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The Potential for Structural Change in the Northeast Dairy Manufacturing Sector

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Abstract

A transshipment model of the Northeast dairy sector is developed to assess the potential for structural change in the manufacturing industry. It is determined that the reduction of existing hard product processing capacity near metropolitan areas would diminish total costs. Industry-wide savings of about 60 million dollars annually would be realized by fluid, soft product, cheese and butter/powder manufacturers. The model points to firm level as well as industry level incentives to move toward a more concentrated dairy manufacturing sector in the Northeast.

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The processing sector of the dairy industry has undergone considerable change over the last fifty years. Advances in milk handling, processing technologies and transportation have created an economic environment conducive to fewer and larger plants (Figure 1).

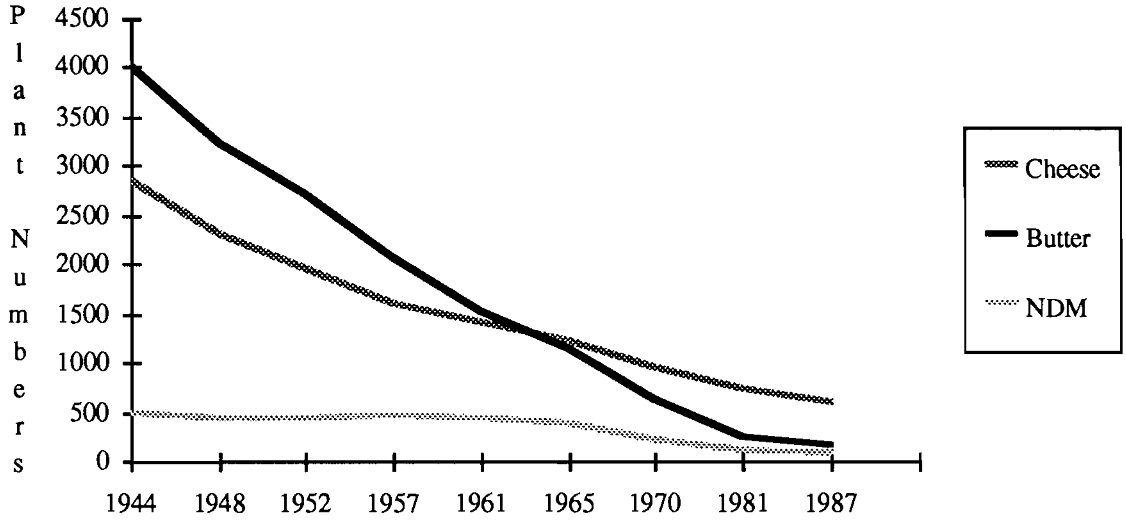

Figure 1. Numbers of Plants Producing Cheese, Butter and NDM.

The first dairy farms were also the processors and distributors of their products. As late as 1930, nearly half of dairy farms in this country were still manufacturing and selling their own cheese, butter and fluid milk (Manchester). The decline of this practice and subsequent specialization into manufacturing often occurred with farm–processors located near a population center. This established market for a processor was expanded by purchasing milk from increasingly distant farms. Two questions are considered in this paper: given the current processing and transportation environment, is there an incentive for greater concentration of the manufacturing industry in the Northeast; and given the evolutionary path of producer/processor to processor situated near the market, are plants optimally located in the Northeast.

A transshipment model is developed to describe the dairy sector from production to consumption in the Northeast.[1] For this model, the Northeast region is defined to include; Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia and the District

[1] A more complete description of the original NEDSS (Northeast Dairy Sector Simulator) or USDSS (U.S. Dairy Sector Simulator) model may be found in Pratt et.al. (1986) and Pratt (1989).

of Columbia. Additionally, Florida is included as a point of demand outside the Northeast region and the Upper Midwest is included as a point of supply to provide for the Northeast's net deficit of dairy products. The mathematical programming model operates as a single commodity, single time period network. Given estimated milk marketings, dairy product consumption, and assembly, processing and distribution costs, the model solves for optimal processing locations and product flows, given any constraints on processing locations and/or capacities. Figure 2 displays a simplified diagram of the network structure.

Milk production is allocated to 236 points of supply within the Northeast and one point in the Upper Midwest. 1985 County level data for each state are used. Aggregation decisions for the 436 counties in the region are made on the basis of the spatial distribution of production, volume of milk and geographic isolation.[2] Likewise, 1985 population data at the county level are aggregated to provide consumption estimates at 153 points within the Northeast, one point in the Southeast and at an unspecified location for the CCC purchases. Processing is allowed to occur at any of 303 locations within the Northeast and in the Upper Midwest.

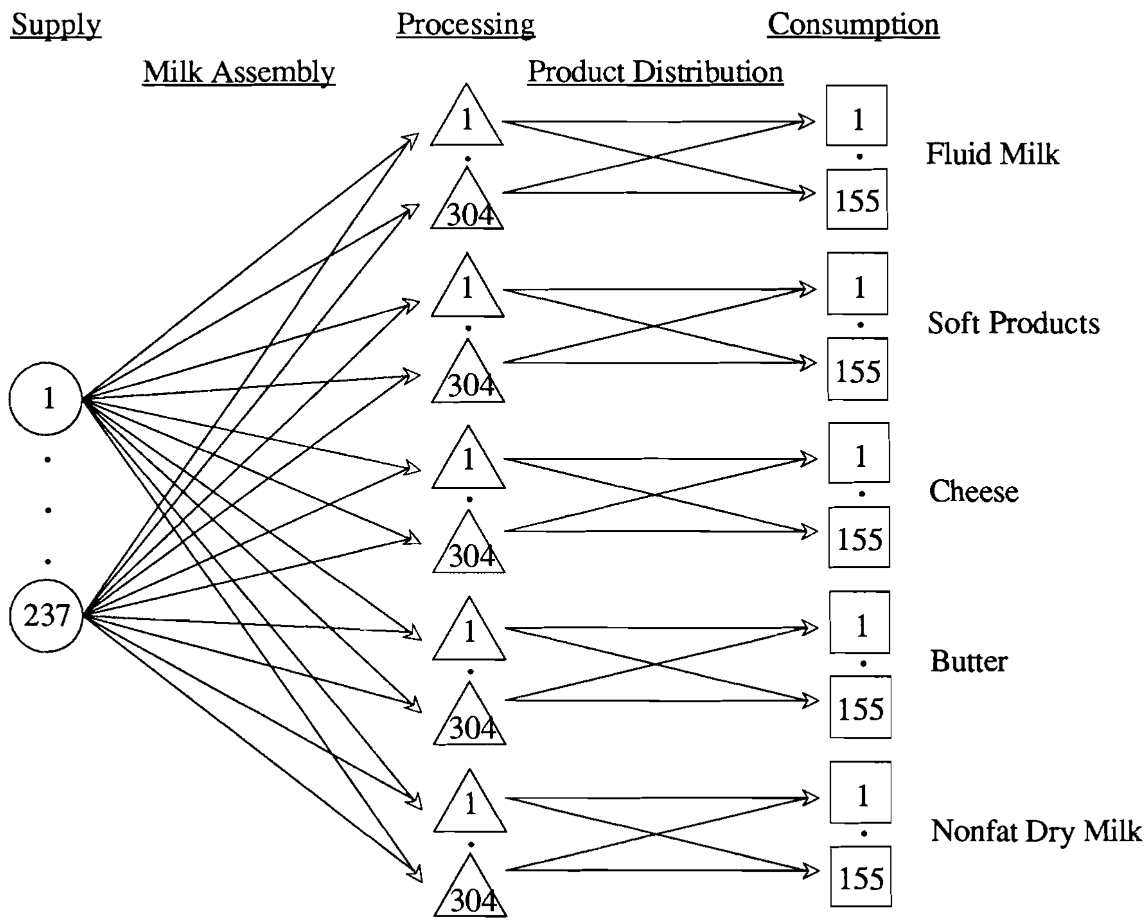

Figure 2. Network Structure of the Model.

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2 State boundaries were respected in that contiguous counties from different states were not aggregated.

Five product categories are identified; fluid milk, soft products, cheese, butter and nonfat dry milk (NDM). Per capita consumption estimates for the 1985 year are used to determine the demand for each product at each consumption point. Federal and state milk marketing order data within the region provide the basis for per capita fluid consumption. Determining per capita consumption in the soft products category is the most problematic. Federal and state milk marketing order data are used to assess sales of all products other than fluid, cheese, butter and NDM within the region. These values are compared to national consumption estimates for the major soft products and weighted average consumption values are determined. Per capita cheese demand is calculated from national average values and state consumption indices (Raunikar, 1972). However, because no known values for per capita consumption differences over regions exist, average U.S. consumption estimates are used for butter and NDM. As a check on assumptions, annual per capita milk equivalent values are determined for each state and average 573 pounds. This compares favorably with a 1988 national estimate by USDA of 585 pounds (Dairy Situation and Outlook Report, April 1989).

Per pound milk assembly and product distribution costs are a function of the miles between points in the network. Actual road mileages between all supply, processing and consumption points are determined. The cost functions used in the model are compiled from a number of sources. Table 1 displays the cost functions used and the basis for determining them.

Table 1. Transportation and Processing Cost Functions.

Category	Cost Function	Basis[3]
Transportation Costs[4]		
Milk Assembly	= 0.35 * one–way miles	(Pratt, 1989)
Fluid Milk	= 1.0006 * one–way miles	(Metzger)
Soft Products	= 1.1906 * one–way miles	(Metzger)
Cheese, Butter, NDM	= 14.437 + (1.1064 * one–way miles)	(Metzger)
Processing Costs[5]		
Fluid Milk	= $e^{(5.03 - 0.201 * ln(\text{lbs milk}))}$	(Thraen, Hahn and Roof)
Soft Products	= $e^{(6.27 - 0.269 * ln(\text{lbs milk}))}$	(Smith)
Cheese	= $e^{(8.08 - 0.386 * ln(\text{lbs milk}))}$	(Mesa-Dishington, Barbano and Aplin)
Butter	= $e^{(15.45 - 0.826 * ln(\text{lbs milk}))}$	(Stephenson and Novakovic)
Nonfat Dry Milk	= $e^{(16.87 - 0.860 * ln(\text{lbs milk}))}$	(Stephenson and Novakovic)

3 The functions shown here are based on the works cited but they have been updated to reflect 1985 prices and the functional forms may have been altered.

4 These values are in terms of cents per hundred pounds of product moved.

5 These values are in terms of cents per pound of milk used annually. Butter and NDM are milk equivalent values.

Given the geographic locations of milk supplies, dairy product consumption of each of the five classes, and dairy product processing capabilities, least cost flows of milk and dairy products as well as least cost locations of dairy processing facilities are determined. As a base scenario, no constraints to processing locations or volumes are specified at any site in the model. When processing and transportation costs are minimized, the solution reveals some strategies employed in achieving the least cost solution. Plant location and product flow solutions for the unconstrained case are displayed graphically in Figures 3 to 7. Figure 3 demonstrates the model's preference to move raw milk to fluid processing plants located at the point of consumption. The other extreme, seen in Figure 7, shows butter processors located at points of supply and moving finished product to consumption areas. The other product categories employ transportation strategies between these two bounds.

Of the five product categories, fluid milk and soft products are the most perishable, highest value and most costly to transport on a milk equivalent basis. The making of these products leaves cheese and butter/powder plants to claim the residual local milk supply. It should be clear that this outcome is a cost driven result of the model, not a precondition postulated by the researchers. Similar work in the past has often assumed this result as a way to minimize the methodological difficulties inherent in multiple commodity transshipment models. Figure 8 displays a dot density map of the residual supply after fluid and soft products have appropriated their milk in the unconstrained model solution. Most of the residual milk supply is located along the northwest portions of Vermont and New York and in central Pennsylvania and, it is in these areas areas that cheese and butter/powder plants would be expected to locate. As can be seen from Figure 8, the distribution of plants sites in the Northeast is somewhat uniformly dispersed. At least half of the actual plant locations do not coincide with the least cost supply of milk.

A typical cheese plant will process 200–250 million pounds of milk annually. This means that each of the plant locations in Figure 8 must capture 4–5 of the dots on the map. At this volume of throughput, a plant achieves much of the scale economies. A butter/-powder plant will process 300–400 million pounds and thus require 6–8 of the dots. Those manufacturing points that are located some distance from the residual milk and closer to consumption centers will compete with fluid and soft product manufacturers for a supply in their local area.

A substantial effort was undertaken to identify the location of all dairy processors in the Northeast and to determine the products produced there. The model is then constrained to process the known products at those locations. Additionally, where some knowledge of quantities processed at a location is available, approximate volume constraints are imposed. Table 2 shows the milk assembly, processing and distribution costs for the five product categories in the model runs constrained to simulate the existing processing composition and the unconstrained structure. Based on these two model runs, there are potentially 100 million dollars in annual industry gains that would accrue to a restructuring of processing in the Northeast. While this value is less than 1% of the 14 billion dollars that was spent by consumers on dairy products in the Northeast (Statistical Abstract of the United States), it represents nearly 9% of the cost of processing and transportation. The major portion of these gains are not from savings in processing costs but rather in transportation expenses. The reduction of transportation costs is about 41% from the existing industry structure.

As shown in Table 3, it is not just plant locations that differ but also the number of locations. The unconstrained, least–cost solution indicates a net gain in processor points which is almost entirely due to the number of fluid processing sites. Fluid plants sacrifice some returns to scale because they compete over a wider area for milk supplies. The number of soft product locations is little changed and cheese sites only slightly more so. However, butter/powder plant numbers are greatly different on a percentage basis.

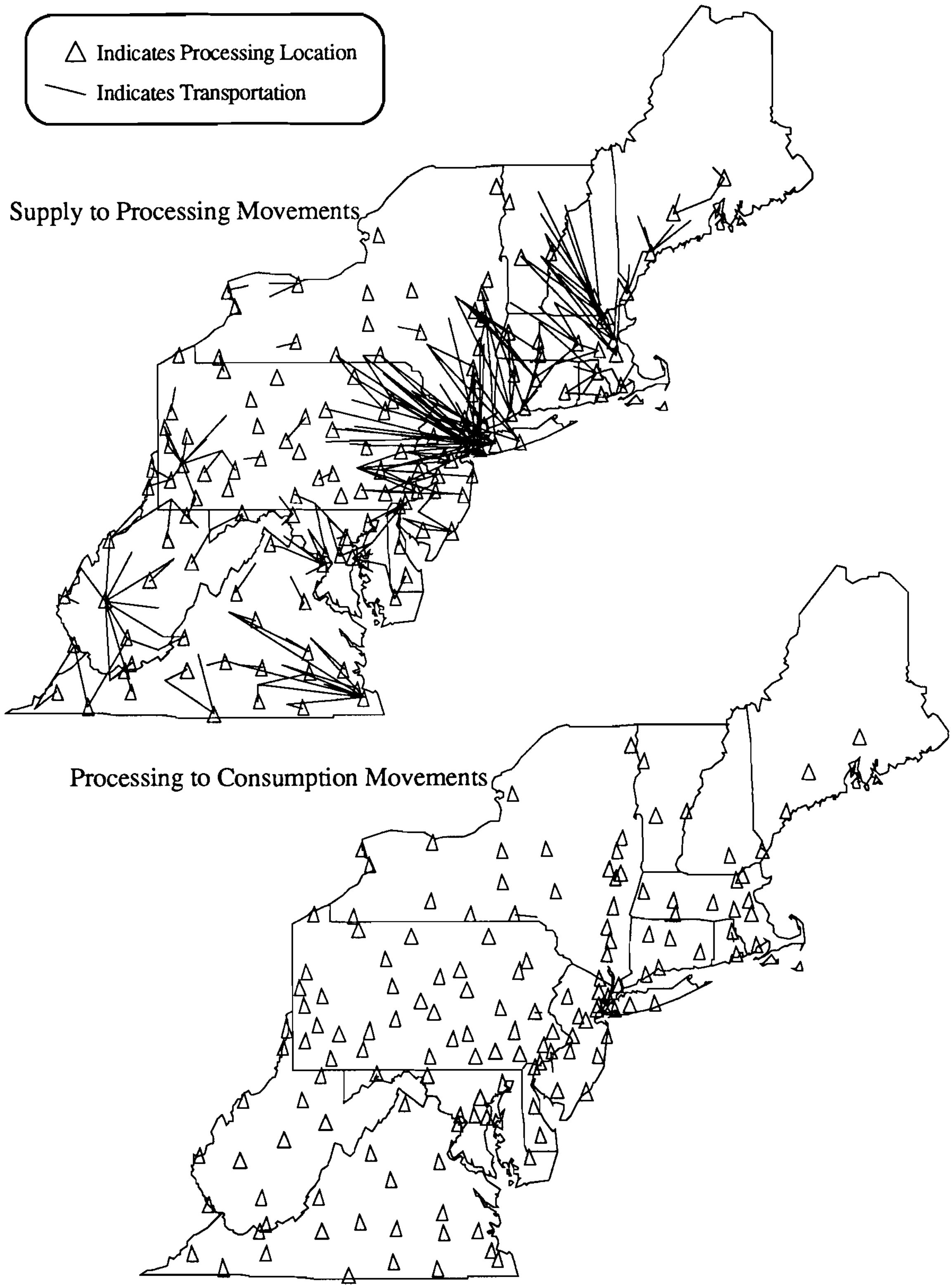

Figure 3. Fluid Milk Processing and Transportation.

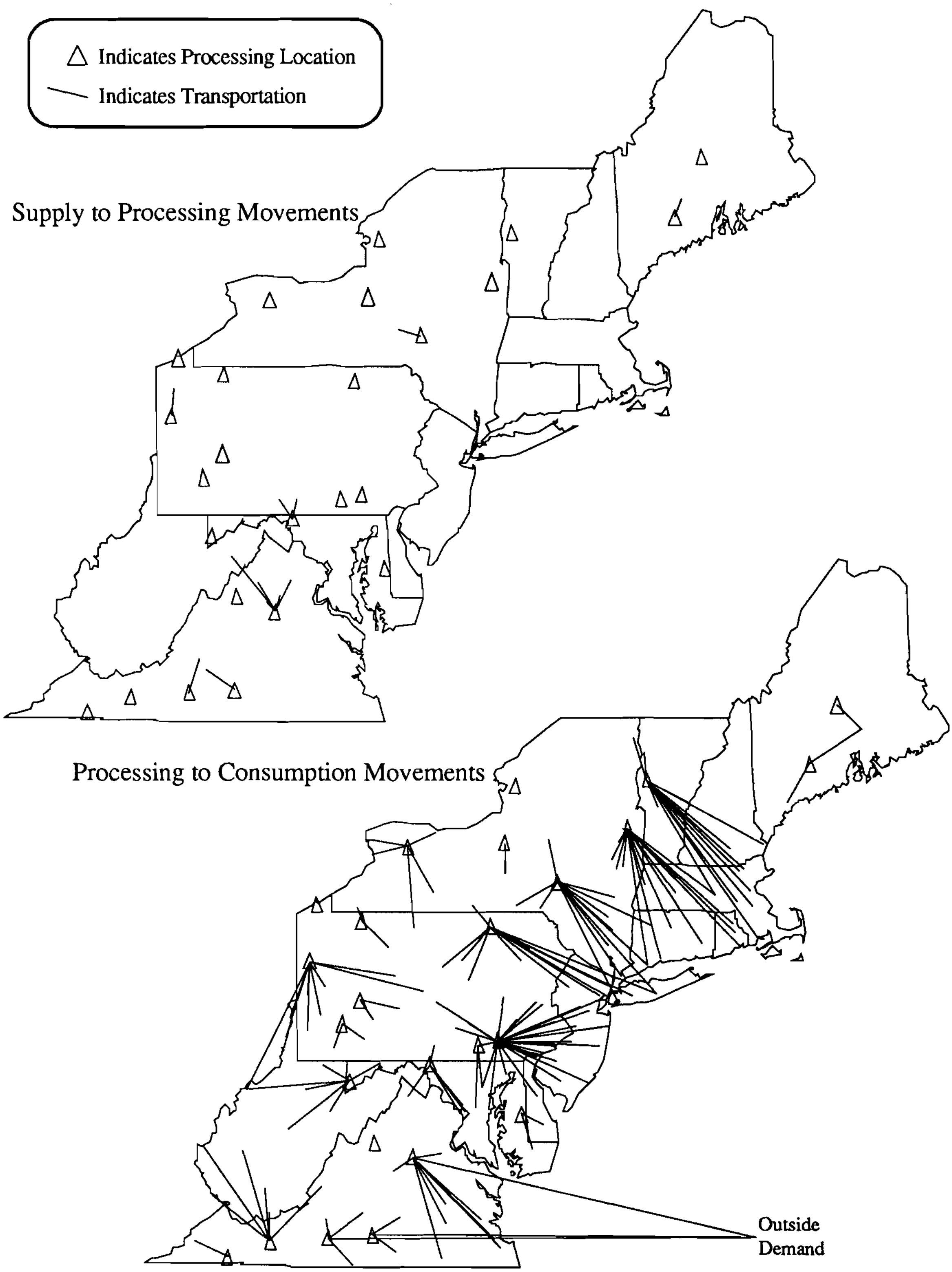

Figure 4. Soft Products Processing and Transportation.

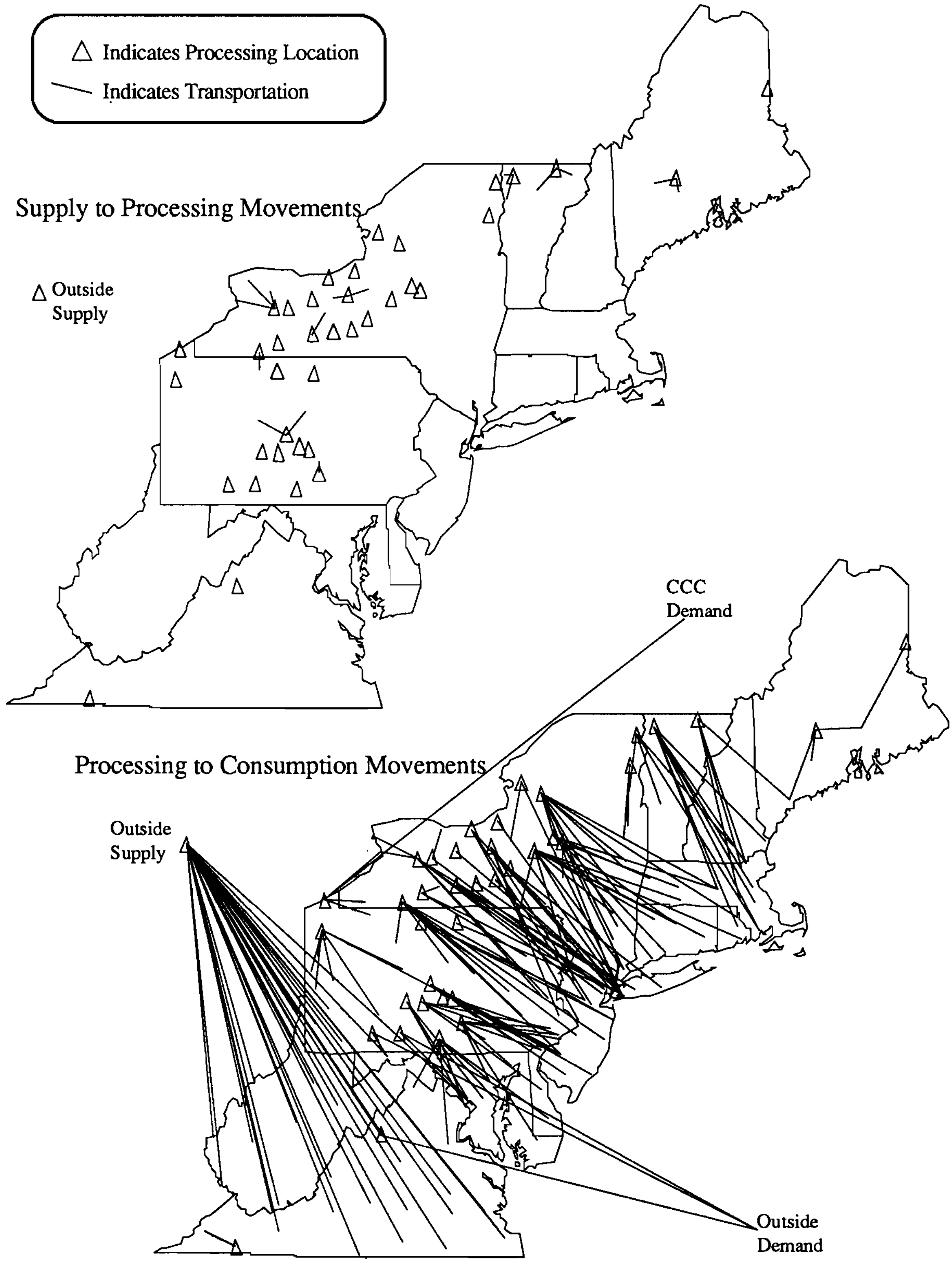

Figure 5. Cheese Processing and Transportation.

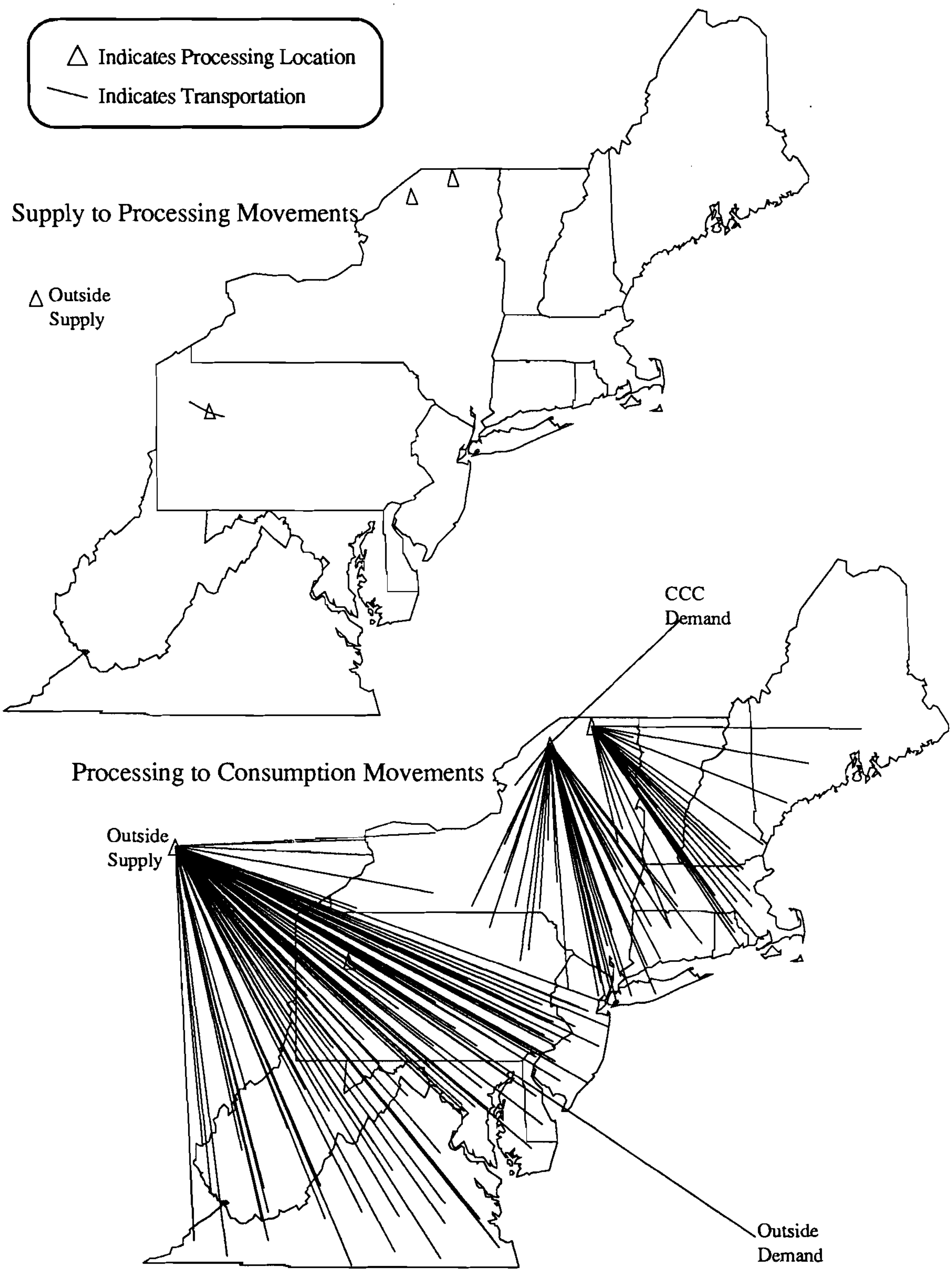

Figure 6. Nonfat Dry Milk Processing and Transportation.

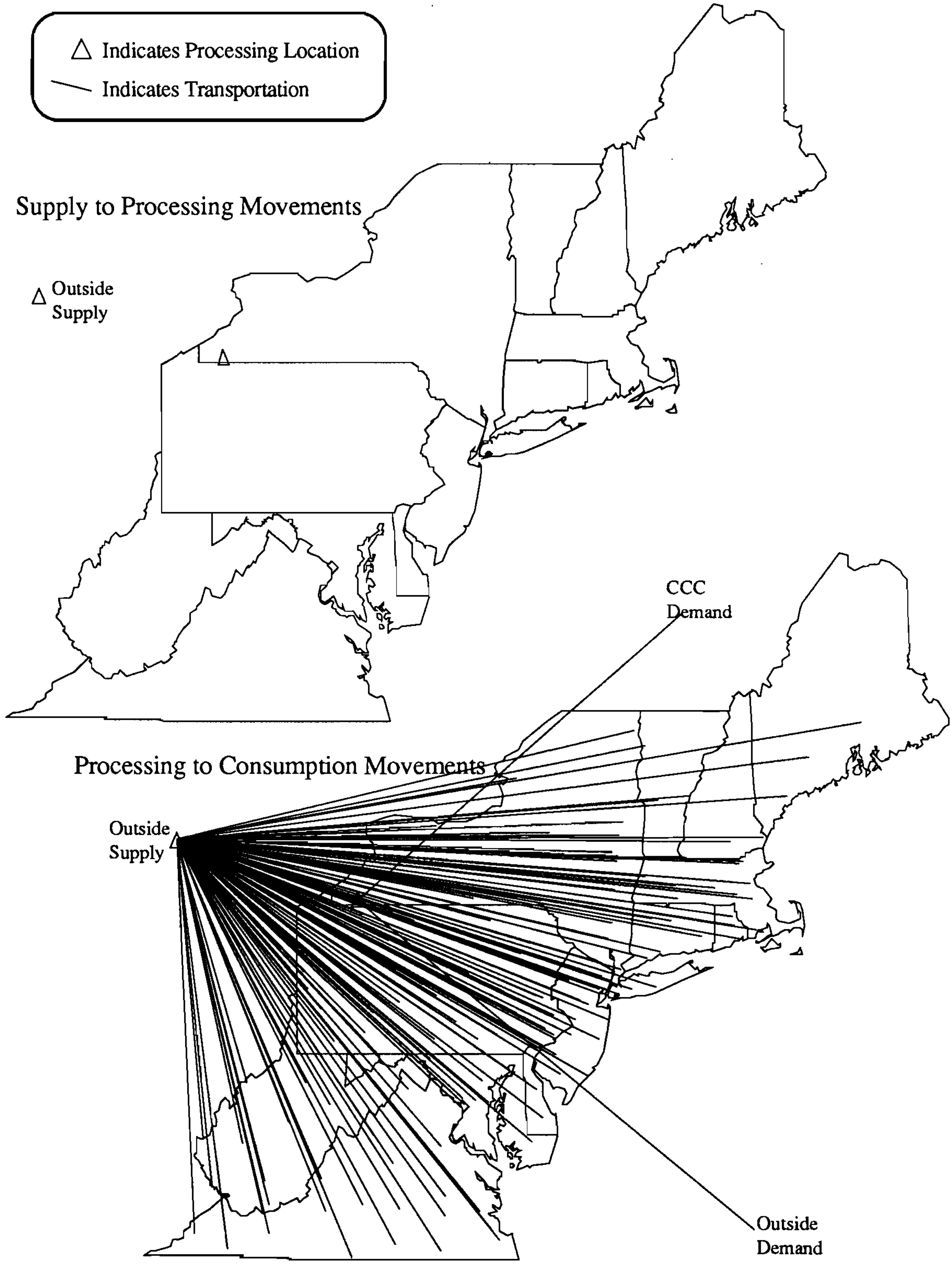

Figure 7. Butter Processing and Transportation.

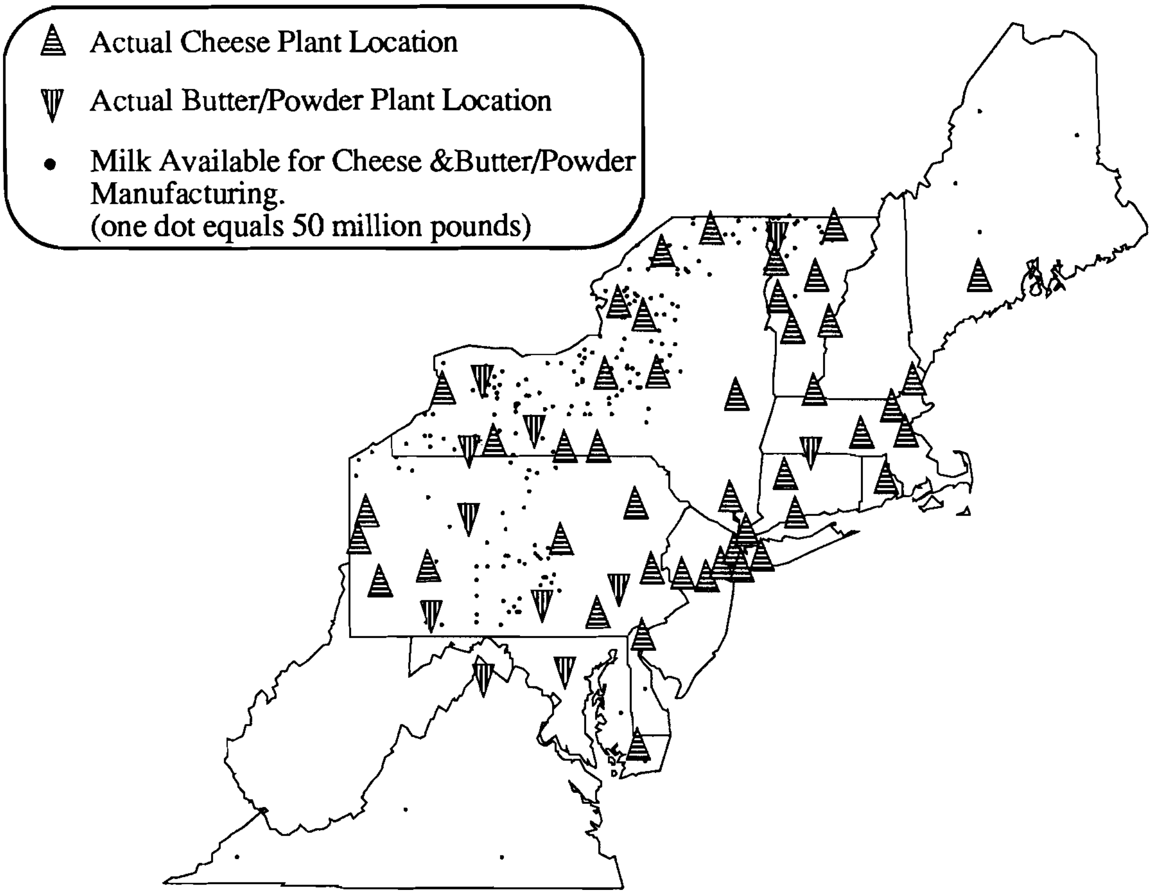

Figure 8. Residual Milk and Plant Locations.

While individual firms would be expected to seek minimum costs at the firm and not the industry level, shadow prices indicate that plants producing different products differ in their ability to compete for a milk supply at the same location. I.e., the incentives for change exist at both the firm and sector level. A change in industry structure would occur dynamically and not spontaneously as represented in the unconstrained run. For example, given the increased per unit processing costs, there would not be any incentive for fluid plants to alter their current size or location. Soft product plants look as though they have large gains to achieve by locating nearer points of consumption thus lowering distribution costs. Hard products manufacturing (cheese and butter/powder) can realize scale economies by reducing plant numbers in areas near population centers. To simulate the potential for realistic change, another model run is made constraining all processors to their existing locations and product class but volumes of milk received and processed is unconstrained. Where information is available on plant capacities, the volume at a given location is restricted to be less than or equal to some maximum. The results of this simulation are seen in Table 4.

Table 2. Transportation and Processing Costs of Actual and Unconstrained Plant Locations

		Existing Plants	Unconstrained	Difference
	Fluid	$52,873,238	$35,879,366	$16,993,872
Milk	Soft Products	$2,589,303	$1,000,176	$1,589,127
Assembly	Cheese	$24,861,549	$738,480	$24,123,069
	Butter	$4,341,259	$0[6]	$4,341,259
	Nonfat Dry Milk	$1,166,402	$25,576	$1,140,826
	Total	$85,831,751	$37,643,598	$48,188,153
	Fluid	$8,276,362	$233,502	$8,042,860
Product	Soft Products	$74,560,990	$16,622,533	$57,938,457
Distribution	Cheese	$31,918,987	$46,563,399	($14,644,412)
	Butter	$17,411,316	$24,000,404	($6,589,088)
	Nonfat Dry Milk	$10,073,118	$9,846,330	$226,788
	Total	$142,240,773	$97,266,168	$44,974,605
Total Transportation		$228,072,524	$134,909,766	$93,162,758
	Fluid	$479,244,074	$508,689,892	($29,445,818)
	Soft Products	$139,133,625	$139,553,704	($420,079)
Processing	Cheese	$208,655,255	$189,977,978	$18,677,277
	Butter	$56,823,782	$42,278,580	$14,545,202
	Nonfat Dry Milk	$57,294,937	$50,017,415	$7,277,522
	Total	$941,151,673	$930,517,569	$10,634,104
	Fluid	$540,393,674	$544,802,760	($4,409,086)
	Soft Products	$216,283,918	$157,176,413	$59,107,505
Total Costs	Cheese	$265,435,791	$237,279,857	$28,155,934
	Butter	$78,576,357	$66,278,984	$12,297,373
	Nonfat Dry Milk	$68,534,457	$59,889,321	$8,645,136
	Total	$1,169,224,197	$1,065,427,335	$103,796,862

Table 3. Numbers of Plant Locations.

	Existing Plants	Unconstrained	Difference %	Difference #
Fluid	105	147	40%	42
Soft Products	23	25	9%	2
Cheese	47	39	-17%	-8
Butter	10	2	-80%	-8
Nonfat Dry Milk	11	4	-64%	-7
Total	196	217	11%	21

6 Processing that occurs at the point of supply or consumption is assumed to incur no transportation costs. I.e. local assembly and distribution costs are assumed to have no bearing on the optimal location of plants and transportation of milk and dairy products.

Table 4. Transportation and Processing Costs of Actual and Unrestricted Plant Volumes

		Existing Plants	Constrained Locations	Difference
	Fluid	$52,873,238	$42,296,233	$10,577,005
Milk	Soft Products	$2,589,303	$3,098,455	($509,152)
Assembly	Cheese	$24,861,549	$10,260,718	$14,600,831
	Butter	$4,341,259	$340,881	$4,000,378
	Nonfat Dry Milk	$1,166,402	$1,042,367	$124,035
	Total	$85,831,751	$57,038,654	$28,793,097
	Fluid	$8,276,362	$8,174,056	$102,306
Milk	Soft Products	$74,560,990	$31,242,552	$43,318,438
Distribution	Cheese	$31,918,987	$49,214,719	($17,295,732)
	Butter	$17,411,316	$21,563,437	($4,152,121)
	Nonfat Dry Milk	$10,073,118	$6,865,933	$3,207,185
	Total	$142,240,773	$117,060,697	$25,180,076
Total Transportation		$228,072,524	$174,099,351	$53,973,173
	Fluid	$479,244,074	$479,917,157	($673,083)
	Soft Products	$139,133,625	$146,758,479	($7,624,854)
Processing	Cheese	$208,655,255	$196,392,232	$12,263,023
	Butter	$56,823,782	$50,146,245	$6,677,537
	Nonfat Dry Milk	$57,294,937	$58,665,790	($1,370,853)
	Total	$941,151,673	$931,879,903	$9,271,770
	Fluid	$540,393,674	$530,387,446	$10,006,228
	Soft Products	$216,283,918	$181,099,486	$35,184,432
Total Costs	Cheese	$265,435,791	$255,867,669	$9,568,122
	Butter	$78,576,357	$72,050,563	$6,525,794
	Nonfat Dry Milk	$68,534,457	$66,574,090	$1,960,367
	Total	$1,169,224,197	$1,105,979,254	$63,244,943

The model run with constrained locations indicates monetary benefits for all product categories over the existing situation. In fact, more than 60 percent of the potential gains from the unconstrained run are realized. To effect these gains, the model has dropped some cheese, butter and nonfat dry milk points located near population centers. This has allowed additional soft product sites to come into solution with the milk supplies that have been liberated. Table 5 indicates a loss of 15 hard product operations and the addition of 11 soft product plants. The location of the hard product plants that have dropped out of solution are shown in Figure 9.

The transshipment modeling of the Northeast dairy sector indicates that relative to the supply of milk and the demand for dairy products, there appears to be excess capacity to process cheese, butter and nonfat dry milk in the region. Although some product categories could realize scale economies through plant closures, greater potential savings exist in more efficient milk assembly and product distribution. With the selective closure of existing hard product plants in heavily populated areas, all five product categories are able to reduce total costs. The model points to existing economic incentives at industry and firm levels that would continue the concentration of the dairy manufacturing sector in the Northeast.

Table 5. Numbers of Plant Locations.

	Existing Plants	Constrained Locations	Difference %	Difference #
Fluid	105	105	0%	0
Soft Products	23	34	48%	11
Cheese	47	37	-21%	-10
Butter	10	6	-40%	-4
Nonfat Dry Milk	11	10	-9%	-1
Total	196	192	-2%	-4

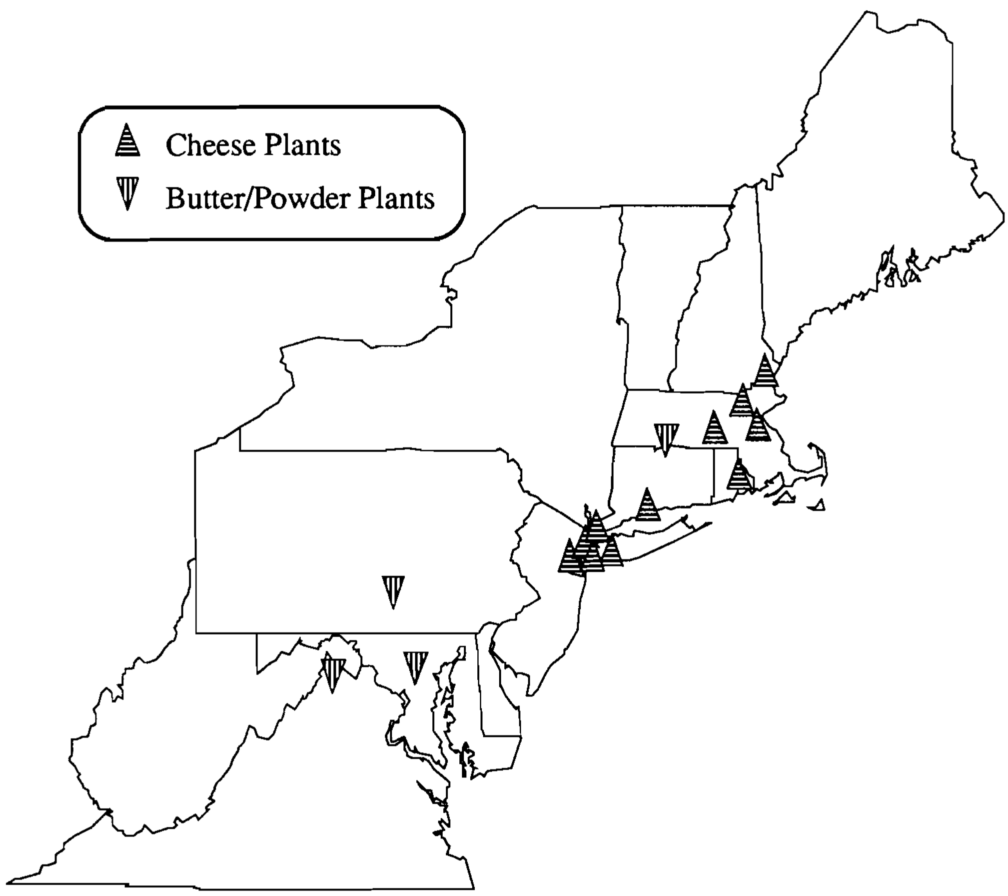

Figure 9. Non–Optimal Plant Locations.

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