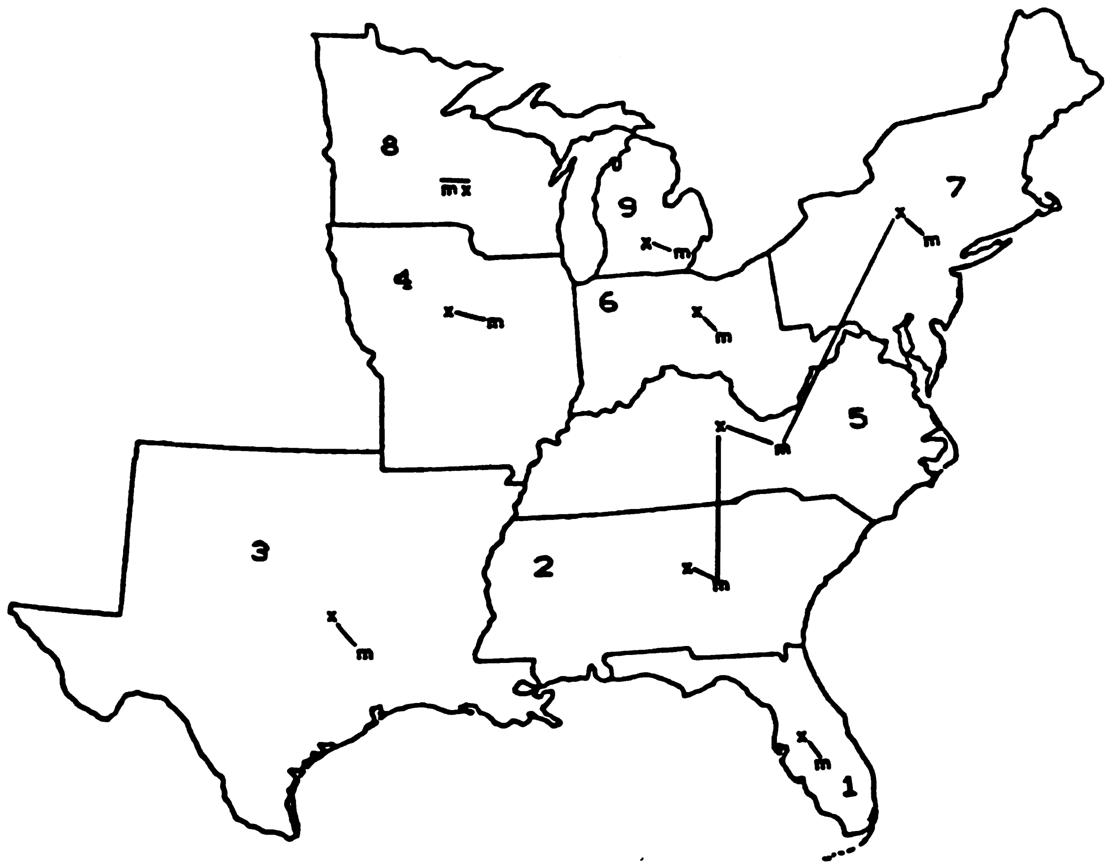

Figure 5.15. Distribution pattern under 1985 market conditions and fifty percent increased transportation costs, (TC2)

The percentage change comparisons shown in Table 5.14 also uphold the solutions compatibility with theory. The increased per mile transportation cost restricts the ability of lower relative cost of production regions from capitalizing on their combined comparative advantage and lower relative Class I differentials. Region 8 appears to be hardest hit suffering a 50 percent decline in Class I sales. This corresponds to a loss in total revenues of over 7.7 percent. The biggest gainer is region 7 (total revenues up 3.9 percent) which no longer finds itself losing markets to more distant regions because of its relatively high Class I differential.

Table 5.14. Market Impact Under 1985 Conditions and Fifty Percent Increased Transportation Costs, (TC2)

		Regions				
Variable	All	1	2	7	8	9
(Numbers are as a percentage change of BASE values)						
Exports						
Total		7.35	3.05	0.00	0.00	-0.55
Class I	-0.23	8.16	3.39	51.49	-0.11	-50.10
Class III		0.00	0.00	-27.02	0.01	443.32
Price	0.78	9.06	3.78	0.00	0.00	-2.09
Revenues						
Total		16.69	6.74	3.88	0.00	-7.74
Class I	0.55	17.97	7.30	51.49	-0.10	-51.14
Imports						
Total		-1.15	-0.61	-0.19	-0.11	0.01
Costs	2.45	9.92	5.86	2.35	1.95	-0.13

Regions 1 and 2 also gain. The additional cost of shipping down to region 1 causes its export price to jump over 9 percent. This, in turn, allows its higher cost of production industry to burgeon. Total production in region

1 increases over 7.3 percent with total Grade A revenues rising by approximately 16.7 percent. Overall, when transportation costs increase 50 percent, all other variables held constant, producers stand to come out about even (total revenues across all regions increase less than .4 percent).

For consumers, the cost of increased transportation is passed directly on to them. The overall import price increases 2.45 percent. As expected, southern regions see the largest increase in import price (9.9 percent in region 1 and 5.9 percent in region 2). In contrast, the import price actually falls, though negligible, in region 9 where the decline in Class I exports floods its market.

5.7.1b Applying RO Filtration at $.90/cwt

The application of RO filtration in the face of increased transportation costs allows Upper Midwest producers to once again become gainers. Under transportation cost increases, the adoption of RO filtration would allow region 9 to regain its lost market and region 8 to develop new markets. Figure 5.16 illustrates the resulting Class I shipment pattern under this run (TC2RO9).

Figure 5.16. Distribution pattern under 1985 market conditions with transportation costs increased fifty percent and RO filtration applied at $.90/cwt, (TC2RO9)

The increase in Class I sales by both region 8 and 9 are substantial, 19.5 and 101 percent respectively. However, the gains obtained through RO filtration go beyond the status quo established by the original BASE solution[1]. This is illustrated by the percentage changes listed in Table 5.15. A comparison indicates that revenues in region 1 would actually fall a total of 6.45 percent versus a revenue gain of 1.4 percent in region 9. Hence, while the

[1] Note that this scenario represents a simultaneous increase in transportation costs and application of RO filtration.

Table 5.15. Market Impact Under 1985 Conditions with Fifty Percent Increased Transportation Costs and RO Applied at $.90/cwt, (TC2RO9)

Variable	All	Regions 1	2	7	8	9
(Numbers are as a percentage change of BASE values)						
Exports						
Total		-3.02	-2.92	0.00	0.00	0.32
Class I	-0.12	-3.36	-3.25	-2.60	19.33	0.35
Class III		0.00	0.00	1.37	-2.05	0.00
Price	-0.83	-3.72	-3.63	0.01	0.01	1.19
Revenues						
Total		-6.45	-6.24	-0.19	0.19	1.41
Class I	-0.94	-6.95	-6.76	-2.60	19.34	1.55
Imports						
Total		0.30	0.13	-0.19	-0.11	-0.24
Costs	1.44	-2.59	-1.22	2.35	1.96	3.02

introduction of RO filtration appears essential for producers in regions 8 and 9 given a 50 percent increase in transportation costs, the end result is not an even distribution of gains when RO filtration is priced at $.90/cwt.

5.7.2 Alternative Supply Elasticities

Elasticities may be difficult to estimate even for the simplest of commodities. Judging by the range of elasticity sets developed and of estimation techniques employed, estimation of milk supply elasticities has not been an easy task. Accordingly, the model used in this study was tested for its sensitivity to changes in regional supply elasticities.

Initially two sets of short run supply elasticities, Hallberg et al.'s and Huy's, were considered for use in the mod

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the model. In selecting which of these sets to incorporate, base runs were generated for each. When model generated regional supply and demand levels for the two runs were compared to actual 1985 levels, Huy's initial elasticities provided slightly better results than did Hallberg et al.'s; although, the results were not significantly different. In light of the base run's role of providing the opportunity for finer calibration, Huy's initial 1985 elasticities were selected.

After all runs were generated, a revised set of Huy's 1985 elasticities became available. This increased the importance of testing the model's reaction to alternate elasticities. As an indication of the new elasticities impact on regional supply schedules, intercept terms generated from the new and old elasticities are presented in Table 5.16. Note that while the ordinal ranking of regions remained the same, the degree of impact varied substantially.

Table 5.16. Regional Supply Schedule Intercept Term Values Under New and Old Supply Elasticities

Region	Intercept Old	Intercept New	Percentage Change
1	.96	.59	-38.5
2	1.42	.88	-38.0
3	4.83	3.36	-30.4
4	2.75	.89	-67.4
5	2.84	1.68	-40.1
6	2.70	.79	-70.1
7	11.21	2.19	-80.5
8	5.37	-.52	-109.7
9	1.00	-.84	-184.0

A problem arose in generating model runs due to the negative elasticity values associated with regions 8 and 9. GTP only accepts supply elasticities which are greater than or equal to zero. To test the legitimacy of setting these to zero, region 9's elasticity was adjusted downward from .15 in successive runs, ceteris paribus. Table 5.17 reflects how region 9's supply schedule coefficients and the equilibrium supply quantities for all regions changed. Note that while altering region 9's supply elasticity did significantly impact its supply schedule coefficients, there was a negligible impact on model equilibrium levels.

Table 5.17. Impact of Progressively Lower Supply Schedule Elasticities on Region 9's Supply Schedule Terms and Equilibrium Quantities

Elasticity	Slope	Intercept	Supply Region 9	Supply All Others
.15	.56	44.00	51.652	no change
.10	.37	46.58	51.636	no change
.05	.19	49.17	51.766	no change
.00	.00	51.76	51.760	no change

Given this apparent insensitivity to changes in a single region's supply elasticity, the model was rerun with region 8 and 9's elasticities set at zero. The impact on relevant results was negligible. Table 5.18 displays the overall impact of the new elasticities on model results under 1985 market conditions (BASE). The distributional patterns and regional Class I supply and demand quantities levels remained within +/- 1 percent of initial results, with the exception of regions 4 and 8. Region 4's supply increased

2.5 percent while region 8's increased 1.8 percent. Interestingly though, all of this additional supply was shipped to region 10, the Class III sink. Hence, the effect of the revised elasticities was insignificant in relation to the analysis presented in this chapter.

Table 5.18. Regional Impact of "New" Supply Elasticities on Equilibrium Quantity and Price Levels

Region	Supply			Demand			Price	
	Old	New	Change	Old	New	Change	Old	New
	(mil. cwt)		(%)	(mil. cwt)		(%)	($/cwt)	
1	20.2	20.2	0.0	23.1	23.1	0.0	17.08	17.05
2	27.8	27.9	0.0	34.4	34.4	0.0	15.72	15.69
3	64.6	64.5	0.0	58.1	58.2	0.0	14.86	14.94
4	66.4	68.1	+2.5	50.5	50.5	0.0	13.31	13.28
5	53.0	52.9	-0.3	44.1	44.1	0.0	14.83	14.81
6	65.4	65.9	+0.7	44.5	44.5	0.0	14.06	14.06
7	241.8	243.2	+0.8	118.1	118.1	0.0	14.57	14.57
8	242.8	247.2	+1.8	23.3	23.3	0.0	12.98	12.98
9	51.6	51.8	+0.4	23.1	23.1	0.0	13.67	13.67
10				412.9	421.4	+2.1		

Although there is little doubt that drastic alterations to supply and demand elasticities would impact model results, the test conducted in this section indicates that the model is reasonably insensitive to moderate elasticity changes. This is especially true for near proportional changes. Hence, the results and analysis presented in this study, developed using Huy's initial 1985 elasticities, provide an acceptable level of accuracy.

5.8 Comparison of Results with Other Studies

This section addresses the cross comparison of results presented in this thesis with those from other dairy model

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modeling studies. Specific studies addressed are those by Novakovic et al., DAMPS, (1980); Hallberg et al. (1978); Whipple (1983); and, Hammond, Buxton and Thraen (1979). Although these studies most closely follow the design of this thesis, they differ in specification and intent. In general, the time period covered, data incorporated, regionalization, and issues addressed vary considerably among studies. Given these intrinsic differences, only broad comparisons are made and general insights gained.

The DAMPS study addressed the realigning of regional differentials according to actual transportation costs. Their results indicate that in no region does the resultant pricing structure lead to a near or total reduction in production. In contrast, within this thesis the differentials were held constant and, when the transportation cost structure changed significantly with adoption of RO filtration, several production regions experienced a total withdrawal from the market.

Although the two alternative approaches to handling Class I differentials do prohibit direct comparison, they also help to illustrate one effect of the short-run model: it does not allow for the industry's ability to make policy or marketing adjustments in response to a new technology. Furthermore, there are several areas where general DAMP's results coincide with those obtained within this study. For example, producer price and marketings in the Northeast

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are found to be highest when the Class I price and differential are highest in that region; consumption varies relatively minimally with changes in the Class I price; producers in the Upper Midwest do better the higher the Class III price; and the Southeast and Southcentral regions' prices are lowest when Class I differentials are set according to the cost of shipping milk in ingredient form. While these observations correspond with the results obtained within this thesis, they are more comparisons with accepted beliefs and theory than a good test of model results and they do not provide any new understanding of spatial market response under RO filtration.

Hallberg et al. focused on equalizing the prices of fresh and reconstituted milk via altering Class I differential levels. As with the DAMPS study, there is limited capacity for cross comparisons to be made. For example, they found that consumer expenditures increase by a greater proportion than producer revenues when Class I differentials are increased. Although no proportional increases in Class I differentials are made within this thesis, the general relationship between producer revenues and consumer expenditures is exhibited when Class I differentials are removed entirely: Grade A export revenues fall between 7.5 and 11.5 percent while Class I import expenditures fall by 13.7 percent. Additionally, Hammond et al. note that approximately 60 percent of shipments to the Northeast regio

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region's demand centers are intraregional. The corresponding region in this study, region 7, supplied 70 percent of its Class I demand.

Whipple found that if ingredients were priced at their manufactured price then farm level prices would fall by up to 15 percent in Florida and by up to 2 percent in the Lake States. Furthermore, the gross farm receipts across all regions would drop. Although this thesis expresses producer prices as export prices, responds only in the short-run, and does not directly deal with the issue of pricing reconstituted milk (due to only Grade A milk being RO filtrated), it does produce similar responses in terms of direction of impact. For example, when RO is priced at $.30/cwt (yielding a transportation cost function nearest to that for shipping milk in ingredient form), export prices in Florida fall by over 13 percent, export prices in the Upper Midwest increase by approximately .25 percent, and total export revenue for Grade A milk drops between 5 to 40 percent across all regions (depending upon the actual amount of Grade A produced for Class III use). Again these results suggest compatibility between research results in very general terms.

Hammond, Buxton, and Thraen approached analyzing the regional impact of reconstituted milk on regional Class I differentials and production via altering the differentials and

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and via pricing ingredients at their manufactured price. The first method is not used in this study and the second is not applicable; thus, direct comparison of results is not feasible. Of general interest however, they find that changing supply elasticities proportionally has a rather minor influence on results. While this is analogous to results presented in this chapter, it is more an indication of model sensitivity to elasticity changes than it is to the markets' reaction to a policy or technology change.

5.9 Summary

In this chapter the model specified in Chapter Four was directly applied to the dairy industry under several different policy and economic scenarios. When tested against actual 1985 marketings, the model responded with reasonable accuracy. As more drastic policy changes were implemented and the model was stretched further beyond its original design, less confidence was held in any one result. However, even under these more extreme conditions, the model does provide insight as to what the market impact of alternative scenarios would be under a perfectly competitive, spatial equilibrium framework.

Throughout all model runs, changes to regional Class I sales, revenues, and distribution patterns were used as indications of the possible market impact of alternative scenarios. Of specific interest was the viability of RO filtration within the model.

Although results under alternative scenarios varied significantly, across all model runs it was found that the introduction of RO filtration would benefit importers at the expense of exporters. Regionally, the impact was inconsistent across runs. In general, exporters in the lower relative cost of production and Class I differential regions saw prices and revenues fall less than did exporters in other regions. The converse was true for importers.

In terms of impact on the two low cost of production regions, 8 and 9, introduction of RO filtration had a mixed impact under alternative scenarios. Under the BASE scenario series, only region 8 gained export revenues under RO filtration priced at $.30 and $.90/cwt; region 9 saw no revenue change under RO at any price. During SEPT conditions, adoption of RO filtration actually reduced region 8's revenues while increasing region 9's. When Class I differentials are removed, RO filtration had no significant impact on any region under any pricing scheme.

It appears region 9 benefits substantially from full scale adoption of RO filtration under the two remaining scenarios. First, under the new 1986 differentials both regions 8 and 9 experienced substantial revenue gains via RO filtration. Second, under a significant (50 percent) increase in transportation costs and RO filtration priced at either $.30 or $.90/cwt, region 9 enjoyed substantial revenue gains; region 8 experienced no change in revenues.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

This study examined the potential economic feasibility and market impact of applying reverse osmosis filtration to fluid milk. The motivation for this research stemmed from a combination of factors. Primary among them were the tightening of financial resources within the industry and improvements in reverse osmosis technology. A short-run spatial equilibrium model of a selected segment of the U.S. Grade A milk market was developed and applied under a range of pricing and policy scenarios. Specific questions asked were: (1) Who stands to gain from the nation-wide adoption of RO filtration? (2) How will production shift and what are the regional implications of such a change? And (3) Is RO filtration even potentially feasible in the political economic marketing sense?

This thesis has approached these questions through both descriptive and quantitative analysis. Regional competitive advantage in milk production was established. The key marketing variables affecting and potentially affected by the industry-wide adoption of RO filtration for Class I use were identified. The current policy constraints to marketing reconstituted milk were discussed.

A brief summary of the motivation behind this research, the model utilized, and the results obtained are presented below. The remainder of the chapter focuses on the implications of model results and on conclusions which can be drawn from them.

6.1 Background to Research Issue

The U.S. dairy industry is immersed in an era of transition. In an effort to decrease government expenditures and reduce the milk surplus, the dairy support price has been lowered by over two dollars per hundredweight in the past five years. Under the burden of heavy debt and reductions in the support price, many dairy operations have been forced out of production. In contrast to these pressures to reduce supply, productivity expanding technologies, such as bovine growth hormones, are on the horizon. The result of these opposing forces is both increased tension and an intensified effort to identify means by which to minimize the negative effects of transition and achieve greater economic efficiency.

Technological advances related to the long distance transportation of bulk milk have made the topic of greater efficiency gains through comparative advantage relevant. Of primary interest is the advance in reverse osmosis (RO) filtration. This process would allow bulk milk to be reduced in volume and weight by fifty percent and would provide a fluid product meeting taste, consistency and nutritional requirements of the consumer.

While the present regulatory environment restricts the economic marketing of an RO filtrated milk product, given a positive environment, RO filtration could be an attractive means by which transportation costs could be reduced and efficiency increased. In the process, the dairy industry could be aligned according to competitive advantages in production. Such a realignment would allow the industry to achieve increased economic efficiency. It appears this may be of importance to the industry's long-run success.

6.2 The Model

An annual spatial equilibrium model was specified according to the market characteristics of the dairy industry and the objectives of this study. The modeled area was broken down into nine supply and ten demand regions covering 29 federal orders and 33 states. Estimated costs of applying RO filtration, transportation cost functions, supply and demand elasticities, and regional data were all incorporated into the model.

The fully specified model was then applied to establishing the potential economic feasibility and regional and market impact of RO filtration on the Class I milk market. To capture the range of possible impacts, several pricing and policy scenarios were developed. Specific scenarios were as follows: (1) three possible costs of applying RO filtration were incorporated into the base model; (2) the model was adjusted to reflect market conditions during September, when supply is low, demand is high and inter-regional shipments are greatest; (3) a significant cut in CCC purchases precipitating a drop in the support price was simulated; (4) the total removal and the realignment of Class I differentials were incorporated; (5) the impact of a fifty percent increase in transportation costs was simulated; and finally, (6) alternative supply elasticities were applied to determine the model's sensitivity to that important parameter. Solutions were then generated through the Generalized Transportation Problem microcomputer program developed by Holland and Sharples (1984) and Holland (1985).

Results from each of these alternative market scenarios were compared to their respective baseline runs on a percentage change basis. Under each scenario the primary questions addressed were (1) how supply and demand quantities were affected, (2) how the distributional pattern changed, and (3) what was the resulting impact on costs and revenues. Specific interest was paid to the regions believed to experience the greatest impact under scenario changes: Florida, Southeast, Northeast, Minnesota-Wisconsin, and Michigan.

6.3 Summary of Results

Model generated results were both insightful and, in some cases, surprising. The fully specified model generated baseline results reflecting 1985 market levels with acceptable accuracy. This provided the foundation upon which alternative scenario results were compared in order to determine the potential market impact of policy and price changes.

6.3.1 RO Filtration

When RO filtration was applied to the baseline model, regional impacts were significant. Distributional changes tended to favor the Minnesota-Wisconsin region to the detriment of the Florida, Southeast and Northeast regions. In terms of producer revenues, the overall impact of RO filtration was a significant loss in total revenues. Regionally, producers in Florida, the Southeast and Northeast suffered the greatest loss in revenues. Under each pricing scheme, the benefits of full scale adoption of RO filtration under 1985 market conditions were passed directly on to consumers. The regions which saw the greatest fall in producer prices also saw the largest fall in consumer prices.

6.3.2 September

The impact of RO filtration under September market conditions remained substantial. The Minnesota-Wisconsin region gained markets while the two southernmost regions sustained the largest declines in price. The net impact to all producers continued to be negative, however, the degree of this impact was less than experienced under the baseline 1985 scenario. Regionally, consumer and producer prices once again moved together.

6.3.3 Reduction in CCC Purchases

When CCC purchases were limited to 5 billion pounds, the M-W price dropped to $10.32. This, in turn, led to a significant decline in the weighted average Grade A market price. The inelastic nature of milk demand limited the impact of this price fall to a relatively minor change in demand; hence, the majority of the 8.2 billion pound decrease was acheived through reduced supply. Producers in the relatively high cost of production regions absorbed the greatest impact of the reduction both in terms of fallen prices and sales. The Northeast region was the only region to experience a significant increase in Class I sales but no region saw an increase in total revenues. The most significant revenue loss hit the Florida, Southeastern, Northeastern and Minnesota-Wisconsin regions.

When RO filtration was applied under this scenario, regions with relatively low Class I differentials benefited. As a result, many of the regions which suffered the largest losses under decreased CCC purchases received the greatest benefit from the adoption of RO filtration.

Specifically, model results indicate that producers in the Minnesota-Wisconsin and Michigan regions benefited significantly by the market-wide adoption of RO filtration in the face of significant reductions in CCC purchases or the M-W price. Producers in the Florida, Southeast and Northeast regions, however, experienced compound negative impacts.

6.3.4 Change in Class I Differentials

Model results under a one hundred percent removal of Class I differentials indicate that interregional shipments of Class I milk decrease and the market wide Class I price falls substantially. Class I revenues drop dramatically but surprisingly, the greatest loss is felt by the Michigan region. In contrast, the Florida region becomes an isolated market, experiencing a negligible fall in Class I price and an increase in total revenues. It appears from this that Class I differentials actually serve to subsidize exports to certain regions -- perhaps preventing local producers from supplying local Class I markets. The application of RO filtration led to a reduction in prices but no alteration in distributional patterns, as would be expected.

When 1986 differentials were substituted, revenues and export prices remained unchanged overall, but regionally, shifts occurred. The Michigan region received the greatest gain in overall Grade A price while the Florida region received the greatest loss. Regional revenue gains favored the two Upper Mid-west regions as the "export subsidy" characteristic of relative Class I differentials was enhanced.

When RO filtration was implemented, the imbalance of benefits swung even wider. The Minnesota-Wisconsin region's Class I sales increased dramatically to the detriment of the two southernmost regions, the Southern Plains and the Northeast.

6.3.5 Increased Transportation Costs

A fifty percent increase in transportation costs had the effect of altering the impact of Class I differentials. As a result, a decrease in interregional Class I shipments and an increase in intraregional sales occurred. The Florida region actually became self-sufficient while other regions imported their additional supply from closer markets. Hence, the ability of the low cost of production Upper Midwest regions to capitalize on their competitive advantage was limited. Minnesota-Wisconsin producers were most adversely affected while their counterparts in the Florida, Southeast and Northeast regions experienced a significant increase in total revenues.

Consumers paid directly for the increased cost of transportation; likewise, when RO filtration was applied they benefited directly from the reduction in transportation costs. Producer benefits from the application of RO filtration were primarily allocated to the Michigan and

Minnesota-Wisconsin regions. This suggests that, in the face of increasing transportation costs, all other factors held equal; in order for producers in those regions to maintain revenues, they may find it necessary to adopt a bulk reduction technology such as RO filtration.

6.4 Points of Caution

The model utilized to gain these insights is simplistic relative to the dairy industry itself. It can only give the theoretical solution to the spatial equilibrium model as specified. It is a short-run annual model and as such is not capable of capturing all the subtleties of the market's long-run adjustment to a new technology. The model produces an instantaneous shift to a new equilibrium position while in reality the market adjusts in a far more interactive and dynamic manner. For example, it is inevitable that policy changes would be made during transition, altering the path towards the new long-run equilibrium. Given this understanding, it would be misleading to extract any given model generated coefficient and compare it to the true value found in an isolated, dynamic Grade A market. Even with these caveats, significant insights were gained in approaching the general objectives of this research.

6.5 Conclusions

The impact of RO filtration on the Grade A milk market, as indicated by model solutions, could be significant. However, the overall impact appears to effect producers adversely while providing significant benefits to consumers. This remains true across all pricing and policy scenarios.

Economic theory suggests that RO filtration would be implemented if sufficient gains could be captured to cover all costs. Therefore, it would be necessary for consumers to properly compensate producers and for the underlying political costs to remain unprohibitive. The model can not account for these elements.

In terms of industry dynamics, market power and bargaining among producer cooperatives play a very real and important role. The industry does not operate according to perfectly competitive market theory. Recognizing this, it is reasonable to suggest that some of the benefit gained by consumers in the theoretical case could be usurped by producers. Across scenarios and regions this represents a possible average revenue gain of four percent. In an industry where profit margins are slim and producers are struggling to remain viable, this represents a significant increase. How much of that gain could be negotiated away from consumers and how it would be distributed regionally is unclear and not the subject of this research. One can merely say that under the model developed and presented within this thesis, it is not likely that RO filtration would find use within the U.S. Grade A milk market at this time. Actual long-run results would likely differ from those presented here to some unknown degree.

To summarize the implication of model results, the full scale adoption of RO filtration within the Grade A milk market would depend heavily on three related factors. First, the magnitude of the potential gain to consumers and the degree to which that gain could be transferred to producers must be large enough to instigate the necessary changes. Second, the gain captured by producers must be large enough to cover the indirect costs of policy changes (i.e. lobbying and developing new market institutions) and it must be large enough to compensate the regional losers. Third, the adoption of RO filtration would be dependent upon development of a set of mechanisms facilitating these compensatory transfers between producers.

This thesis neither addresses questions related to the social welfare and policy implications of RO filtration nor does it confront issues of market efficiency and equity. These are important areas to be researched when adoption of RO filtration is under serious consideration. This thesis merely develops and presents a model with the objective of testing that model and providing insights as to possible changes within the industry. The results obtained together with the analysis presented meet that objective.

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Allocation Provision: The FMMO accounting system whereby either Class I milk not originating from a federal order or reconstituted milk is matched in volume by "up-allocated", non-Class I milk. Such milk in excess of what is available to up-allocate is charged a Compensatory Payment equal to the local Class I differential. Together, allocation provisions and compensatory payments ensure that the cost of non federal order or reconstituted milk is at least as great as the minimum Class I price within a given federal order; thereby encouraging use of local supplies and effectively removing the incentive to reconstitution.

Blended Milk Product: A product made from a blend of fresh whole milk, water and nonfat milk powder or butter oil. Blended milk allows an area's milk supply to be stretched.

Blend Price: The price which producers receive for their Grade A milk pooled within federal orders. The blend price is a weighted average price determined according to the proportion of milk allocated to the alternative Grade A classes.

Call Provision: A FMMO provision implemented at the discretion of the Market Administrator and which forces a set amount of milk to be channeled into fluid use, in times of deficient local supply.

Capper-Volstead Act: A 1922 Federal act allowing producers to organize for the purpose of buying and selling farm products cooperatively. In the absence this legislation, producer cooperatives were subject to antitrust suits.

Casein: A protein component found naturally in milk and cheese. During the RO filtration process, casein often becomes clogged on the membrane surface, reducing the the system's effectiveness and requiring thorough cleaning of the membrane.

Classified Pricing: The pricing system under which processors regulated by federal order provisions pay for Grade A milk according to the class in which it is used.

Class I Milk: Grade A milk sold for fluid consumption in federal milk marketing orders.

Class II Milk: Grade A milk sold for use in soft manufactured products, such as sour cream, yogurt and cottage cheese, under a FMMO with three Grade A classes. Where only two classes exist, Class II comprises Grade A milk used in any form of manufacturing.

Class III Milk: Grade A milk sold in federal orders with three classes and used in the manufacturing of hard products, such as cheese, butter and milk powder.

Class I Differentials: The assessment added onto the M-W price for Grade A milk sold in federal orders and going to Class I use. Class I differentials from a price surface which increases with distance from Eau Claire Wisconsin, the base pricing point.

Commodity Credit Corporation (CCC): Government operated organization through which storeable dairy products are purchased at a set price. CCC purchases directly serve to support the market price of manufactured dairy products and indirectly support the price of all milk.

Compensatory Payments: A FMMO surcharge assessed on either Class I milk not originating from a federal order or reconstituted milk above what has been up-allocated (see Allocation Provision). The payment is equal to the local Class I differential.

Flux: The rate at which the solution passes through the membrane. The flux within an RO system is a function of total solids in solution and the pressure under which the solution flows through the system.

Formula Pricing: An institutional pricing system whereby a given commodity's price is calculated from a formula incorporating economic variables related to the commodity's value and which act as "price movers". Examples of such variables are cost indices and prices of substitute and complementary goods.

Grade A Milk: Milk meeting fluid consumption health and quality standards. Only Grade A milk is regulated under federal orders.

Grade B Milk: Milk meeting health and quality standards for manufactured use but not for fluid use.

M-W Price Series: The USDA estimated average price paid per hundredweight of milk, f.o.b., by manufacturing plants in the states of Minnesota and Wisconsin.

Osmosis: The naturally occurring process in all organisms where water and a solution are separated by a membrane. Under osmosis, the water passes through the membrane to dilute the solution until the pressure exerted on both sides of the membrane are equal.

Osmotic Pressure: The force exerted by a solution against the membrane system. Each solution exerts a different osmotic pressure.

Over-Order Premium: An additional charge negotiated by producer cooperatives and paid by handlers for milk going towards Class I use. This premium is often associated with the costs of marketing services such as transportation, full-supply agreements, and handling of Class III milk.

Permeate: The liquid which has passed through the membrane within the reverse osmosis process.

Phase Change: A phase change occurs when a discrete homogeneous characteristic of the solution is separated from the rest of the solution by some external force. For example, a phase change can be evidenced by altered taste, consistency, color or odor of the solution.

Price Linkage: The collection of marketing variables which act as a link between regional equilibrium price levels. Examples of these linkage variables are transportation costs, over-order premiums, and Class I differentials between regions.

Retentate: The substance remaining after a removal process, such as RO filtration, is complete.

Reverse Osmosis: When sufficient pressure is applied to the solution to offset its osmotic pressure. Under reverse osmosis, the water existing within the solution is forced through the membrane leaving a more concentrated solution behind.

Reverse Osmosis (RO) Filtration: A pressure driven membrane separation technique applied to liquid substances such as milk and cheese whey. The primary difference between RO filtration and ultrafiltration is the finer degree of particle separation obtained with RO.

Spatial Equilibrium: The achievement of an equilibrium price surface, across regions, at which regional equilibrium price levels differ by the price linkage and the total quantity produced across all markets is exactly equal to the total quantity demanded.

Ultrafiltration (UF): A pressure driven membrane separation technique applied to liquids, such as milk, for water removal.

Whey: The part of milk remaining after the cheese making process.

APPENDICIES

APPENDIX A

SUPLEMENTAL EQUATIONS TO CHAPTER TWO

The market variables which exist within the dairy industry, as outlined in Chapter Two, are complex and difficult to model in general terms. The pricing mechanisms and relationships which where discussed can be placed within the general fluid milk marketing model as follows.

* Processors Price:

The Class I price in any region i is:

$$pI_i = pM\text{-}W_i + D_i + O_i$$

where, pI_i = the Class I price

$pIII_i$ = the Manufactured goods price (lagged two months)

D_i = the Class I differential

O_i = the region's average over-order premium

The Class III price for any region i is approximately:

$$pIII_i = pM\text{-}W + V$$

where V = the weighted change in gross value of milk used to make chedder cheese and butter/nonfat dry milk.

* Producer price:

For each region i the blend price is:

$$pB_i = (pI_i QI_i + pIII_i QIII_i)/(QI_i + QIII_i)$$

where: $QI_i / (QI_i + QIII_i)$ = Class I utilization ratio, U_i, in region i; thus, $pB_i = pI_i * UI_i + pIII_i * UIII_i$ for any region i.

* Demand Functions

Demand for Class I use: $D^I = a + bP^I$

Demand for Class III use: $D^{III} = c + dP^{III}$

Demand for Grade B milk: $D^b = e + fP^b$

* Supply Functions

Supply of Grade A milk: $S^a = a + bP^B$

Supply of Grade B milk: $S^b = c + dP^b$

* Equilibrium occurs where total supply equals total demand across all regions.

APPENDIX B

SUPPLEMENTAL EQUATIONS TO CHAPTER TWO

Table B.1. Regionally Adjusted 1985 Annual Average Supply, Demand, Price and Class I Differential Levels

Region	Quantity Supplied	Quantity Demanded	Price	Class I Differentials 1985	1986
	(mil. cwt)		(dollars per cwt.)		
1	2,021	2,310	14.09	3.03	4.27
2	2,785	3,454	13.30	2.48	3.30
3	6,369	5,854	12.48	2.20	3.07
4	6,890	5,046	12.78	1.44	1.69
5	5,259	4,438	12.80	1.94	2.52
6	6,618	4,550	12.70	1.68	2.03
7	24,376	11,843	12.00	2.79	3.05
8	24,720	2,323	12.60	1.20	1.31
9	5,176	2,318	12.28	1.60	1.75
10	na	42,079	na	na	na

Table B.2. Regionally Adjusted Demand, Supply and Revised Supply Elasticities

Region	Supply	Demand	Revised Supply
1	.811	-.113	.500
2	.805	-.100	.496
3	1.113	-.091	.775
4	.567	-.078	.183
5	.793	-.089	.468
6	.584	-.078	.172
7	.680	-.078	.133
8	.300	-.057	0
9	.268	-.078	0

Table B.3. Regional Weighted Average Class I Utilzation, Population and Per Capita Consumption, 1985 Adjusted

Region	Class I Utilization	Population	Per Capita Consumption
1	88	11,215	206
2	79	15,923	217
3	64	26,345	222
4	45	19,517	258
5	71	20,463	217
6	58	18,234	250
7	45	55,085	215
8	17	8,966	259
9	42	9,100	255

Table B.4. Mileage Matrix Between all Supply and Demand Regions, One-Way Miles

	Supply								
Demand	1	2	3	4	5	6	7	8	9
1	30	488	1,200	1,322	840	1,058	1,261	1,486	1,229
2	385	86	892	932	463	732	985	1,090	838
3	1,048	738	93	917	1,010	1,122	1,628	1,250	1,181
4	1,289	829	762	122	604	519	986	335	280
5	684	377	1,146	1,042	210	898	564	948	624
6	1,018	655	1,004	609	355	50	584	698	276
7	1,168	913	1,491	1,108	708	504	128	1,081	613
8	1,498	1,045	1,067	387	811	622	1,153	0	505
9	1,256	813	1,158	644	551	223	760	572	55

APPENDIX C
MODEL GENERATED SOLUTIONS: ALL REGIONS ALL RUNS

Run Title	Description
BASE	Initial annual run serving as the standard for comparisons. 1985 market conditions with no RO applied.
BRO3	BASE specification with RO incorporated at a cost of $.30/cwt.
BRO9	BASE specification with RO incorporated at a cost of $.90/cwt.
BRO175	BASE specification with RO incorporated at a cost of $1.75/cwt.
CCC	BASE model adjusted for reduced CCC purchases. An import quota was placed on Class III milk, reducing purchased by 444 million pounds.
CCCRO9	CCC specification with RO incorporated at a cost of $.90/cwt.
ND	BASE model adjusted for the full removal of Class I differentials. No RO applied.
NDRO9	ND specification with RO incorporated at a cost of $.90/cwt
NDCCC	ND specification with reduced CCC purchases
NDCCRO9	ND specification with reduced CCC purchases and RO incorporated at $.90/cwt
D86	BASE model with 1986 Class I differentials substituted for the 1985 levels. No RO applied.
D86RO9	D86 specification with RO incorporated at a cost of $.90/cwt.

Figure C.1. (con't)

TC2	BASE model with a fifty percent increase in transportation costs incorporated. No RO applied.
TC2RO9	TC2 specification with RO incorporated at a cost of$.90/cwt.
SEPT	Model run generated based on September 1985 market conditions. Serves as a base upon which RO feasibility during month when shipments are high. No RO applied.
SRO3	SEPT specification with RO incorporated at a cost of $.30/cwt.
SRO9	SEPT specification with RO incorporated at a cost of $.90/cwt.
SRO175	SEPT specification with RO incorporated at a cost of $1.75/cwt.
HUYOO	Base model with Huy's adjusted supply elasticities incorporated (region 8 and 9's elasticities set equal to zero)
HUYO5	HUY specification with region 9's supply elasticity set at .05
HUY10	HUY specification with region 9's supply elasticity set at .10
HUY15	HUY specification with region 9's supply elasticity set at .15

Figure C.1. Reference to model generated solution titles and discriptions

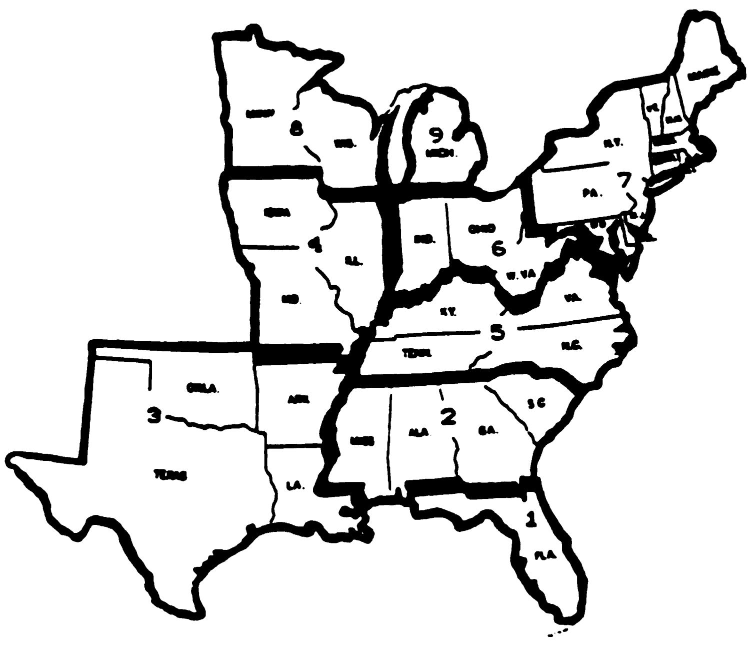

Figure C.2. Delineation of model regions

Region	FMMO's Encompassed	States Encompassed	Demand Center	Supply Center
1	Upper Florida Tampa Bay SE Florida	Florida	Lake Wales,FL	Lakeland,FL
2	AL-West FL Georgia New Orleans-MS	Alabama Georgia Mississippi South Carolina	Macon,GA	Newnan,GA
3	Central AR Greater LA Lubbock TX Panhandle SW Plains Texas	Arkansas Louisiana Oklahoma Texas	Lufkin,TX	Greenville,TX
4	Central IL Iowa Southern IL St.Louis-Ozarks	Illinois Iowa Missouri	Galesberg,IL	Ottumwa,IA
5	Louis-Lex-Evan Memphis Nashville Puducah TN Valley	Kentucky North Carolina Tennessee Virginia	Mount Airy,NC	Hazard,KY
6	Indiana Ohio Valley	Indiana Ohio West Virginia	Newark,OH	Mansfield,OH
7	Mid Atlantic New England NY-NJ E.OH-W.PA	Connecticut Delaware Maine Maryland Massachusetts New Hampshire New Jersey New York Pennsylvania Rhode Island Vermont	Port Jarvis,NY	Oneonta,NY
8	Chicago Reg Upper Mid-West	Minnesota Wisconsin	Eau Claire,WI	Eau Claire,WI
9	S. Michigan	Michigan	Highland,MI	Lansing,MI
10	All of above	All of above	All of above	------

Figure C.3. Federal milk marketing order (FMMO's) and states encompassed within regions, regional demand and regional supply centers

Table C.1. Import/Export Quantities and Prices for All Regions Under 1985 Market Data (BASE)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt.)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	18.18	17.08	1	18.18	17.44
	10	2.02	11.78	2	3.34	17.44
	Total[1]	20.20		Total[1]	23.05	
2	1	3.35	15.72	2	21.68	16.46
	2	21.68	15.72	4	8.99	16.46
	10	2.79	11.78	5	3.72	16.46
	Total	27.81		Total	34.38	
3	3	58.19	14.86	3	58.19	15.65
	10	3.67	11.78	Total	58.19	
	Total	64.56				
4	2	8.99	13.31	4	50.52	14.00
	4	50.52	13.31	Total	50.52	
	10	6.89	11.78			
	Total	66.40				
5	2	3.72	14.83	5	44.05	15.91
	5	44.05	14.83	Total	44.05	
	10	5.26	11.78			
	Total	53.03				
6	1	1.52	14.06	6	45.45	14.56
	6	45.45	14.06	Total	45.45	
	7	11.83	14.06			
	10	6.62	11.78			
	Total	65.42				
7	7	83.05	14.57	6	11.83	15.29
	10	158.27	11.78	7	83.05	15.29
	Total	241.32		9	23.23	15.29
				Total	118.12	
8	8	23.31	12.98	8	23.31	12.99
	10	219.50	11.78	Total	23.31	
	Total	242.81				
9	7	23.23	13.67	9	23.14	14.20
	9	23.14	13.67	Total	23.14	
	10	5.18	11.78			
	Total	51.55				

[1] Totals may not equal the sum of the parts due to rounding

Table C.2. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with RO Applied at $.30/cwt (BRO3)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	10	18.03	11.78	8	23.46	14.75
	Total[1]	18.03		Total[1]	23.46	
2	10	25.74	11.78	8	34.83	14.44
	Total	25.74		Total	34.83	
3	3	54.25	14.04	3	54.25	14.83
	10	6.37	11.78	4	4.24	14.83
	Total	60.62		Total	58.49	
4	3	.34	13.23	8	50.56	13.85
	10	61.94	11.78	Total	50.56	
	Total	66.17				
5	5	44.41	13.73	5	44.41	14.56
	10	5.47	11.78	Total	44.41	
	Total	49.88				
6	6	45.52	13.75	6	45.52	14.25
	7	12.46	46.75	Total	45.52	
	10	6.62	11.78			
	Total	64.60				
7	10	241.37	11.78	6	12.46	14.11
	Total	241.37		8	83.24	14.11
				9	23.15	14.11
				Total	118.85	
8	1	23.46	12.99	8	23.31	12.99
	2	34.83	12.99	Total	23.31	
	4	50.56	12.99			
	7	83.24	12.99			
	8	23.31	12.99			
	10	27.44	11.78			
	Total	242.83				
9	7	23.15	13.60	9	23.15	14.13
	9	23.15	13.60	Total	23.15	
	10	5.18	11.78			
	Total	51.48				

[1] Totals may not equal the sum of the parts due to rounding

Table C.3. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with RO Applied at $.90/cwt (BRO9)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	16.17	14.98	1	16.17	15.35
	10	2.02	11.78	8	7.20	15.35
	Total[1]	18.19		Total[1]	23.37	
2	2	23.00	14.30	2	23.01	15.04
	10	2.79	11.78	8	11.69	15.04
	Total	25.79		Total	34.69	
3	3	57.14	14.64	3	57.14	15.42
	10	6.37	11.78	4	1.13	15.42
	Total	63.51		Total	58.27	
4	3	1.13	13.23	4	50.54	13.92
	4	50.54	13.23	Total	50.54	
	10	14.50	11.78			
	Total	66.17				
5	5	44.35	13.73	5	44.35	14.80
	10	5.53	11.78	Total	44.35	
	Total	49.88				
6	6	45.52	13.75	6	45.52	14.25
	7	12.45	13.75	Total	45.52	
	10	6.62	11.78			
	Total	64.59				
7	10	241.35	11.78	6	12.45	14.71
	Total	241.35		8	82.87	14.71
				9	23.15	14.71
				Total	118.48	
8	1	7.20	12.99	8	23.31	12.99
	2	11.69	12.99	Total	23.31	
	7	82.87	12.99			
	8	23.31	12.99			
	10	117.76	11.78			
	Total	242.82				
9	7	23.15	13.60	9	23.15	14.13
	9	12.15	13.60	Total	23.15	
	10	5.18	11.78			
	Total	51.48				

[1] Totals may not equal the sum of the parts due to rounding

Table C.4. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with RO Filtration Applied at $1.75/cwt (BRO175)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	16.98	15.83	1	16.98	16.20
	10	2.02	11.78	8	6.26	16.20
	Total[1]	19.00		Total[1]	23.24	
2	2	24.21	15.15	2	24.21	15.89
	10	2.79	11.78	5	1.95	15.89
	Total	27.00		8	8.35	15.89
				Total	34.51	
3	3	58.19	14.86	3	58.19	15.65
	10	6.37	11.78	Total	58.19	
	Total	64.56				
4	4	50.54	13.22	4	50.54	13.92
	10	15.62	11.78	Total	50.54	
	Total	66.16				
5	2	1.95	14.27	5	44.20	15.38
	5	44.20	14.27	Total	44.20	
	10	5.26	11.78			
	Total	51.41				
6	6	45.45	14.06	6	45.45	14.56
	7	13.36	14.06	Total	45.45	
	10	6.62	11.78			
	Total	65.42				
7	7	81.52	14.57	6	13.36	15.29
	10	159.81	11.78	7	81.52	15.29
	Total	241.33		9	23.23	15.29
				Total	118.12	
8	1	6.26	12.98	8	23.31	12.99
	2	8.35	12.98	Total	23.31	
	8	23.31	12.98			
	10	204.91	11.78			
	Total	242.81				
9	7	23.23	13.67	9	23.14	14.20
	9	23.14	13.67	Total	23.14	
	10	5.18	11.78			
	Total	51.55				

[1] Totals may not equal the sum of the parts due to rounding

Table C.5. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with CCC Purchases Reduced and no RO Applied (CCC)

		Exports			Imports	
Region	Importer	Quantity	Price	Exporter	Quantity	Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	16.78	15.62	1	16.78	15.99
	10	2.02	10.32	6	6.49	15.99
	Total[1]	18.80		Total[1]	23.27	
2	2	23.11	14.38	2	23.11	15.12
	10	2.79	10.32	4	3.28	15.12
	Total	25.89		9	8.29	15.12
				Total	34.68	
3	3	56.67	14.54	3	56.67	15.33
	10	6.37	10.32	4	1.64	15.33
	Total	63.04		Total	58.30	
4	2	3.28	11.96	4	50.89	12.66
	3	1.64	11.96	Total	50.89	
	4	50.89	11.96			
	10	6.89	10.32			
	Total	62.70				
5	5	44.37	13.64	5	44.37	14.71
	10	5.26	10.32	Total	44.37	
	Total	49.63				
6	1	6.49	12.60	6	45.81	13.10
	6	45.81	12.60	Total	45.81	
	7	2.58	12.60			
	10	6.62	10.32			
	Total	61.49				
7	7	103.15	13.12	6	2.58	13.83
	10	121.84	10.32	7	103.15	13.83
	Total	224.99		9	13.30	13.83
				Total	119.03	
8	8	23.45	11.53	8	23.45	11.53
	10	211.53	10.32	Total	23.45	
	Total	234.98				
9	2	8.29	12.21	9	23.33	12.74
	7	13.30	12.21	Total	23.33	
	9	23.33	12.21			
	10	5.18	10.32			
	Total	50.09				

[1] Totals may not equal the sum of the parts due to rounding

Table C.6. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with Reduced CCC Purchases and RO Filtration Applied at $.90/cwt (CCCRO9)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	15.20	13.97	1	15.20	14.34
	10	2.02	10.32	8	8.32	14.34
	Total[1]	17.22		Total[1]	23.52	
2	2	21.57	13.29	2	21.57	14.03
	10	2.79	10.32	8	13.35	14.03
	Total	24.35		Total	34.92	
3	3	52.67	13.72	3	52.67	14.50
	10	6.37	10.32	4	5.93	14.50
	Total	59.04	10.32	Total	58.60	
4	3	5.93	12.30	4	50.80	12.99
	4	50.80	12.30	Total	50.80	
	10	6.89	10.32			
	Total	63.62				
5	5	43.11	13.19	5	43.11	14.27
	10	5.26	10.32	8	1.38	14.27
	Total	48.37		Total	44.49	
6	6	45.77	12.74	6	45.77	13.24
	7	9.48	12.74	Total	45.77	
	10	6.62	10.32			
	Total	61.87				
7	10	230.04	10.32	6	9.48	13.70
	Total	230.04		8	87.61	13.70
				9	22.01	13.70
				Total	119.11	
8	1	8.32	11.98	8	23.40	11.98
	2	13.35	11.98	Total	23.40	
	5	1.38	11.98			
	7	87.61	11.98			
	8	23.40	11.98			
	10	103.33	10.32			
	Total	237.40				
9	7	22.01	12.59	9	23.28	13.12
	9	23.28	12.59	Total	23.28	
	10	5.18	10.32			
	Total	50.47				

[1] Totals may not equal the sum of the parts due to rounding

Table C.7. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with Total Removal of Class I Differentials and no RO Filtration Applied (ND)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	20.58	16.15	1	20.58	16.52
	10	2.02	11.78	6	2.07	16.52
	Total[1]	22.60		Total[1]	22.65	
2	2	26.87	14.37	2	26.87	15.11
	10	2.79	11.78	5	3.8	15.11
	Total	29.66		6	3.39	15.11
				Total	34.07	
3	3	58.14	12.62	3	58.14	13.41
	10	6.37	11.78	Total	58.14	
	Total	64.51				
4	4	50.55	11.78	4	50.55	12.47
	10	15.30	11.78	Total	50.55	
	Total	65.85				
5	2	3.80	12.94	5	44.00	14.02
	5	44.00	12.94	Total	44.00	
	10	5.26	11.78			
	Total	53.06				
6	1	2.07	11.78	6	45.62	12.28
	2	3.39	11.78	Total	45.62	
	6	45.62	11.78			
	10	12.30	11.78			
	Total	63.38				
7	7	118.04	11.78	7	118.04	12.50
	10	122.70	11.78	Total	118.04	
	Total	240.75				
8	8	23.32	11.78	8	23.32	11.79
	10	219.07	11.78	Total	23.32	
	Total	242.39				
9	9	23.18	11.78	9	23.18	12.32
	10	28.02	11.78	Total	23.18	
	Total	51.20				

[1] Totals may not equal the sum of the parts due to rounding

Table C.8. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with Total Removal of Class I Differentials and RO Filtration Applied at $.90/cwt (NDRO9)

		Exports			Imports	
Region	Importer	Quantity	Price	Exporter	Quantity	Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	19.40	15.13	1	19.40	15.50
	10	2.02	10.32	6	3.45	15.50
	Total[1]	21.42		Total[1]	22.84	
2	2	25.16	13.35	2	25.15	14.09
	10	2.79	10.32	5	4.86	14.09
	Total	27.94		6	4.32	14.09
				Total	34.33	
3	3	58.14	12.62	3	58.14	13.41
	10	6.37	10.32	Total	58.14	
	Total	64.51				
4	4	50.98	10.40	4	50.98	11.09
	10	10.63	10.32	Total	50.98	
	Total	61.61				
5	2	4.86	11.92	5	39.62	13.00
	5	39.62	11.92	7	4.70	13.00
	10	5.26	10.32	Total	44.32	
	Total	49.74				
6	1	3.45	10.76	6	45.90	11.26
	2	4.32	10.76	Total	45.90	
	6	45.90	10.76			
	10	6.62	10.32			
	Total	60.29				
7	5	4.69	10.39	7	119.11	11.11
	7	119.11	10.39	Total	119.11	
	10	97.78	10.32			
	Total	221.59				
8	8	23.46	10.40	8	23.46	10.40
	10	210.76	10.32	Total	23.46	
	Total	234.27				
9	9	23.38	10.40	9	23.38	10.93
	10	26.25	10.32	Total	23.38	
	Total	49.64				

[1] Totals may not equal the sum of the parts due to rounding

Table C.9. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with Removal of Class I Differentials and Reduced CCC Purchases (NDCCC)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	18.88	14.69	1	18.88	15.05
	10	2.02	11.78	6	4.05	15.05
	Total[1]	20.90		Total[1]	22.93	
2	2	25.59	13.61	2	25.59	14.35
	10	2.79	11.78	5	1.73	14.35
	Total	28.37		6	6.94	14.35
				Total	34.26	
3	3	58.14	12.62	3	58.14	13.41
	10	6.37	11.78	Total	58.14	
	Total	64.51				
4	4	50.55	11.78	4	50.55	12.48
	10	15.30	11.78	Total	50.55	
	Total	65.86				
5	2	1.73	12.37	5	44.18	13.44
	5	44.18	12.37	Total	44.18	
	10	5.26	11.78			
	Total	51.17				
6	1	4.05	11.78	6	45.62	12.28
	2	6.94	11.78	Total	45.62	
	6	45.62	11.78			
	10	6.78	11.78			
	Total	63.39				
7	7	118.04	11.78	7	118.04	12.50
	10	122.73	11.78	Total	118.04	
	Total	240.77				
8	8	23.32	11.78	8	23.32	11.79
	10	219.08	11.78	Total	23.32	
	Total	242.40				
9	9	23.18	11.78	9	23.19	12.32
	10	28.03	11.78	Total	23.19	
	Total	51.21				

[1] Totals may not equal the sum of the parts due to rounding

Table C.10. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with Class I Differential Removed, CCC Purchases Reduced and RO Filtration Applied at $.90/cwt (NDCCRO9)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	17.72	13.69	1	17.72	14.06
	10	2.02	10.32	6	5.39	14.06
	Total[1]	19.74		Total[1]	23.11	
2	2	23.91	12.61	2	23.91	13.35
	10	2.79	10.32	6	2.46	13.35
	Total	26.70		9	8.16	13.35
				Total	34.52	
3	3	58.14	12.62	3	58.14	13.41
	10	6.37	10.32	Total	58.14	
	Total	64.51				
4	4	50.93	10.56	4	50.93	11.25
	10	11.18	10.32	Total	50.93	
	Total	62.11				
5	5	43.71	11.69	5	43.81	12.76
	10	5.26	10.32	7	.68	12.76
	Total	48.97		Total	44.39	
6	1	5.37	10.79	6	45.90	11.29
	2	2.46	10.79	Total	45.90	
	6	45.90	10.79			
	10	6.62	10.32			
	Total	60.36				
7	5	.68	10.56	7	118.99	11.28
	7	118.99	10.56	Total	118.99	
	10	104.19				
	Total	223.86				
8	8	23.45	10.56	8	23.45	10.57
	10	211.75	10.32	Total	23.45	
	Total	235.19				
9	2	8.16	10.56	9	23.36	11.09
	9	23.36	10.56	Total	23.36	
	10	18.31				
	Total	49.82				

[1] Totals may not equal the sum of the parts due to rounding

Table C.11. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with 1986 Class I Differentials and no RO Applied (D86)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	17.31	16.17	7	17.31	16.54
	10	2.02	11.78	2	5.87	16.54
	Total[1]	19.33		Total[1]	23.18	
2	1	5.87	15.24	2	18.46	15.98
	2	18.46	15.24	5	2.96	15.98
	10	2.79	11.78	8	13.07	15.98
	Total	27.12		Total	34.49	
3	3	58.19	14.86	6	58.19	15.65
	10	6.37	11.78	Total	58.19	
	Total	64.56				
4	4	50.48	13.47	4	50.48	14.16
	10	16.37	11.78	Total	50.48	
	Total	66.84				
5	2	2.96	14.59	5	44.12	15.66
	5	44.12	14.59	Total	44.12	
	10	5.26	11.78			
	Total	52.34				
6	6	45.40	14.23	6	45.40	14.73
	7	13.85	14.23	Total	45.40	
	10	6.62	11.78			
	Total	65.88				
7	7	80.45	14.83	6	13.85	15.55
	10	163.77	11.78	7	80.45	15.55
	Total	244.22		9	23.65	15.55
				Total	177.96	
8	2	13.07	13.09	8	23.30	13.10
	8	23.30	13.09	Total	23.30	
	10	207.03	11.78			
	Total	243.39				
9	7	23.65	14.04	9	23.09	14.57
	9	23.09	14.04	Total	23.09	
	10	5.18	11.78			
	Total	51.92				

[1] Totals may not equal the sum of the parts due to rounding

Table C.12. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with 1986 Class I Differentials and RO Applied at $.90/cwt (D86RO9)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	10	19.22	11.78	8	23.45	14.79
	Total[1]	19.22		Total[1]	23.45	
2	10	26.90	11.78	8	34.73	14.90
	Total	26.90		Total	34.73	
3	10	64.52	11.78	4	10.75	15.48
	Total	64.52		8	47.50	15.48
				Total	58.25	
4	3	10.75	13.89	4	50.36	14.58
	4	50.36	13.89	Total	50.36	
	10	6.89	11.78			
	Total	68.00				
5	5	33.07	14.30	5	33.07	15.37
	10	18.45	11.78	8	11.13	15.37
	Total	51.52		Total	44.19	
6	6	45.44	14.07	6	45.44	14.57
	7	13.39	14.07	Total	45.44	
	10	6.62	11.78			
	Total	65.45				
7	10	244.22	11.78	6	13.39	15.12
	Total	244.22		8	81.10	15.12
				9	23.74	15.12
				Total	118.22	
8	1	23.45	13.55	8	23.25	13.56
	2	34.73	13.55	Total	23.25	
	3	47.50	13.55			
	5	11.13	13.55			
	7	81.10	13.55			
	8	23.25	13.55			
	10	24.72	11.78			
	Total	245.88				
9	7	23.74	14.11	9	23.08	14.65
	9	23.08	14.11	Total	23.08	
	10	5.18	11.78			
	Total	51.99				

[1] Totals may not equal the sum of the parts due to rounding

Table C.13. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with Transportation Costs Doubled and no RO Filtration Applied (TC2)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	19.66	18.63	1	19.66	19.17
	10	2.02	11.78	2	3.12	19.17
	Total[1]	21.68		Total[1]	22.78	
2	1	3.12	16.32	2	22.75	17.42
	2	22.75	16.32	5	11.42	17.42
	10	2.79	11.78	Total	34.17	
	Total	28.65				
3	3	58.06	14.83	3	58.06	16.01
	10	6.37	11.78	Total	58.06	
	Total	64.43				
4	4	50.45	13.22	4	50.45	14.26
	10	15.71	11.78	Total	50.45	
	Total	66.16				
5	2	11.42	14.72	5	36.01	16.32
	5	36.01	14.72	7	7.93	16.32
	10	5.26	11.78	Total	43.94	
	Total	52.69				
6	6	45.53	13.46	6	45.53	14.21
	10	18.25	11.78	Total	45.53	
	Total	63.81				
7	5	7.93	14.57	7	117.89	15.65
	7	117.89	14.57	Total	117.89	
	10	115.50	11.78			
	Total	241.32				
8	8	23.28	12.98	8	23.28	13.24
	10	219.52	11.78	Total	23.28	
	Total	242.81				
9	9	23.14	13.38	9	23.14	14.18
	10	28.12	11.78	Total	23.14	
	Total	51.26				

[1] Totals may not equal the sum of the parts due to rounding

Table C.14. Import/Export Quantities and Prices for All Regions Under 1985 Market Data with Transportation Costs Increased Fifty Percent and RO Filtration Applied at $.90/cwt (TC2R09)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	17.57	16.44	1	17.57	16.99
	10	2.02	11.78	5	2.32	16.99
	Total[1]	19.59		8	3.[1]23	16.99
				Total	23.12	
2	2	24.21	15.15	2	24.21	16.26
	10	2.79	11.78	4	8.92	16.26
	Total	27.00		8	1.30	16.26
				Total	34.43	
3	3	58.06	14.83	3	58.06	16.01
	10	6.37	11.78	Total	58.06	
	Total	64.43				
4	2	8.92	13.26	4	50.44	14.29
	4	50.44	13.26	Total	50.44	
	10	6.89	11.78			
	Total	66.25				
5	1	2.32	14.34	5	44.04	15.94
	5	44.04	14.34	Total	44.04	
	10	5.26	11.78			
	Total	51.61				
6	6	45.37	14.10	6	45.37	14.85
	7	13.55	14.10	Total	45.37	
	10	6.62	11.78			
	Total	65.54				
7	7	80.89	14.57	6	13.55	15.65
	10	160.44	11.78	7	80.89	15.65
	Total	241.33		9	23.45	15.65
				Total	117.89	
8	1	3.23	12.98	8	23.28	13.24
	2	1.30	12.98	Total	23.28	
	8	23.28	12.98			
	10	214.99	11.78			
	Total	242.81				
9	7	23.45	13.83	9	23.08	14.63
	9	23.08	13.83	Total	23.08	
	10	5.18	11.78			
	Total	51.71				

[1] Totals may not equal the sum of the parts due to rounding

Table C.15. Import/Export Quantities and Prices for All Regions Under September 1985 Market Data with no RO Filtration Applied (SEPT)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	1336.19	16.13	1	1336.19	16.50
	10	151.58	11.78	6	717.19	16.50
	Total[1]	1487.76		Total[1]	2053.37	
2	2	1893.81	14.90	2	1893.81	15.64
	10	212.97	11.78	6	244.08	15.64
	Total	2106.78		9	867.55	15.64
				Total	3005.44	
3	3	5020.39	15.02	3	5020.39	15.80
	10	507.86	11.78	Total	5020.39	
	Total	5528.25				
4	4	4677.66	12.54	4	4677.66	13.23
	10	1005.51	11.78	Total	4677.66	
	Total	5683.17				
5	5	3962.73	14.21	5	3962.73	15.28
	10	436.19	11.78	9	15.68	15.28
	Total	4398.92		Total	3978.41	
6	1	717.19	13.12	6	3886.22	13.62
	2	244.08	13.12	Total	3886.22	
	6	3886.22	13.12			
	7	16.38	13.12			
	10	554.15	11.78			
	Total	5418.02				
7	7	9819.00	13.89	6	16.38	14.31
	10	9947.47	11.78	7	9819.00	14.61
	Total	19766.47		Total	9835.38	
8	8	1910.32	12.30	8	1910.32	12.31
	10	17609.27	11.78	Total	1910.32	
	Total	19519.60				
9	2	867.55	12.70	9	1926.36	13.24
	5	15.68	12.70	Total	1926.36	
	9	1926.36	12.70			
	10	1512.84	11.78			
	Total	4322.42				

[1] Totals may not equal the sum of the parts due to rounding

Table C.16. Import/Export Quantities and Prices for All Regions Under September 1985 Market Data with RO Filtration Applied at $.30/cwt (SRO3)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	10	1336.73	11.78	6	873.78	14.10
	Total[1]	1336.73		8	1213.54	14.10
				Total[1]	2087.33	
2	10	1954.54	11.78	8	3042.26	13.79
	Total	1954.54		Total	3042.26	
3	3	4349.02	13.36	3	4319.02	14.15
	10	507.86	11.78	4	726.30	14.15
	Total	4856.88		Total	5075.32	
4	3	726.30	12.55	8	4679.28	13.17
	10	4958.16	11.78	Total	4679.28	
	Total	5684.50				
5	5	3719.34	13.22	5	3719.34	14.06
	10	436.19	11.78	8	290.17	14.06
	Total	4155.53		Total	4009.50	
6	1	873.78	12.79	6	3893.52	13.29
	6	3893.52	12.79	Total	3893.52	
	7	18.70	12.79			
	10	554.15	11.78			
	Total	5340.15				
7	7	9882.00	13.90	6	18.70	13.11
	10	9889.47	11.78	7	9882.00	14.56
	Total	19771.47		Total	9900.70	
8	1	1213.54	12.31	8	1910.28	12.31
	2	3042.26	12.31	Total	1910.28	
	4	4679.28	12.31			
	5	290.17	12.31			
	8	1910.28	12.31			
	10	8386.42	11.78			
	Total	19524.95				
9	9	1926.30	12.71	9	1926.30	13.24
	10	2396.58	11.78	Total	1926.30	
	Total	4322.88				

[1] Totals may not equal the sum of the parts due to rounding

Table C.17. Import/Export Quantities and Prices for All Regions Under September 1985 Market Data with RO Applied at $.90/cwt (SR09)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	1198.83	14.29	1	1198.83	14.65
	10	151.58	11.78	6	880.64	14.65
	Total[1]	1350.41		Total[1]	2079.47	
2	2	1752.49	13.65	2	1752.49	14.39
	10	212.97	11.78	8	1277.81	14.39
	Total	1965.46		Total	3030.30	
3	3	4621.51	14.04	3	4621.51	14.82
	10	507.86	11.78	4	431.52	14.82
	Total	5129.37		Total	5053.02	
4	3	431.52	12.62	4	4675.63	13.31
	4	4675.63	12.62	Total	4675.63	
	10	594.80	11.78			
	Total	5701.94				
5	5	3808.49	13.58	5	3808.49	14.66
	10	426.19	11.78	8	185.82	14.66
	Total	4244.69		Total	3994.32	
6	1	880.64	12.75	6	3894.53	13.25
	6	3894.53	13.75	Total	3894.53	
	10	554.15	11.78			
	Total	5329.32				
7	7	9882.00	13.90	7	9882.00	14.61
	10	9887.93	11.78	Total	9882.00	
	Total	19769.93				
8	2	1277.81	12.31	8	1910.29	12.31
	5	185.82	12.31	Total	1910.29	
	8	1910.29	12.31			
	10	16147.29	11.78			
	Total	19521.22				
9	9	1926.32	12.71	9	1926.31	13.24
	10	2396.42	11.78	Total	1926.31	
	Total	4322.73				

[1] Totals may not equal the sum of the parts due to rounding

Table C.18. Import/Export Quantities and Prices for All Regions Under September 1985 Market Data with RO Filtration Applied at $1.75/cwt (SRO175)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	1262.02	15.13	1	1262.02	15.50
	10	151.58	11.78	6	805.44	15.50
	Total[1]	1413.60		Total[1]	2067.47	
2	2	1848.74	14.50	2	1848.74	15.24
	10	212.97	11.78	8	1164.63	15.24
	Total	2061.71		Total	3013.37	
3	3	4936.65	14.81	3	4936.65	15.60
	10	507.86	11.78	4	90.58	15.60
	Total	5444.51		Total	5027.24	
4	3	90.58	12.54	4	4677.62	13.24
	4	4677.62	12.54	Total	4677.62	
	10	915.28	11.78			
	Total	5683.49				
5	5	3963.04	14.21	5	3963.04	15.28
	10	436.19	11.78	9	15.33	15.28
	Total	4399.23		Total	3978.37	
6	1	805.44	12.74	6	3894.59	13.24
	6	3894.59	12.74	Total	3894.59	
	10	628.63	11.78			
	Total	5328.66				
7	7	9882.00	13.89	7	9882.00	14.61
	10	9885.70	11.78	Total	9882.00	
	Total	19767.70				
8	2	1164.63	12.30	8	1910.31	12.31
	8	1910.31	12.30	Total	1910.31	
	10	16445.24	11.78			
	Total	19520.17				
9	5	15.33	12.70	9	1926.34	13.24
	9	1926.34	12.70	Total	1926.34	
	10	2380.86	11.78			
	Total	4322.53				

[1] Totals may not equal the sum of the parts due to rounding

Table C.19. Import/Export Quantities and Prices for All Regions Under Huy's New Supply Elasticities with Regions 9's Elasticity Set Equal to .00, *ceteris paribus* (HUYOO)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	18.14	17.05	1	18.14	17.42
	10	2.02	10.32	2	4.91	17.42
	Total[1]	20.16		Total[1]	23.05	
2	1	4.91	15.69	2	20.16	16.43
	2	20.16	15.69	4	10.69	16.43
	10	2.79	10.32	5	3.54	16.43
	Total	27.85		Total	34.39	
3	3	58.16	14.94	3	58.16	15.73
	10	6.37	10.32	Total	58.16	
	Total	64.53				
4	2	10.69	13.28	4	706.08	13.97
	4	50.53	13.28	Total	706.08	
	10	6.89	10.32			
	Total	68.11				
5	2	3.54	14.81	5	44.06	15.88
	5	44.06	14.81	Total	44.06	
	10	5.26	10.32			
	Total	52.86				
6	6	45.45	14.06	6	45.45	14.55
	7	13.84	14.06	Total	45.45	
	10	6.62	10.32			
	Total	65.90				
7	7	80.96	14.57	6	13.84	15.29
	10	162.29	10.32	7	80.96	15.29
	Total	243.25		9	23.32	15.29
				Total	118.12	
8	8	23.31	12.98	8	23.31	12.99
	10	223.89	10.32	Total	23.31	
	Total	247.20				
9	7	23.32	13.67	9	23.14	14.20
	9	23.14	13.67	Total	23.14	
	10	5.18	10.32			
	Total	51.76				

[1] Totals may not equal the sum of the parts due to rounding

Table C.20. Import/Export Quantities and Prices for All Regions Under Huy's New Supply Elasticities with Regions 9's Elasticity Set Equal to .05, *ceteris paribus* (HUY05)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	18.14	17.05	1	18.14	17.42
	10	2.02	10.32	2	4.91	17.42
	Total[1]	20.16		Total[1]	23.05	
2	1	4.91	15.69	2	20.16	16.43
	2	20.16	15.69	4	10.69	16.43
	10	2.79	10.32	5	3.54	16.43
	Total	27.85		Total	34.39	
3	3	58.16	14.94	3	58.16	15.73
	10	6.37	10.32	Total	58.16	
	Total	64.53				
4	2	10.69	13.28	4	706.08	13.97
	4	50.53	13.28	Total	706.08	
	10	6.89	10.32			
	Total	68.11				
5	2	3.54	14.81	5	44.06	15.88
	5	44.06	14.81	Total	44.06	
	10	5.26	10.32			
	Total	52.86				
6	6	45.45	14.06	6	45.45	14.55
	7	13.84	14.06	Total	45.45	
	10	6.62	10.32			
	Total	65.90				
7	7	80.96	14.57	6	13.84	15.29
	10	162.29	10.32	7	80.96	15.29
	Total	243.25		9	23.32	15.29
				Total	118.12	
8	8	23.31	12.98	8	23.31	12.99
	10	223.89	10.32	Total	23.31	
	Total	247.20				
9	7	23.45	13.67	9	23.14	14.20
	9	23.14	13.67	Total	23.14	
	10	5.18	10.32			
	Total	51.77				

[1] Totals may not equal the sum of the parts due to rounding

Table C.21. Import/Export Quantities and Prices for All Regions Under Huy's New Supply Elasticities with Regions 9's Elasticity Set Equal to .10, *ceteris paribus* (HUY10)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	18.14	17.05	1	18.14	17.42
	10	2.02	10.32	2	4.91	17.42
	Total[1]	20.16		Total[1]	23.05	
2	1	4.91	15.69	2	20.16	16.43
	2	20.16	15.69	4	10.69	16.43
	10	2.79	10.32	5	3.54	16.43
	Total	27.85		Total	34.39	
3	3	58.16	14.94	3	58.16	15.73
	10	6.37	10.32	Total	58.16	
	Total	64.53				
4	2	10.69	13.28	4	706.08	13.97
	4	50.53	13.28	Total	706.08	
	10	6.89	10.32			
	Total	68.11				
5	2	3.54	14.81	5	44.06	15.88
	5	44.06	14.81	Total	44.06	
	10	5.26	10.32			
	Total	52.86				
6	6	45.45	14.06	6	45.45	14.55
	7	13.84	14.06	Total	45.45	
	10	6.62	10.32			
	Total	65.90				
7	7	80.96	14.57	6	13.84	15.29
	10	162.29	10.32	7	80.96	15.29
	Total	243.25		9	23.32	15.29
				Total	118.12	
8	8	23.31	12.98	8	23.31	12.99
	10	223.89	10.32	Total	23.31	
	Total	247.20				
9	7	23.32	13.67	9	23.14	14.20
	9	23.14	13.67	Total	23.14	
	10	5.18	10.32			
	Total	51.64				

[1] Totals may not equal the sum of the parts due to rounding

Table C.22. Import/Export Quantities and Prices for All Regions Under Huy's New Supply Elasticities with Regions 9's Elasticity Set Equal to .15, *ceteris paribus* (HUY15)

Region	Importer	Exports Quantity	Exports Price	Exporter	Imports Quantity	Imports Price
		(mil.cwt)	($/cwt)		(mil.cwt.)	($/cwt)
1	1	18.14	17.05	1	18.14	17.42
	10	2.02	10.32	2	4.91	17.42
	Total[1]	20.16		Total[1]	23.05	
2	1	4.91	15.69	2	20.16	16.43
	2	20.16	15.69	4	10.69	16.43
	10	2.79	10.32	5	3.54	16.43
	Total	27.85		Total	34.39	
3	3	58.16	14.94	3	58.16	15.73
	10	6.37	10.32	Total	58.16	
	Total	64.53				
4	2	10.69	13.28	4	706.08	13.97
	4	50.53	13.28	Total	706.08	
	10	6.89	10.32			
	Total	68.11				
5	2	3.54	14.81	5	44.06	15.88
	5	44.06	14.81	Total	44.06	
	10	5.26	10.32			
	Total	52.86				
6	6	45.45	14.06	6	45.45	14.55
	7	13.84	14.06	Total	45.45	
	10	6.62	10.32			
	Total	65.90				
7	7	80.96	14.57	6	13.84	15.29
	10	162.29	10.32	7	80.96	15.29
	Total	243.25		9	23.32	15.29
				Total	118.12	
8	8	23.31	12.98	8	23.31	12.99
	10	223.89	10.32	Total	23.31	
	Total	247.20				
9	7	23.32	13.67	9	23.14	14.20
	9	23.14	13.67	Total	23.14	
	10	5.18	10.32			
	Total	51.65				

[1] Totals may not equal the sum of the parts due to rounding

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