IMPACT OF REVERSE OSMOSIS ON SOUTHEAST MILK MARKETS

William A. Schiek and Emerson M. Babb

Abstract

The Southeast is a net importer of milk and milk products. Milk must be imported from other regions at certain times of the year. Reverse osmosis (RO) is a new processing technology which could significantly reduce milk transportation costs between regions by removing half the water from raw milk prior to shipment. A network flow algorithm, which incorporates federal milk orders and solves for the least cost procurement pattern, was used to assess the impact of RO on southeast milk marketing orders under alternative raw product pricing scenarios.

Key words: milk, reverse osmosis, federal milk orders, network flow algorithm.

Regional differences in the production and consumption of milk and milk products have led to situations where some regions are net milk importers, while other regions are net exporters. The cost of transporting milk and milk products can be quite high and contributes to substantially higher milk prices in the deficit regions. Consider Florida as an example. Milk production in Florida is less than fluid milk consumption, especially during August through December. As much as 25 percent of the milk obtained by Florida dairy plants on an annual basis has been produced in other states (Schiek). Some milk is obtained from states as distant as Wisconsin and Minnesota. Transportation costs for such milk may be more than $4.00 per hundredweight, about 25 percent of the cost of milk obtained from Florida dairy farmers. The cost of producing milk in Florida is relatively high (Office of Technology Assessment), but the cost of milk obtained from distant sources is substantially greater. The high costs of both Florida-produced milk and milk from other sources combine to produce some of the highest retail prices in the nation.

Potentially impacting this situation is a new technology which may reduce the cost of interregional milk movements. Reverse osmosis (RO) is a membrane processing technology which reduces the cost of transporting milk and may reduce price differences between the northern surplus regions and the southern deficit regions. The RO process can remove 50 percent or more of the water from milk (Stabile). The concentrated product can then be transported in tank trucks now used for whole milk and recomposed at a milk processing plant using water which is purified by the RO process. The recomposed milk can be packaged or blended with locally produced milk and then packaged. RO is currently being used to concentrate skim milk for use in manufactured dairy products, particularly cheese. Despite recent improvements in membrane construction which have made RO concentration of whole milk possible, RO has not been used for that purpose. Fat particles in whole milk tend to foul the membrane unless temperatures are high enough to process the fat in liquid form. Unfortunately, these temperatures are also ideal for bacterial growth. Separation of fat and skim before RO processing can alleviate the problem, but continued improvements in membrane construction and cleaning techniques are expected to be the ultimate solution for RO processing of whole milk.

The purpose of this paper is to examine the impacts of the RO technology on raw milk procurement patterns and costs, interregional price relationships, levels of milk production and consumption, and prices received by producers and paid by consumers. The economic feasibility of the new technology is examined by focusing on RO plants in the northern states

---

William A. Schiek is a graduate student and Emerson M. Babb is a Professor, Food and Resource Economics Department, University of Florida.

The authors wish to thank Dr. Thomas Spreen for helpful suggestions pertaining to the presentation of the model used in the analyses. Helpful suggestions and support were also given by Paul Halnon, Market Administrator for the Florida Milk Marketing Orders, and the late Thomas Wilson, former Market Administrator for the New York-New Jersey Milk Marketing Area.

and fluid milk processing and distributing plants in the Southeast. If the technology is not feasible and does not have economic impacts in these extreme cases, it is not likely to be used elsewhere.

POLICY SETTING

Economic regulation of the dairy industry is extensive. There are 41 federal milk marketing orders for the United States which regulate 81 percent of all Grade A milk (milk that meets health and sanitary requirements for consumption in fluid form). Milk is priced by these orders according to use. Milk processed and sold as a fluid product is assigned a Class I use, milk used for perishable manufactured products (cottage cheese, ice cream) is assigned a Class II use, and milk used for storable manufactured products (butter, cheese) receives a Class III designation. All class prices in federal orders are based on the price of Grade B milk in the Upper Midwest (M-W price), which can only be used to produce storable manufactured products.

For each order, the Class I price is the M-W price plus a differential which is supposed to reflect the added cost of producing Grade A milk and the cost of transporting residual supplies from the center of the production area in the Upper Midwest to consumption centers. In practice, these differentials have been about half the cost of transporting bulk milk. The differential added to the M-W price to obtain the Class I price is $1.40 for Chicago and $4.18 for Miami.

Producers in each order receive a blend price which is equal to the sum of the class prices weighted by the uses of all milk. In addition to minimum class prices that processors must pay for milk, over-order payments are made by processors in most federal orders to reimburse cooperatives for the cost of obtaining supplemental supplies and providing marketing services.

The concept of concentrating milk prior to long-distance shipment is not new. Studies of the economic feasibility of reconstituted (RCN) milk have reported cost savings to consumers in the Southeast as a result of substituting RCN milk for whole milk (Hammond et al.; Whipple). Reconstitution involves using manufactured dairy products (butter or butter oil and nonfat dry milk powder or condensed milk) with purified water to create a fluid milk product. In theory, the reconstituted product could be priced either as a Class I or Class III product. In practice, there are serious difficulties with Class I pricing of RCN milk. Class I pricing would require that the milk source for the manufactured ingredients used in the reconstitution process be identifiable, a practical impossibility. Also, many states have laws prohibiting the sale of fluid milk products made from Grade B milk. Once again, the source of the ingredients would have to be identifiable to ensure that the ingredients were made from Grade A milk. While transportation cost savings would occur under Class I pricing of RCN milk, these would be offset somewhat by the relatively high cost of manufacturing milk into ingredient form and then reconstituting the product at its ultimate destination. Hence, a large part of the cost savings associated with RCN milk comes from the lower raw product costs associated with Class III pricing of the ingredients and from avoiding regulation under the federal order.

In contrast, RO milk could easily be priced as either Class I or Class III under a northern order. The cost savings to southeast consumers are obviously greater if RO milk is priced as Class III, and that is a decision which can be made by policymakers. However priced, RO milk, unlike RCN milk, can be integrated into current regulation with little difficulty. From a regulatory standpoint, RO milk regulated under a federal order in the northern states can be treated exactly the same as whole milk which is shipped to a processor in the Southeast for use in a fluid milk product. While transportation costs for RCN milk ingredients are less than those for RO milk, the concentration and recombining costs for RCN milk, which involve manufacturing the ingredients and then converting them back into fluid form, are significantly greater than comparable RO costs. Since excessive heat treatments are not used in the RO process, taste differences between RO and fresh milk should be less perceptible than for RCN milk. There is also little or no likelihood that Grade B milk would be used in RO milk, unlike the case for RCN milk. The cost and consumer acceptability advantages of RO milk suggest that it would dominate RCN milk, whether markets were regulated or unregulated.

ANALYTICAL MODEL

The Federal Milk Market Order Policy Simulator (FMMOPS), which models the U.S. federal milk order system, was updated to a 1985 base and used to analyze the impacts of RO milk (Babb et al.; Novakovic et al.). It uses a capacitated network flow algorithm developed by Bradley et al. to solve for least-cost movements of milk from production areas to processing plants and then to final consumers. Using this model, the optimal raw milk procurement pattern is determined for conventional and RO milk supplies, and the consequences of the introduction of RO milk for dairy farmers and consumers are assessed.

A network flow algorithm is an alternative means of solving the conventional transshipment problem in mathematical programming. A simple transshipment network can be represented by supply points, processing centers, and demand points. These points are called nodes and are connected by arcs. In a linear programming context, the objective is usually defined as minimizing the total cost of moving required quantities of product from the supply points to consumption centers via processing locations.

$$(1)\ \text{Min} \sum_i \sum_j C_{ij} X_{ij} + \sum_j P_j Y_j + \sum_j \sum_k D_{jk} Z_{jk},$$

subject to:

$$(a)\ \sum_j X_{ij} \leq S_i \quad i = 1, 2, \ldots, n,$$

$$(b)\ Y_j \leq Q_j \quad j = 1, 2, \ldots, m,$$

$$(c)\ \sum_j Z_{jk} \geq R_k \quad k = 1, 2, \ldots, o,$$

$$(d)\ -\sum_i X_{ij} + Y_j \leq 0 \quad j = 1, 2, \ldots, m, \text{ and}$$

$$(e)\ -Y_j + \sum_k Z_{jk} \leq 0 \quad j = 1, 2, \ldots, m$$

$$X_{ij}, Y_j, Z_{jk} \geq 0 \quad \text{for all } i, j, k,$$

where:

C_{ij} = cost of moving raw product from supply point i to processing plant j;
X_{ij} = amount of raw product moved from point i to plant j;
P_j = unit cost of processing raw product at plant j;
Y_j = amount of product processed at plant j;
D_{jk} = cost of moving finished product from plant j to consumption point k;
Z_{jk} = amount of finished product shipped from plant j to point k;
S_i = supply available at point i;
Q_j = processing capacity at plant j;
R_k = demand requirement at point k;
n = number of supply points;
m = number of processing points; and
o = number of demand points.

The first constraint of the problem (1a) ensures that the total amount of supply shipped from a given point cannot exceed the supply available at that point. The second constraint (1b) requires that the quantity processed at any plant cannot exceed the processing capacity of the plant. The third constraint (1c) ensures that the total quantity shipped to any demand point must be at least equal to the demand requirement at that point. The fourth constraint (1d) requires that the amount processed at any plant cannot exceed the quantity shipped to that plant. Finally, the fifth constraint (1e) requires that the quantity shipped from any plant cannot exceed the amount processed at the plant.

The total time required to solve large transshipment problems can be significantly reduced if the arc connections between two nodes are made only in plausible cases. Bradley et al. describe the network formulation of the transshipment model as follows:

$$(2)\ \text{Min} \sum_k C_k x_k, \quad k \,\varepsilon\, A,$$

subject to:

$$(a)\ \sum_{k \,\varepsilon\, A \text{ with tail } i} X_k - \sum_{k \,\varepsilon\, A \text{ with head } i} X_k = b_i, \ i \,\varepsilon\, N, \text{ and}$$

$$(b)\ l_k \leq x_k \leq u_k, \quad k \,\varepsilon\, A,$$

where:

b_i = supply if i is a supply node; negative of demand if i is a demand node; 0 otherwise;
A = set of all defined arcs;
N = set of all nodes;
c_k = cost along arc k;
x_k = amount of product moved along arc k;
l_k = lower bound on arc k; and
u_k = capacity of arc k.

This formulation is equivalent to the standard representation of the transshipment problem. Note that each arc is defined by a pair of nodes (tail, head). The primary direction of flow is from the tail node to the head node. Here, the objective function of minimizing the sum of assembly, processing and distribution costs is defined as minimizing the sum of total arc costs. The first constraint (2a) in the network formulation encompasses both the supply and the demand constraints (1a and 1c) of the standard formulation. For purposes of illustration, consider the fact that a supply node is a tail for some arcs but is a head for no arcs. Hence, when node i is a supply node, the constraint simply states that the product moving along all the arcs emanating from a particular node must equal the supply at that node. Likewise, a demand node serves as a head but not a tail. Hence, when node i is a demand node, the constraint requires that the quantity of product moving along all the arcs leading into the node be equal to the demand requirement at that node. When node i is a transshipment node, it serves as both a head and a tail. In this case, the constraint merely states that the quantity flowing into a transshipment node equals the quantity flowing out of that same node. Hence, this first constraint also encompasses the balancing constraints (1d and 1e) of the standard formulation. The second constraint in the network formulation (2b) defines upper and lower bounds for movements along particular arcs; hence, this constraint includes the plant capacity constraint (1b) from the standard formulation.

The network formulation requires that allowable arcs are predefined by the set A; hence, unrealistic linkages are not considered in the solution process. The problem is solved using a primal-simplex algorithm that is many times faster than conventional linear programming codes.

Total milk production in each production area is partitioned into that part which is shipped directly by farmers to processing plants (direct ship) and that which is collected at a plant or reload station prior to shipment (supply plant). Supply plants must meet the federal order shipping requirement, which requires a certain percentage of milk receipts to be shipped to processing centers within the same market order, otherwise they may ship to any processing center. Supply plant and direct ship milk can move to processing centers or three types of manufacturing centers, all of which may have capacity restrictions. The algorithm computes the disposition of total milk production from all sources to satisfy total milk usage in such a way that total costs for the order system are at a minimum. These dispositions also result in minimum retail milk prices in the aggregate. Total cost is composed of class prices for milk (raw product costs), transportation cost for bulk and packaged milk, handling charges, processing costs, and retailing costs.

The model is designed to handle disequilibrium in the national milk market by allowing for governmental purchase of manufactured milk products. Milk production in excess of commercial fluid demand is disposed of in the manufacturing sector. In reality, there are short-run restrictions on shifts in raw and packaged milk sales among orders. These restrictions are used when the focus of the research is on optimal adjustments over some time period. In this instance, the focus is on the longer term or final adjustments that would obtain with the introduction of RO milk; hence, most restrictions were relaxed.

Reverse osmosis was included in the model by modifying the transportation cost on a given set of arcs. Six RO centers were specified: New York-New Jersey, Eastern Ohio-Western Pennsylvania, Tennessee Valley, Southern Michigan, Chicago Regional, and Upper Midwest. The transportation cost was reduced by half on the arcs between the supply plants assumed to have RO facilities and the processing centers in several southern orders. The southern orders specified to receive RO shipments (when economically feasible) were Southeast Florida, Tampa Bay, Upper Florida, Georgia, New Orleans-Mississippi, Greater Louisiana, and Texas. These arcs were chosen because the large distances implied that there should be greater incentives to use RO milk. If RO movements are not feasible in these extreme cases, they will probably not be feasible anywhere. The cost of RO processing and recombining is also included on these arcs. RO costs were determined by updating cost information from Winchell and Hammond.

RESULTS

The impacts of RO milk on participants in the Southeast federal milk orders were assessed using FMMOPS. First, a base run was made to establish performance in the absence of RO milk. These results were then used for comparing results under two scenarios when RO milk was available. In the first scenario, the raw milk cost for RO milk was the Class I price for the federal order where the RO milk originated. In the second scenario, the raw milk cost was the Class III price. These two pricing scenarios were chosen because they are the most likely alternatives and because they were used in previous studies which examined the market impacts of butter-powder reconstitution. Both scenarios assumed a per-hundredweight transportation cost for RO milk of 2.6 cents plus 0.15 cents per mile, which is equal to one-half of the unconcentrated raw

TABLE 1. BASE RUN FOR SELECTED SOUTHEAST MILK ORDERS

Response Variable	Florida	Georgia	New Orleans-Mississippi
Milk Production (mil. lb.)	2822.5	1850.0	1095.5
Class I Sales (mil. lb.)	2266.5	1458.7	785.8
Producer Blend Price ($/cwt.)	15.55	14.29	14.12
Inshipments—Raw Milk			
Direct Ship (mil. lb.)	362.6	16.8	0.0
Supply Plant (mil. lb.)	12.7	0.0	0.0
Total (mil. lb.)	375.3	16.8	0.0
Outshipments—Raw Milk			
Manufacturing Plants (mil. lb.)	130.3	159.3	0.0
Processing Plants (mil. lb.)	0.0	12.6	0.0
Total (mil. lb.)	130.3	171.9	0.0
Milk Consumption (mil. lb.)	2278.1	1447.1	785.8
Fluid Raw Milk Cost ($/cwt.)	16.56	15.04	15.13
Retail Price (¢/1/2 gal.)	117.2	110.0	111.1

milk transportation cost. RO processing and recombining costs were assumed to be 52 cents per hundredweight. In the context of simulation analysis, policy variables regarding RO milk were changed and response variables were measured to determine performance under the different policies.

Results for Texas were not included because throughout all the scenarios examined, the Texas order was virtually unaffected by the availability of RO milk. Likewise, results for the Greater Louisiana order were not included. This order received small amounts of RO inshipments when RO milk was available at Class III prices, but manufacturing capacity constraints made utilization of RO milk unprofitable because of the high cost associated with disposing of milk in excess of fluid needs.

Base Run

FMMOPS uses data for 1985 to solve the transshipment problem for the next period, given the next period's prices for the different classes of milk usage. A base run was made using 1985 prices and marketing conditions for purposes of comparison with scenarios where the RO technology was available. The base run assumed no RO milk was available, handling charges for milk shipped from supply plants were equal to 40 cents per hundredweight, and per-hundredweight transportation costs were 5.2 cents plus 0.3 cents per mile. Raw milk costs used in the study were federal order minimum class prices plus applicable over-order payments (effective class prices). The results of the base run closely correspond to actual performance for the orders in 1985 (Table 1).

Milk production refers to the amount of milk that was received by plants regulated under the designated federal order, and Class I sales indicate the amount of such milk that was assigned a Class I use. Inshipments identify additional milk shipped to processors direct from dairy farmers and from supply plants regulated by other orders. Outshipments are primarily shipments of milk in excess of Class I use to out-of-state manufacturing plants, but also include shifts of dairy farmers from processors to fluid plants regulated by other orders. Milk consumption refers to sales of fluid milk within the order, regardless of its source (in-area sales). The producer blend price is the average price received by dairy farmers who supply plants regulated by the order. The fluid raw milk acquisition cost reflects the class prices, handling charges, and transportation cost paid by processors. It is the cost of raw milk assigned a Class I use at the plant location. The retail price consists of raw milk costs, processing costs, distribution costs, and retailing costs. For this analysis, processing, distributing, and retailing costs do not change with policy variable settings. Differences in retail prices are thus the result of differences in raw milk costs.

In the base run (Table 1), results for the three Florida orders are reported in aggregate. Most inshipments into Florida are direct ship from dairy farmers in nearby states, and all outshipments are milk in excess of fluid use to manufacturing plants in other states.

Inshipments are about 13 percent of all milk shipped to processors regulated under the Florida milk orders. The model suggests that it is cheaper to meet continuous annual shortfalls by using direct ship milk (362.6 million pounds). Seasonal and other supplemental needs of a temporary nature are satisfied by shipments from supply plants regulated under other orders (12.7 million pounds). It is interesting to note that fluid raw milk costs for Florida were approximately $1.50 per hundredweight higher than the other southeast orders.

For Georgia, inshipments are a much smaller percentage of total supply, accounting for less than one percent of total production. All inshipments are of the direct ship type (16.8 million pounds). For Georgia, unlike Florida, outshipments exceed inshipments. Most of the outshipments go to out-of-state manufacturing plants (159.3 million pounds), but some go to processing plants regulated under another order (12.6 million pounds). For the New Orleans-Mississippi order, no inshipments or outshipments were projected.

Class I Pricing of RO Milk

The availability of RO milk at effective Class I prices from the source orders resulted in major changes in Florida with respect to the inshipments of raw milk. However, the other southeast orders were not significantly affected. In fact, Florida was the only area to receive any shipments of RO milk. Georgia experienced a small decline in the blend price ($0.07 per hundredweight) and Class I utilization (2.2 percentage points) because supply plant shipments of Class I milk to Florida were replaced by RO milk shipments from northern orders. However, packaged milk sales and retail milk prices in Georgia were unaffected.

The results for Florida under this scenario are shown in Table 2. Inshipments changed from direct ship and supply plant shipments of whole milk to shipments of RO milk from supply plants in Southern Michigan and Eastern Ohio-Western Pennsylvania. As a result, less milk production was regulated by the Florida orders, and Class I sales assignments shifted from Florida to the federal orders with RO processing plants. Blend prices for dairy farmers supplying the Florida milk orders declined slightly because of lower Class I utilization, but the lower cost of raw milk for fluid use resulted in a decline in retail prices and a slight increase in fluid milk consumption.

In sum, RO milk provided cost savings up to the point where local production used for fluid purposes was displaced and therefore incurred transportation cost for movements to distant manufacturing plants. The per-hundredweight cost of transporting milk to out-of-state manufacturing plants was the same as the transportation cost of raw milk inshipments (5.2 cents + 0.3 cents per mile). If more nearby manufacturing plant capacity had

TABLE 2. THE IMPACT OF REVERSE OSMOSIS (RO) ON FLORIDA MARKETS WHEN RO MILK IS PRICED AS A CLASS I PRODUCT

Response Variable	Base Run	RO Available	Change from Base	Percent Change
Milk Production (mil. lb.)	2822.5	2455.4	-367.1	-13.0
Class I Sales (mil. lb.)	2266.5	1901.3	-365.2	-16.1
Producer Blend Price ($/cwt.)	15.55	15.42	-0.13	-0.8
Inshipments—Raw Milk				
Direct Ship (mil. lb.)	362.6	0.0	-362.6	-100.0
Supply Plant (mil. lb.)	12.7	413.3	400.6	3154.3
Total (mil. lb.)	375.3	413.3	38.0	10.1
Outshipments—Raw Milk				
Manufacturing Plants (mil. lb.)	130.3	135.3	5.0	3.8
Processing Plants (mil. lb.)	0.0	0.0	0.0	0.0
Total (mil. lb.)	130.3	135.3	5.0	3.8
Milk Consumption (mil. lb.)	2278.1	2280.1	2.0	0.1
Fluid Raw Milk Cost ($/cwt.)	16.56	16.48	-0.08	-0.5
Retail Price (¢/ 1/2 gal.)	117.2	116.9	-0.3	-0.3

TABLE 3. THE IMPACT OF REVERSE OSMOSIS (RO) SHIPMENTS ON SOUTHEAST ORDERS WHEN RO MILK IS PRICED AS A CLASS III PRODUCT

	—Florida—		—Georgia—		-New Orleans-Mississippi	
Response Variable	RO Available	Percent Change From Base	RO Available	Percent Change From Base	RO Available	Percent Change From Base
Milk Production (mil. lb.)	1824.6	-35.4	784.8	-57.6	669.7	-38.8
Class I Sales (mil. lb.)	1076.3	-52.5	308.3	-78.9	64.7	-91.8
Producer Blend Price ($/cwt.)	14.70	-5.5	13.26	-7.2	12.04	-14.7
Inshipments—Raw Milk						
Direct Ship (mil. lb.)	0.0	-100.0	0.0	-100.0	0.0	0.0
Supply Plant (mil. lb.)	1328.0	10356.7	1285.6	—	868.8	—
Total (mil. lb.)	1328.0	253.9	1285.6	7552.4	868.8	—
Outshipments—Raw Milk						
Manufacturing Plants (mil. lb.)	1404.5	210.4	130.5	-18.1	0.0	0.0
Processing Plants (mil. lb.)	562.2	—	1006.2	7885.7	416.9	—
Total (mil. lb.)	966.7	641.9	1136.7	561.3	416.9	—
Milk Consumption (mil. lb.)	2294.3	0.7	1456.4	0.6	788.9	0.4
Fluid Raw Milk Cost ($/cwt.)	15.62	-5.7	14.31	-4.9	14.60	-3.5
Retail Price (¢/1/2 gal.)	112.2	-4.3	106.2	-3.4	108.3	-2.5

been available, RO shipments would have increased and more local production would have shifted from fluid use. The sensitivity of these results under varying milk prices, transportation costs, and RO processing costs was examined. It appears that RO milk rather than whole milk would be the least-cost source of supplemental milk supplies under a wide range of costs.

A scenario under which Florida processors purchased milk from the cheapest source without regard to the cost of disposing of milk in excess of Class I sales was analyzed by Schiek and Babb. This situation was approximated by setting the disposal cost for milk in excess of fluid needs at zero. In this case, RO milk displaced almost half of Florida production, blend prices declined $2.13 per hundredweight, and raw milk cost declined 29 cents per hundredweight. Some of the displaced milk was shipped to manufacturing plants and some was shipped to processing plants regulated under other marketing orders. Milk moving to processing plants in other orders essentially switches markets and becomes a part of the other marketing order's milk supply. In reality, the cost of moving milk to out-of-state manufacturing plants will be paid by producer cooperatives. The transportation cost for milk moving to processing plants in other orders is assumed to be paid by the producers. In the other marketing orders that received displaced milk, Class I utilization and blend prices decline because the total milk volume has increased while Class I (fluid) milk demand has not. Florida producers could prevent displacement of their milk by accepting a lower price. It was found that a reduction of 35 cents in the Class I price was sufficient to make Florida milk supplies competitive with RO milk under the scenario which assumed disposal costs were zero (Schiek and Babb).

Class III Pricing of RO Milk

All of the southeast orders under consideration were affected when RO milk was priced as a Class III product. In many cases, the availability of RO milk at effective Class III prices resulted in substantial displacement of locally produced milk. The consequences of inexpensive RO milk for the Southeast were lower Class I utilization and blend prices, greater levels of inshipments and outshipments, lower fluid raw milk costs and retail prices, and increased milk consumption. It should be noted that under the Class III pricing scenario it was assumed that RO milk would not be subject to down-allocation and compensatory payments under federal milk marketing orders. The orders currently apply these provisions to any Class III product that is used in the processing of fluid products. The effect of these provisions is to eliminate the raw product cost advantages brought about by using Class III ingredients in fluid milk.

Florida experienced the greatest level of RO inshipments under this scenario, amounting to 1.3 billion pounds or 57.8 percent of fluid milk consumption (Table 3). A substantial amount of Florida milk was displaced as milk production fell by almost one billion pounds relative to base levels. The producer blend price fell by $0.85 per hundredweight or 5.5 percent. Outshipments were split between those going to manufacturing plants (404 million pounds) and those going to processing plants regulated under another order (562 million pounds). Total outshipments increased by 836 million pounds. The fluid raw milk cost fell by $0.94 per hundredweight (5.7 percent, and the retail price fell by 5.0 cents per half gallon. Milk consumption increased by 16.2 million pounds or 0.7 percent.

Georgia experienced similar results when RO milk was priced as a Class III product. Inshipments of RO milk amounted to just under 1.3 billion pounds or 88.3 percent of fluid milk consumption. Milk production fell by 57 percent, and Class I utilization declined as Class I sales fell by 79 percent. The resulting drop in the Georgia blend price was $1.03 per hundredweight or 7.2 percent. Total outshipments increased by 965 million pounds with most of these going to processing plants regulated under other marketing orders. Fluid raw milk costs fell by $0.73 per hundredweight, and the retail price fell by 3.8 cents per half gallon. Milk consumption rose by 9.3 million pounds or 0.6 percent.

The New Orleans order experienced the greatest drop in producer prices. The blend price fell by $2.08 per hundredweight as milk production fell by 425 million pounds and Class I sales fell by 721 million pounds. RO inshipments amounted to 869 million pounds and actually exceeded milk consumption by 80 million pounds. Outshipments were 417 million pounds with all of them going to other order processing plants. The fluid raw milk cost fell by 53 cents per hundredweight, and the retail milk price fell by 2.8 cents per half gallon. Milk consumption increased by 3.1 million pounds.

The large decline in the New Orleans blend price, which is four times larger than the decline in the fluid milk cost, bears further examination. RO milk can be obtained by processors more cheaply than local milk supplies; however, the difference in raw milk cost from the two sources is not great. Nevertheless, processors pick the cheapest source and purchase all their needs in RO form. Some of the local milk that was displaced by RO milk becomes regulated under nearby orders and is used for their processing needs. Milk production in New Orleans falls, but the Class I utilization declines dramatically. Hence, the blend price falls to near Class III price levels, while the fluid milk cost declines by a much smaller amount.

The transportation cost associated with moving displaced milk under this scenario is the same as when RO milk is priced as a Class I product. Also, the Class I utilizations and blend prices decrease in those marketing orders

TABLE 4. REVERSE OSMOSIS (RO) MILK MOVEMENTS WHEN RO MILK IS PRICED AS A CLASS III PRODUCT

	Destination				RO Shipments as a % of Base Production
	Florida	Georgia	New Orleans-Mississippi	Total	
	million pounds				
Source					
New York-New Jersey	1328.0	773.7	0.0	2101.7	17.9%
Southern Michigan	0.0	88.5	591.3	699.7	14.1%
Eastern Ohio-Western Pennsylvania	0.0	350.7	256.0	606.7	17.3%
Tennessee Valley	0.0	72.7	21.5	94.2	6.4%
Total	1328.0	1285.6	868.8	3502.3	
RO receipts as a % of Base Production	47.1%	69.5%	79.3%		

Table 5. Changes in Producer Blend Prices in Destination Orders Under Alternative Reverse Osmosis (RO) Pricing Scenarios

	Base	RO Milk Priced as Class I	Actual Change	Percent Change
Destination		($/cwt.)		
Florida	15.55	15.42	-0.13	-0.8
Georgia	14.29	14.22	-0.07	-0.5
New Orleans-Mississippi	14.12	14.12	0.00	0.0

	Base	RO Milk Priced as Class III	Actual Change	Percent Change
Destination		($/cwt.)		
Florida	15.55	14.70	-0.85	-5.5
Georgia	14.29	13.26	-1.03	-7.2
New Orleans-Mississippi	14.12	12.04	-2.08	-14.7

where fluid processing plants receive milk displaced by RO inshipments. This impact is not surprising because milk supply in those orders has increased, while fluid demand is essentially unchanged.

DISCUSSION

Pattern of Interregional RO Milk Movements

When RO milk was priced as Class I, Florida was the only recipient of RO shipments. Of the total RO shipments amounting to 413 million pounds under this scenario, 121 million pounds originated in the Southern Michigan order, while 292 million pounds came from the Eastern Ohio-Western Pennsylvania order. Since neither of these shipments represents a large proportion of their total supplies, effects on prices and utilization in the source orders were minimal.

The sources and destinations of RO milk shipments when RO milk is priced as a Class III product are shown in Table 4. The New York-New Jersey order was the only RO supplier for Florida and the major supplier for Georgia. The New York-New Jersey order accounted for 60 percent of all RO shipments under this scenario, and these RO shipments were equal to 17.9 percent of the total base production in that order.

The Southern Michigan order made some RO shipments to Georgia, but most of its shipments (85 percent) went to New Orleans. Southern Michigan's RO shipments accounted for 14.1 percent of that order's base production and 20 percent of total RO shipments. Eastern Ohio-Western Pennsylvania shipped RO milk to Georgia and New Orleans. RO shipments accounted for 17.3 percent of the order's base production and 17.3 percent of total RO shipments. Tennessee Valley was not a large supplier of RO milk, accounting for only 2.7 percent of total RO shipments. Tennessee's shipments amounted to only 6.4 percent of its base production and were split between the Georgia and New Orleans orders.

RO shipment receipts from all sources were a major part of the milk supply in the Southeast under this scenario. As a proportion of base level production, RO milk accounted for 47.1 percent in Florida, 69.5 percent in Georgia, and 79.3 percent in New Orleans.

Impact on Blend Prices and Fluid Milk Costs

When RO milk was priced as a Class I product, the impact on blend prices in the destination orders was not substantial (Table 5). Florida's blend price fell by 13 cents per hundredweight. Georgia's blend price also falls 7 cents per hundredweight because receiving displaced Florida milk lowers the Class I utilization. In the source orders, the relatively small volumes involved lead to only a 4 cent per hundredweight increase in the blend price in Southern Michigan and no increase in the blend price in Eastern Ohio-Western Pennsylvania.

The impact when RO milk was priced as a Class III product was considerably greater (Table 5). Blend price decreases in the southeast orders were substantial. No blend price changes were predicted in the source orders under this scenario, as shipments to Florida priced at Class III merely replaced existing Class III uses. However, the model did predict some movements of milk from other orders into RO shipping orders.

With Class I pricing of RO milk, fluid raw milk acquisition costs are affected only in Florida. Hence, Florida is the only location where consumers benefit directly from the new technology. The fluid milk cost in Florida declines by 8 cents per hundredweight or 0.5 percent (Table 6). Since fluid milk cost is only one component of the retail price, the percentage decrease in retail price is even smaller. Thus, the consumer benefit is measurable, but not large.

When RO milk is priced as Class III, the fluid milk cost is affected significantly in the Florida, Georgia, and New Orleans orders. Percentage decreases in fluid milk costs ranged from 5.7 percent in Florida to 3.5 percent in New Orleans (Table 6). Consumer benefits are thus substantially greater under the Class III pricing scenario.

Comparisons with Other Studies

The results from this study are not exact, but provide some indicators of performance if RO milk becomes available. The cost of RO processing and transportation may be higher or lower than the mean values used in this study, depending in part on the size of the market for RO milk. Based on the study results and assuming Class I pricing of RO milk, the size of the market may not be large. Health and sanitary regulations and other state and federal laws and regulations may also limit the market for RO milk. Also, the simulated results indicate what might happen without adjustments to the Class I prices received by producers in the southeast orders. Such results are not likely to hold because downward adjustments in the prevailing Class I prices can be expected when transportation costs are dramatically reduced by RO.

When RO milk is priced as Class I, the Class I price reductions necessary to make raw milk in the destination orders competitive with RO milk are relatively small, about $0.35 per hundredweight in Florida (Table 7). The blend price reductions caused by the availability of RO milk at Class I prices were small, $0.08 and $0.13 per hundredweight in Georgia and Florida, respectively.

Fleming examined the impact of Class I pricing of RO milk on markets in the eastern half of the United States. Her work indicated substantial changes in the prevailing Class I prices after the introduction of RO. Class I prices fell by $2.26 per hundredweight in Florida and by $1.45 per hundredweight for the rest of the Southeast. It should be noted that Fleming's study assumed milk in excess of

TABLE 6. CHANGES IN FLUID RAW MILK COSTS IN DESTINATION ORDERS UNDER ALTERNATIVE REVERSE OSMOSIS (RO) PRICING SCENARIOS

	Base	RO Milk Priced as Class I	Actual Change	Percent Change
Destination		($/cwt.)		
Florida	16.66	16.48	-0.08	-0.5
Georgia	15.04	15.04	0.00	0.0
New Orleans-Mississippi	15.13	15.13	0.00	0.0

	Base	RO Milk Priced as Class III	Actual Change	Percent Change
Destination		($/cwt.)		
Florida	16.56	15.62	-0.94	-5.7
Georgia	15.04	14.31	-0.73	-4.9
New Orleans-Mississippi	15.13	14.60	-0.53	-3.5

TABLE 7. COMPARISON OF RESULTS FROM VARIOUS STUDIES OF CONCENTRATED MILK IMPACTS ON CLASS I AND BLEND PRICES IN THE SOUTHEAST

	Range of Changes in Class I Price	Range of Changes in Blend Price
Recomposed Product Priced as Class I	($/cwt.)	
Schiek and Babb, RO	$0.00 to -$0.35	$0.00 to -$0.13
McDowell et al., RO[a]	-$0.53 to -$1.72	-$0.74 to -$1.78
Fleming, RO[b]	-$1.45 to -$2.26	Not Applicable
Hammond et al., RCN[c]	-$0.75	-$0.58
Whipple, RCN[d]	Not Applicable	Not Applicable
Recomposed Product Priced as Class III	($/cwt.)	
Schiek and Babb, RO	-$0.83 to -$2.20	-$0.85 to -$2.08
McDowell et al., RO[a]	Not Applicable	Not Applicable
Fleming, RO[b]	Not Applicable	Not Applicable
Hammond et al., RCN[c]	-$1.57	-$1.07
Whipple, RCN[d]	-$0.47 to -$1.30	-$0.63 to -$1.33

[a] This model examined impact of reverse osmosis (RO) priced as Class I product, and alternative pooling arrangements where RO milk is pooled in destination orders. Results included Florida and two aggregated southern markets.

[b] This model examined impact of Class I RO milk pricing on an aggregated southeast region as well as Florida. Disposal of milk in excess of Class I was assumed to be costless.

[c] This model examined impact of Class I and Class III pricing of reconstituted (RCN) milk. Results shown are for an aggregated southeast region.

[d] This model used a pricing scheme which most closely approximates Class III pricing of RCN milk. Results included Florida and an aggregated southern region.

Class I needs could be disposed of in unlimited quantities in any region at no cost. Her results indicated that all Class I sales in Florida and the Southeast would be displaced by RO milk when an RO processing cost of $0.30 per hundredweight was assumed.

A study of federal milk marketing orders by McDowell et al. also examined the impact of RO milk availability. Predicted declines in the Class I differentials were $0.53 for the Deep South (Louisiana, Mississippi, and Arkansas), $0.67 for the Southeast (Alabama, Georgia, South Carolina, and North Carolina), and $1.72 for Florida. Blend prices were predicted to decline by $0.74 in the Deep South, $1.13 in the Southeast, and $1.78 in Florida. The McDowell et al. study used an RO processing cost of $0.35 per hundredweight, $0.17 lower than the RO processing cost used in this study, and assumed RO milk would be pooled in destination orders. The impact of RO milk on the blend price was more severe because all of the milk pooled at the RO processing plant was not shipped.

Hammond et al. found that Class I price reductions of $0.75 were required for the Southeast in order to neutralize the cost advantage of RCN milk, priced as Class I. This reduction would be substantially higher for Florida. They also predicted that the blend price in the Southeast would fall by $0.58 per hundredweight under this scenario.

When RO milk was priced at Class III in this study, the Class I price reductions required to make local supplies competitive with RO milk increased substantially. Such reductions range from $0.83 per hundredweight in New Orleans to $2.20 per hundredweight in Florida (Table 7). Blend price reductions under this scenario range from $0.85 per hundredweight in Florida to $2.09 per hundredweight in New Orleans.

Hammond et al. also evaluated the impact of Class III pricing of RCN milk. For the Southeast, they predicted that Class I prices would decline by $1.57 per hundredweight and blend prices would fall by $1.07 per hundredweight. Whipple estimated that Florida Class I prices would have to be reduced by about $1.30 per hundredweight to compete with RCN milk. Under such a scenario, he predicted that the producer blend price would fall by $1.33 per hundredweight. Whipple also predicted that Class I prices and blend prices in the Mississippi-Louisiana region would decline by $0.47 and $0.63 per hundredweight, respectively. The magnitude of the price reductions required to make local milk competitive with RCN milk and RO milk when these products are priced at Class III is indicative of the cost advantages to processors of avoiding federal order regulation.

IMPLICATIONS

It seems unlikely that RO milk would be priced as a Class III product, unless policymakers dramatically altered the federal order classified pricing system by reducing Class I differentials to some small amount over the Class III price. Some federal orders, such as Florida, already have provisions that would permit RO milk to be treated as a Class I product. Policymakers are currently considering the adoption of a uniform pricing policy for concentrated milk. The results of their deliberations will certainly affect the magnitude of RO milk impacts.

In many studies of the impacts of a new technology there is often some group that is adversely affected, at least in the short run. If RO milk is priced as a Class I product, it may be one of those rare cases where no group is adversely affected, even in the short run. If Class I prices are reduced to a level that provides incentives for the use of RO milk on a supplemental basis only, the reduction in Class I price may be offset by lower transportation cost for RO milk. In this instance, producers' welfare remains essentially unchanged while consumers' welfare is improved as a consequence of lower retail milk prices. While the benefits of the RO technology may not be huge, they do appear to be significant.

In summary, if RO milk is priced as a Class I product, producers are not dramatically affected, consumers experience small gains, and only the procurement pattern for Florida is altered significantly. When RO milk is priced as a Class III product, producers experience substantial losses from lower farm prices, consumers' gains are substantial because of lower retail prices, and the raw milk procurement pattern is altered radically in most of the southeast orders.

REFERENCES

Babb, E.M., D.E. Banker, D. Goldman, D.R. Martella, and J.E. Pratt. *Economic Model of Federal Milk Marketing Order Policy Simulator.* Indiana Agr. Exp. Sta. Bull. No. 158, Purdue University, Apr. 1977.

Bradley, G.H., G.G. Brown, and G.W. Graves. "Design and Implementation of Large Scale Primal Transshipment Algorithms." *Management Science.* 24(1977):1–34.

Fleming, A. "A Spatial Economic Analysis of the Impact of Reverse Osmosis Filtration on the Grade A Milk Market." M.S. Thesis, Michigan State University, 1987.

Hammond, J.W., B.W. Buxton, and C.S. Thraen. *Potential Impacts of Reconstituted Milk in Regional Prices, Utilization and Production.* Minnesota Agr. Exp. Sta. Bull. No. 529, University of Minnesota, 1979.

McDowell, H., A.M. Fleming, and R.F. Fallert. *Federal Milk Marketing Orders: An Analysis of Alternative Policies.* Commodity Economics Division, ERS, USDA, Ag. Econ. Report No. 598, September 1988.

Novakovic, A.M., E.M. Babb, D.R. Martella, and J.E. Pratt. *An Economic and Mathematic Description of the Dairy Market Policy Simulator.* Dept. Agr. Econ. Report A.E. Res. 80–21, Cornell University, Sept. 1980.

Office of Technology Assessment. *Technology, Public Policy and the Changing Structure of American Agriculture.* Washington, D.C.: OTA-F-285, March 1986.

Schiek, W.A. "The Impact of Reverse Osmosis on Florida Milk Supplies." Master's Thesis, Department of Food and Resource Economics, University of Florida, 1988.

Schiek, W.A., and E.M. Babb. "Impact of Reverse Osmosis on Florida Milk Markets." Staff Paper No. 364, Food and Resource Economics Department, University of Florida, July 1989.

Stabile, R.L. "Economics of Reverse Osmosis and Multistage Evaporation for Concentrating Skim Milk from 8.8 to 45% Solid." *J. Dairy Science,* 66(1983):1765–71.

Whipple, G.D. "An Analysis of Reconstituted Fluid Milk Pricing Policy." *Amer. J. Agr. Econ.,* 65(1983): 207–13.

Winchell, E.H., and J.W. Hammond. *An Analysis of the Marketing Cost Impacts of Reverse Osmosis Concentration of Milk.* Dept. Agr. Econ. Report ER 84-1, University of Minnesota, Jan. 1984.