Historical Development and Current Description of Spatial Dairy Models at Cornell University

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DaMPS - Dairy Market Policy Simulator

Beginning in 1976, an effort to develop a spatially oriented model of Federal Milk Marketing Orders (FMMO's) was undertaken at Purdue University. By 1979 the original model was expanded (see, Novakovic et. al.) to include state milk marketing orders, unregulated milk, fluid and manufacturing processing sectors, and government and commercial storage of manufactured products. The model is solved using optimization and is recursive for 20 quarters from some user specified base period. In 1981, DaMPS was moved from Purdue to Cornell University, where the programming code was updated and standardized to the current versions of Fortran. In 1988, it was moved to the University of Florida by Emerson Babb and Bill Schiek, where a micro-computer version was developed and an updated 1988 base data set was established. Cornell University and Florida currently work together to keep the model functioning and current.

Given 1) FMMO, State order, and unregulated milk supplies, 2) the spatial demand for fluid and three classes of manufactured dairy products, 3) FMMO and State order pricing and pooling provisions, and 4) federal government policy with respect to support program activities, DaMPS gives the minimum cost spatial organization of dairy market activities, i.e. intermarket flows of milk and milk products and the resulting prices, quantities, and stocks of milk and dairy products.
Least-Cost Milk Assembly

Beginning in 1983, Cornell became involved in various studies of optimal farm-to-plant assembly. Initially, this involved a detailed study of farm milk assembly in central New York State that included approximately 470 farms, 6 processing plants, and 6 haulers operating 63 every-other-day farm milk assembly routes. Computerized vehicle scheduling algorithms were used to find sets of "best" routes under various organizational constraints and these were compared to actual route patterns.

Computerized vehicle scheduling has been used to measure the level of efficiency in various milk assembly operations. It has also been used to analyze the economic potential of on-farm ultrafiltration of milk and the economic incentives for assembly of milk from farms segregated on the basis of herd-level protein content.

Regional and National Models of the Geographic Organization of the Dairy Industry

Beginning in 1986, Cornell became involved in efforts to model detailed spatial dairy markets. The Northeast Dairy Sector Simulator (NEDSS), the U.S. Dairy Sector Simulator (USDSS), and the Federal Order Simulator (FOS) are all highly disaggregated optimization models of spatial dairy markets. They are based on three market levels, supply-processing-consumption, for various numbers of products (fluid, soft, cheese, powder, butter, etc.) and cover various geographic areas with varying degrees of spatial density. For instance, the most recent model, FOS,
basically uses county level disaggregation for supply and consumption and includes data on processing operations which is almost firm specific. USDSS on the other hand is based on multi-county aggregations at all three market levels.

These models give us optimum flows of milk and milk products from supply to processing and from processing to consumption points. They also give us the optimum processing locations and sizes and the marginal values of constrained resources (shadow prices) for supplies, demands, and processing capacities. Under various scenarios, these results can be used to look at issues of efficient operations for individual firms or to analyze policy related issues involving individual markets or sets of markets.

The most recent model, FOS, allows for the movement of skim milk and cream between processors as inputs and outputs of dairy product processing. It also includes the capability to model various forms of spatial competition between processors for milk supplies and various regulatory constraints, such as shipping requirements on pooled processors.

Description of the Current Model - FOS

The Federal Order Simulator (FOS) is a mathematical programming model of physical dairy marketing activities that simulates a generic federal milk marketing order in a specific geographic area. The model, a modification of work done by Pratt, et. al. (1986, 1989) and Stephenson (1990), incorporates a transshipment network flow structure into a more general linear programming framework.
The FOS model departs from previous spatial models with respect to 1) the explicit consideration of regulatory pricing and milk movement rules, 2) interplant transfers of skim milk and cream as possible types of marketing flows, and 3) the multi-commodity nature of milk component movements.

As adapted, the model represents a more complete system of basic marketing activities identifying flows of farm milk, skim and cream milk components, and finished milk products from farms through processing plants to final consumers. Development of the model focused on constructing a flexible tool for regulated dairy market analysis. As such, the resultant model can be adapted for a wide range of market structures to examine optimal market outcomes.

The tableau representation of FOS is presented in Figure 1. It describes the physical block structure layout and relative size of the current linear programming model. The size of the problem is not fixed. Any number of supply, demand, and processing locations can be modelled. The tableau is partitioned into five blocks of columns or sets of activities that describe a dairy market operating under a milk marketing regulatory structure.

Milk receiving (block 2), milk processing (block 4), and three functional types of movement activities are identified representing assembly (block 1), interplant transfers (block 3), and distribution (block 5). These activities describe farm-to-plant, plant-to-plant, and plant-to-consumer movements, respectively.

For the 1991 application of FOS, milk supply locations were identified for 98 farm milk production points. Each supply point was assigned information on the
volume of production, the percentage of milk fat, and the percentage of the milk that is affiliated with a dairy cooperative.

Final consumer milk and milk product demands were aggregated to 31 consumption locations plus one outside demand balancing point. Populations and estimated per capita consumption for five different product types determine consumer demand. Product types are classified into fluid, soft products, cheese, butter, and nonfat dry milk categories.

Processing activities for each of five product types are free to occur at any supply or demand location with no restrictions on the capacity processed at any given location. This can be modified to replicate known processing locations and/or plant capacities.

The level of skim milk and milk fat components needed to produce a given volume of finished consumer product determines the plant-level demand for skim and cream. The level of milk fat and skim milk needed at processing locations is obtained through direct procurement of farm milk and/or interplant shipments of skim milk and 40 percent cream.

Although not programmatically necessary for the FOS solution procedure, the level of farm milk supplies which are in excess of plant level demand are forced to be utilized in either butter or nonfat dry milk processing activities. This requirement can simulate the balancing function provided by certain processing firms in dairy markets or the role of the Commodity Credit Corporation (CCC) purchasing storable dairy commodities. The estimated levels of excess skim and
cream component demands are allocated to an assumed outside consumer demand point for butter and nonfat dry milk.

Road distances between each milk supply point, plant location, and market consumption location form a road network that describes the available transportation system within a geographic area. Raw milk assembly (farm-to-plant) transportation costs are modelled using a linear fixed plus variable cost relationship. Interplant transfer (plant-to-plant) movements use a similar linear cost function; however, an additional fixed charge per hundredweight is added to cover the extra cost involved in reloading and handling interplant transfers. Milk and milk product distribution (plant-to-consumer) costs are identified for each product type with a linear fixed plus variable cost relationship. All milk or milk product movement cost functions are the same throughout the geographic region on a per unit basis. All per unit movement costs are linearly dependent only on the distance that the volume is moved.

FOS processing costs are non-linear relationships that exhibit scale economies involved in milk processing. The assumed cost functions used in FOS display both declining average and declining marginal costs as more volume is processed. Although the underlying functional forms do not exhibit increasing marginal processing costs even at large volumes, economic theory suggests that there are limits to potential scale economies achievable at processing facilities. Stephenson (1990) suggests using a maximum achievable scale economy plant size equivalent to 1.5 million pounds of raw milk processed per day. Thus, the processing cost
functions are specified to maintain constant average cost characteristics beyond this volume. The non-linear processing costs are incorporated into the linear programming model using an iterative heuristic solution procedure outlined by King and Logan (1964).

Any single time period can be analyzed using FOS. For the time frame chosen, both raw milk supply and final product demand profiles are fixed. This allows market movement and volume activities to be analyzed isolated from any recursive or dynamic effects of supply and demand price responses.

Within this structural framework, FOS determines optimal milk component movement allocations and processing locations given a set of imposed regulatory constraints with fixed levels of supply and demand.
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Figure 1. Tableau Representation of the Block Structure of FOS
BIBLIOGRAPHY


