September 1980

A.E. Res. 80-21

An Economic and Mathematic Description of the Dairy Market Policy Simulator (Model A)

A.M. Novakovic, E.M. Babb,

D.R. Martella, and J.E. Pratt

Department of Agricultural Economics
Cornell University Agricultural Experiment Station
New York State College of Agriculture and Life Sciences
A Statutory College of the State University
Cornell University, Ithaca, New York 14853

TABLE OF CONTENTS

LIST OF FIGURES

AN ECONOMIC AND MATHEMATIC DESCRIPTION OF THE DAIRY MARKET POLICY SIMULATOR (Model A)

AN OVERVIEW OF THE CONCEPTUAL DESIGN

The Dairy Market Policy Simulator, or DAMPS, is a transshipment model of the U.S. dairy sector. DAMPS is designed to simulate cost minimizing behavior in the dairy sector for quarterly periods for one to five years. Dynamic elements of the dairy sector are represented in DAMPS by the carryover of dairy stocks between quarters and by a lagged response of production and consumption to prices. Supply and demand functions used in DAMPS represent the behavior of producers and consumers in the short run. Geographically, the dairy sector is divided into federal milk marketing order areas, states having state order regulations, multi-state regions for unregulated Grade A milk, and multi-state regions for Grade B milk.

A diagrammatic sketch of the conceptual elements of DAMPS is shown in Figure 1. Model components include:

- supplies of Grade A milk
- supplies of Grade B milk
- processing activities
- demands for fluid (Class I) products, soft (Class II) manufactured products, cheese, butter, nonfat dry milk, and miscellaneous hard (Class III) manufactured products
- imports of cheese, butter, nonfat dry milk and miscellaneous Class III products
- commercial stocks of cheese, butter, and nonfat dry milk
- government stocks of cheese, butter, and nonfat dry milk
- transportation activities

Dairy markets are represented by a three-stage process. In the first stage of DAMPS, regulated and unregulated Grade A milk supplies and fluid product demands are modeled. Grade B milk supplies and perishable manufactured products, cheese, and miscellaneous storable products demands are described in stage two. The third stage treats butter and nonfat dry milk markets. For each quarter that the model is run, the three stages are solved sequentially.

All subsectors, except the unregulated Grade A milk subsector, are assumed to behave in a manner conforming to the transshipment problem, where the objective is to minimize the sum of assembly, processing, and distribution costs subject to constraints reflecting plant capacities, federal and state order requirements, and economic or institutional barriers to trade. The unregulated Grade A milk subsector is modeled in a more traditional, static, supply and demand framework.

The transshipment problem is formulated and solved as a capacitated network, hence it may be appropriate to discuss the general methodology of network models prior to the discussion of DAMPS.

THE TRANSSHIPMENT PROBLEM AS A CAPACITATED NETWORK

The general transshipment problem can be described as one of determining an optimal allocation of a good from a set of source (supply) points to a set of destination (demand) points, after passing through a set of intermediate (processing or transshipment) points. Optimality is usually defined by a cost minimizing objective function, where cost is at least a transportation cost.

The set of source points could be supply points for some raw material, representing supplying firms or centers of supplying regions (e.g., supply in New York). Intermediate points could correspond to processing firms, warehouses or centers of processing regions (e.g., manufacturing in southeastern New York). Destination points could represent consumers or centers of demand regions (e.g., demand in New York City).

Transshipment problems can, in general, be formulated and solved as a linear programming, transportation, or network model. A network or, more precisely, a capacitated network formulation is used in DAMPS because network algorithms are more computationally efficient for solving large transshipment problems (8). The adjective "capacitated" simply implies that there are upper or lower bounds on movements in the network.

Points in a network are called nodes. Each production, processing, and consumption point in the transshipment problem is represented by a node. Artificial or dummy nodes may be used to set up restrictions or bounds on movements. The paths connecting nodes are called arcs. It is assumed that the quantities supplied and demand are measured in the same units and are fixed and constant at the points of origin.[1/]

Consider a simple example with three production points (S_1, S_2, and S_3); two processing points (P_1 and P_2); three consumption points (C_1, C_2, and C_3); a production good (X); and a consumption good (Z). Suppose that the quantities supplied at S_1, S_2, and S_3 are X_1, X_2, and X_3, respectively. Assume that a unit of good X is proportional to a unit of good Z by a factor b, such that the market clearing constraint could be written as:

1/ Progress has been made in adapting network models to handle price responsive supply and demand. Polito (14) offers an example of the work in this direction. Unfortunately, current methods involve a considerable sacrifice in computational efficiency, limiting their usefulness for large models.

Figure 2. A Capacitated Network Formulation of a Simple Transshipment Problem

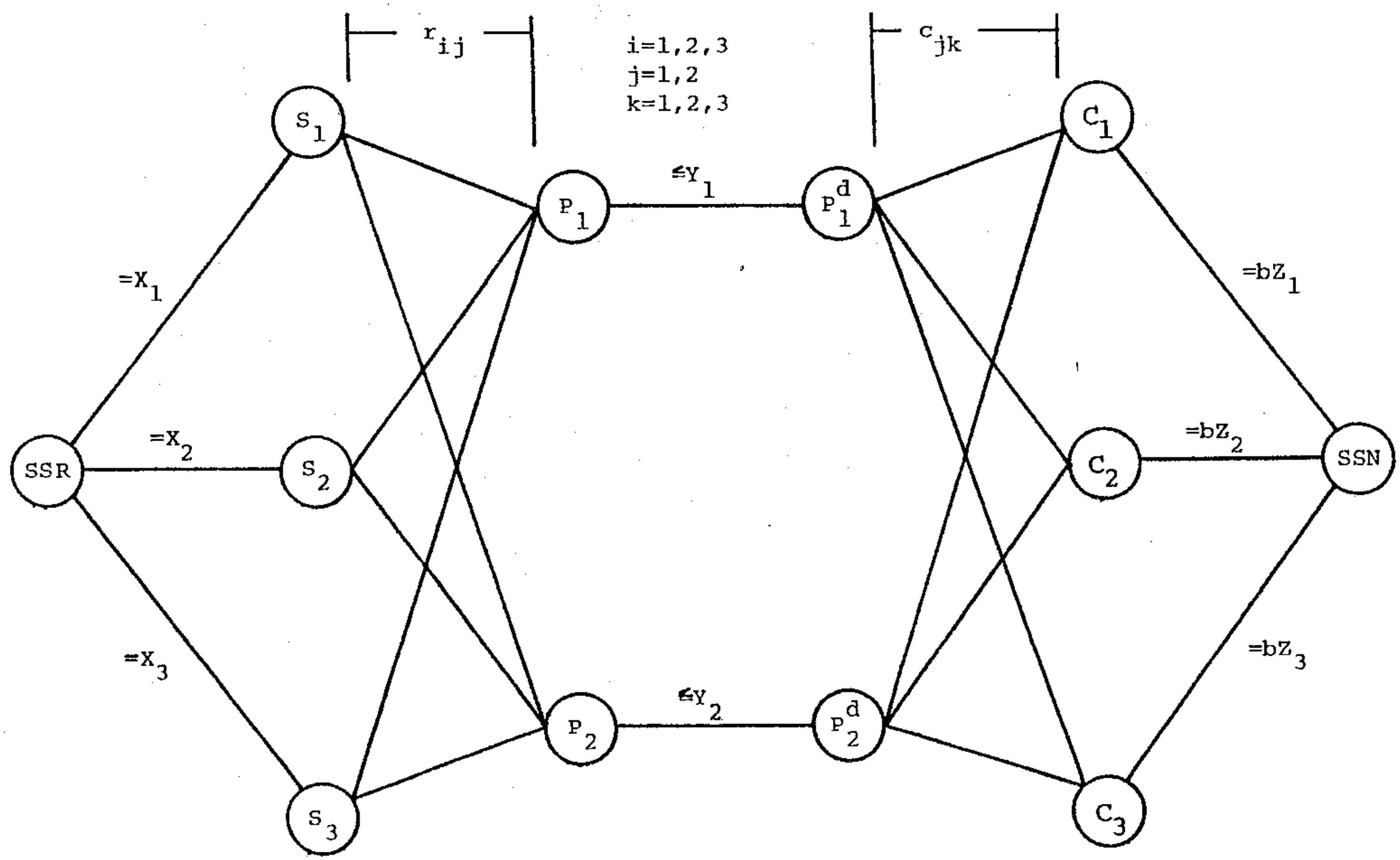


Figure 3. Stage One of the Dairy Market Policy Simulator

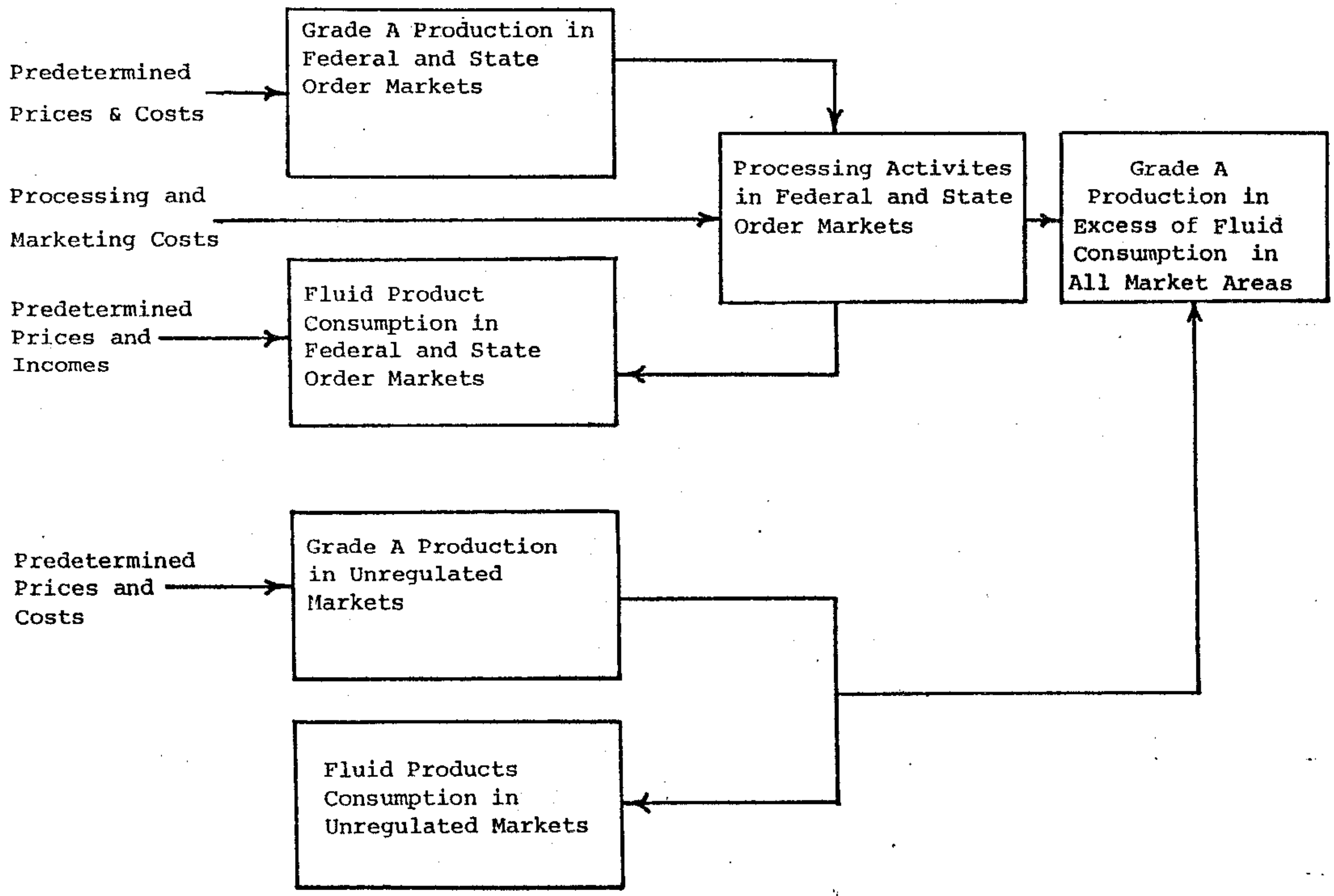


Table 1. Labels, Numbers and Definitions of Nodes in Stage One of DAMPS

Label	Identification Number	Number of Nodes	Definitions
DS	1-29	29	Direct-shipped production centers for federal orders without supply plant milk.
DS	30-45	16	Direct-shipped production centers for federal orders with supply plant milk.
SP	46-61	16	Supply plant production centers for federal orders with supply plant milk.
DSS	62-75	14	Direct-shipped production centers for state orders.
DSD	76-120	45	Direct-shipped production center dummies for federal orders.
DSSD	121-134	14	Direct-shipped production center dummies for state orders.
P	135-179	45	Fluid milk processing centers for federal orders.
PS	180-193	14	Fluid milk processing centers for state orders.
SM	194-219	26	Single manufacturing centers for federal orders
SMS	220-233	14	Single manufacturing centers for state orders.
SMD	234	1	Single manufacturing center dummy.
MM	235-261	27	Multiple manufacturing centers for federal orders.
MMD	262	1	Multiple manufacturing center dummy.
PD	263-307	45	Fluid milk processing center dummies for federal orders.
PSD	308-321	14	Fluid milk processing center dummies for state orders.
C	322-366	45	Fluid consumption centers for federal orders.
CS	367-380	14	Fluid consumption centers for state orders.
MS	381	1	Manufacturing center sink.
SSR	382	1	Super source.
SSN	383	1	Super sink.

Table 2. Federal Order Market Areas and Production Centers Used in DAMPS

Order Number	Federal Order Name[a/]	Production Center
1	New England-DS	Pittsfield, MA
	-SP	Montpelier, VT
2	New York-New Jersey-DS	Oneonta, NY
	-SP	Cortland, NY
4	Middle Atlantic	Gettysburg, PA
12	Tampa Bay	Tampa, FL
13	Southeastern Florida	Okeechobee, FL
6	Upper Florida	Lake City, FL
7	Georgia-DS	Macon, GA
	-SP	Atlanta, GA
40	Southern Michigan-DS	Lansing, MI
	-SP	Lansing, MI
36	E. Ohio-W. Pennsylvania-DS	Canton, OH
	-SP	Canton, OH
33	Ohio Valley	Bellafontaine, OH
44	Michigan Upper Peninsula	Marquette, MI
30	Chicago Regional-DS	Janesville, WI
	-SP	Oshkosh, WI
46	Lous.-Lex.-Evan.	Louisville, KY
49	Indiana	Kokomo, IN
32	Southern Illinois-DS	Centralia, IL
	-SP	Centralia, IL
50	Central Illinois	Peoria, IL
68	Upper Midwest-DS	Rochester, MN
	-SP	Minneapolis, MN
76	Eastern South Dakota	Sioux Falls, SD
75	Black Hills	Rapid City, SD
79	Iowa-DS	Waterloo, IA
	-SP	Waterloo, IA
65	Nebraska-Western Iowa-DS	Columbus, NB
	-SP	Columbus, NB
62	St. Louis-Ozarks-DS	Springfield, MO
	-SP	Springfield, MO
64	Kansas City/Neosho Valley-DS	Kansas City, KS
	-SP	Kansas City, KS
73	Wichita	Wichita, KS
99	Paducah	Paducah, KY
98	Nashville	Nashville, KY
97	Memphis	Memphis, TN
101	Tennessee Valley-DS	Knoxville, TN
	-SP	Knoxville, TN

Table 3. Regulated States, Production Centers, and Processing and Consumption Centers Used in DAMPS

Regulated States	Production Center	Processing-Consumption Center
Alabama	Birmingham	Birmingham
California	Fresno	San Luis Obispo
Maine	Auburn	Portland
Massachusetts	Pittsfield	Boston
Montana	Helena	Helena
Nevada	Fallon	Carson City
New York	Watertown	Rochester
North Carolina	Statesville	Raleigh
North Dakota	Bismarck	Bismarck
Pennsylvania	Lock Haven	Scranton
South Carolina	Columbia	Charleston
Vermont	Montpelier	Montpelier
Virginia	Lynchburg	Richmond
Wyoming	Lander	Casper

Figure 5. Super Source to Production Nodes, a Cross-Section of Stage One of DAMPS

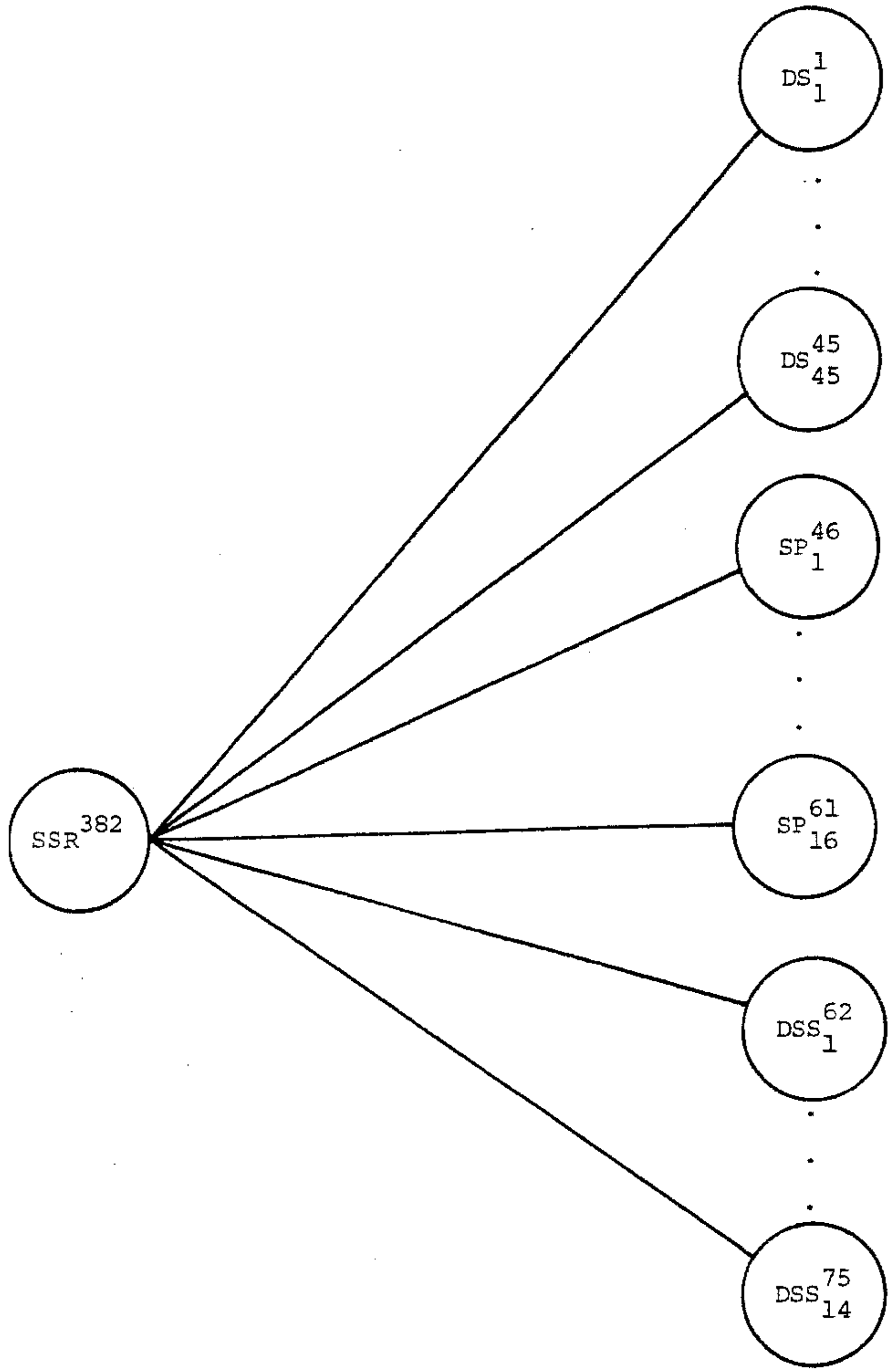


Table 5. Regulated Grade A Areas Aggregated by Manufacturing Milk Regions

Manufacturing Milk Region		Grade A Areas[a/]
Northeast	FO:	Middle Atlantic
		Ohio Valley
		New England
		New York-New Jersey
		Eastern Ohio-Western Pennsylvania
	SO:	Maine
		New York
		Pennsylvania
		Vermont
		Virginia
Corn Belt	FO:	Michigan Upper Peninsula
		Louisville-Lexington-Evansville
		Indiana
		Central Illinois
		Paducah
		Southern Michigan
		Southern Illinois
		Iowa
		St. Louis-Ozarks
Lake	FO:	Chicago Regional
		Upper Midwest
Southeast	FO:	Tampa Bay
		Southeastern Florida
		Upper Florida
		Georgia
South Central	FO:	Nashville
		Memphis
		Central Arkansas/Fort Smith
		Okalahoma Metropolitan
		Red River Valley
		Texas Panhandle
		Lubbock-Plainview
		Greater Louisiana
		New Orleans-Mississippi
		Tennessee Valley
		Texas
	SO:	Alabama

varied, the projected increases in direct costs are subtracted from the farm price of milk to reflect the reduced real return to dairy producers.

The amount of Grade A milk produced in any period can be affected by the number of Grade B milk producers who convert to Grade A milk production. Grade B milk producers have had economic and institutional incentives to convert to Grade A milk production. This increases the number of Grade A producers and decreases the number of Grade B producers. Although economic incentives, such as Grade A milk prices being higher than Grade B milk prices plus the cost of converting, and institutional incentives, such as the unwillingness of handlers to haul cans, seem to play a role, no quantifiable relationship could be found between conversion and measurable incentives. For that reason, the historically stable trend in the quantity of Grade B milk converting to Grade A milk was simply extrapolated for five years. When exogenous factors are varied, the amount of Grade B milk specified in the base data (13) to convert to Grade A milk production in an area is added to Grade A milk production in the current year and the base year. This explicit change in Grade A and Grade B milk production is intended to reflect an implicit change in the number of Grade A and Grade B milk producers.

Movements from Production Centers to Fluid and Manufacturing Milk Plants

The processing plant locations represented in DAMPS for federal and state regulated areas are listed in Tables 6 and 3, respectively. The portion of the DAMPS network that models the links between production centers and these processing plants is shown in Figures 6 through 8. All production nodes are connected to processing nodes and to one of two types of manufacturing nodes--single manufacturing or multiple manufacturing nodes.[4/]

An option in the model permits links between a state area and federal order or other state areas; available links are specified in the base data (13).[5/] To ease the exposition of the model, no inter-area links are shown or further discussed for state areas. The links specified in the base data are not systematic in any node numbering scheme but are based on distances from state areas to other state and federal order areas. In other words, state areas may be linked only to other marketing areas that are in close proximity.

4/Manufacturing plants modeled in this stage (Stage 1) refer to plants that are pooled under market orders. They represent a subset of the manufacturing facilities modeled in Stages 2 and 3, but they are essential in Stage 1 for computing blend prices.

5/Other things being the same, simulations with and without these links resulted in virtually identical solutions in the aggregate, although inter-area movements did occur and could be significant for an individual area.

Figure 6. Federal Order Direct Ship to Processing and Manufacturing Nodes, a Cross-Section of Stage One of DAMPS.

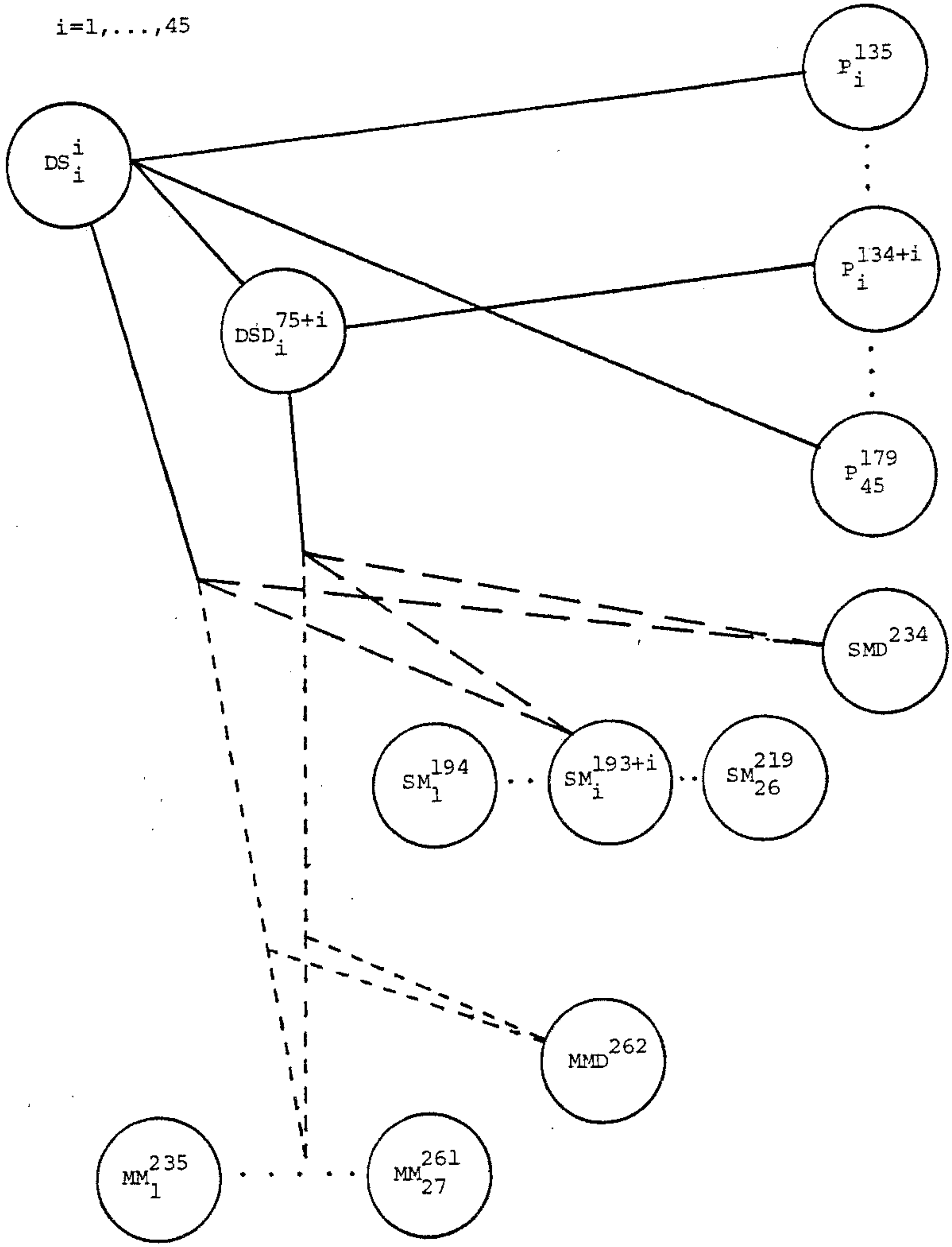
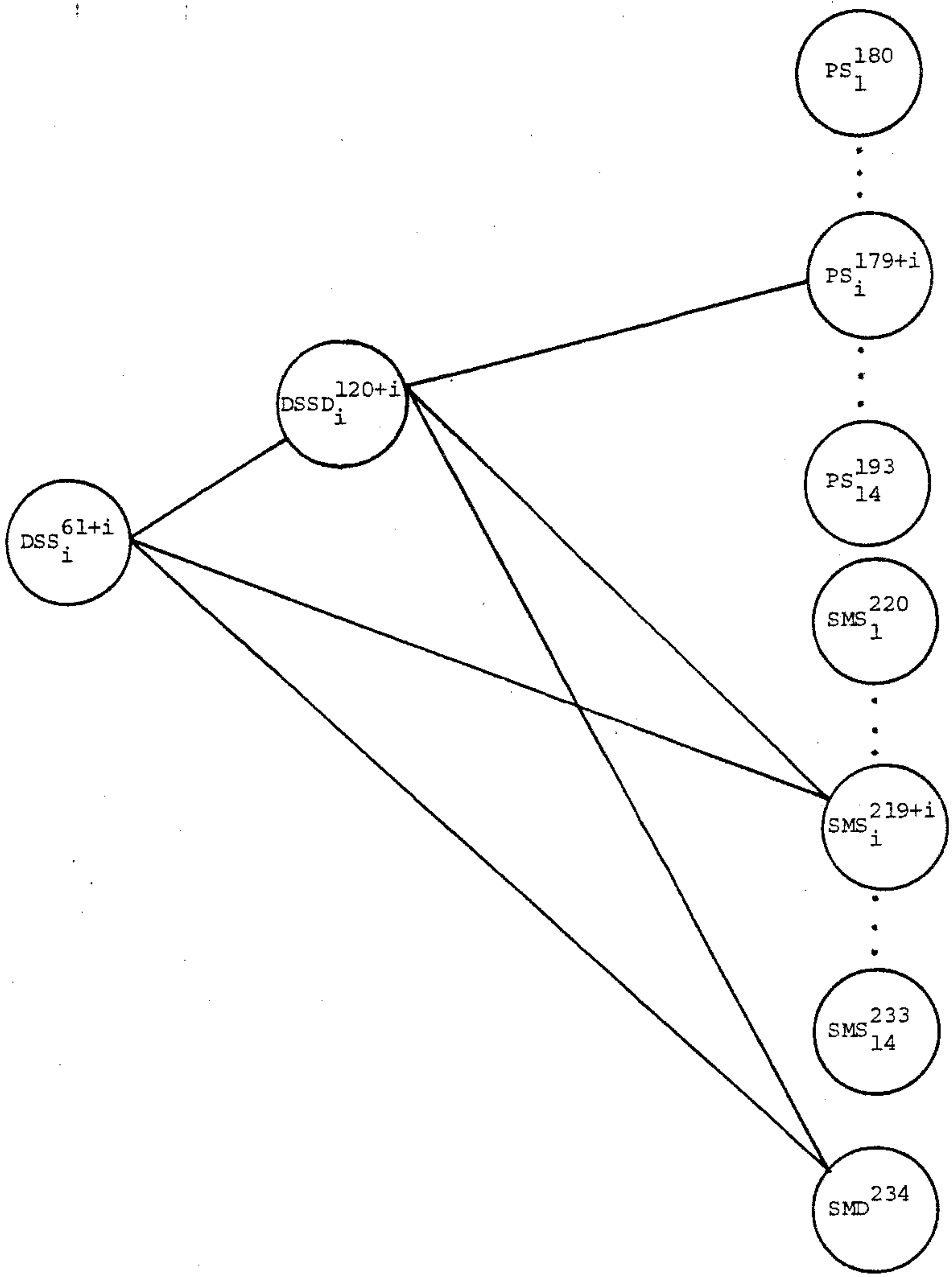


Figure 8. State Order Direct Ship to Processing and Manufacturing Nodes, a Cross-Section of Stage One of DAMPS



Manufacturing Links, Costs, and Restrictions

DAMPS recognizes two types of manufacturing plants--intra-order or single manufacturing plants and regional or multiple manufacturing plants. Single manufacturing nodes represent aggregate manufacturing capacity in areas having substantial excess capacity. There are 26 federal order single manufacturing nodes, and each state area has a single manufacturing node. Multiple manufacturing nodes represent aggregate manufacturing capacity in a region serving several federal order areas. There are 27 multiple manufacturing nodes.

Each direct ship node, direct ship dummy, and supply plant is linked to either one single manufacturing node and the single manufacturing dummy or one or more multiple manufacturing nodes and the multiple manufacturing dummy.

In areas having a single manufacturing center, it is assumed that transportation costs to manufacturing plants are minimal and can be ignored; hence, the only cost on an arc between a production node and its corresponding single manufacturing node is the Class III price. Milk which cannot be handled at a single manufacturing center, due to capacity limits, moves to the single manufacturing dummy at a cost equal to the Class III price plus a transportation charge. The transportation charge reflects the assumption that the single manufacturing dummy represents an unknown manufacturing plant approximately 100 miles more distant than the local manufacturing plant.

In areas using multiple manufacturing plants, direct ship dummies and supply plant nodes are linked to one or more multiple manufcturing nodes and the multiple manufacturing dummy. If capacities at multiple manufacturing nodes are exceeded by shipments from the production areas to which they are connected, the excess supply moves to the multiple manufacturing dummy. As with the single manufacturing dummy, the multiple manufacturing dummy represents more distant manufacturing plants. The multiple manufacturing dummy is assumed to be 100 miles farther away than the most distant multiple manufacturing center to which a production node is connected. Movement costs to a multiple manufacturing node or the multiple manufacturing dummy equal the Class III price plus a transportation cost that is a linear function of shipping distance.

Movements from Processing Plants to Consumption Centers

The portion of the network containing processing and consumption nodes is shown in Figure 9. Each processing node is linked to a processing dummy node. In federal order areas, each processing dummy can be linked to all consumption nodes. As with production to processing nodes, far-fetched linkages are omitted, based on a maximum allowable shipping distance. In this case, a shipping limit of 1,500 miles is set. In state areas, processing dummies can be linked to other areas or they can be linked only to the consumption node for their corresponding area, depending on the option selected by the model user.

Processing capacity is set as an upper bound on the arc between a processing node and its processing dummy. This limits the amount of milk that can be moved from supply nodes to a processing node. These upper bounds can be eliminated via an input form option (12). Processing capacities used in DAMPS are given in the base data (13).

As in the case of raw milk movements to processing centers, shifts in the packaged milk sales of processors among consumption centers are limited. Maximum quarterly percent declines, specified in the base data (13), are used to set lower bounds between processing dummies and consumption nodes. The model accepts two different sales bases for processors--in-area Class I sales and producer receipts used in Class I. When the latter is used, processors start with no inter-area sales. When in-area Class I sales are used, processors start with the share of sales in their own area which they had in the base year.

The cost of an intra-area movement is processing cost plus distribution and administration costs. In addition to that, inter-area movements of fluid milk are also assessed a transportation cost and any inspection cost. Processing and packaged milk transportation costs can be held constant or varied exogenously. The factors used to vary these costs are in the base data (13). [For further details, refer to Banker (3, pp. 91-93, 118-119, and 108-109).]

Movements from Manufacturing Plants

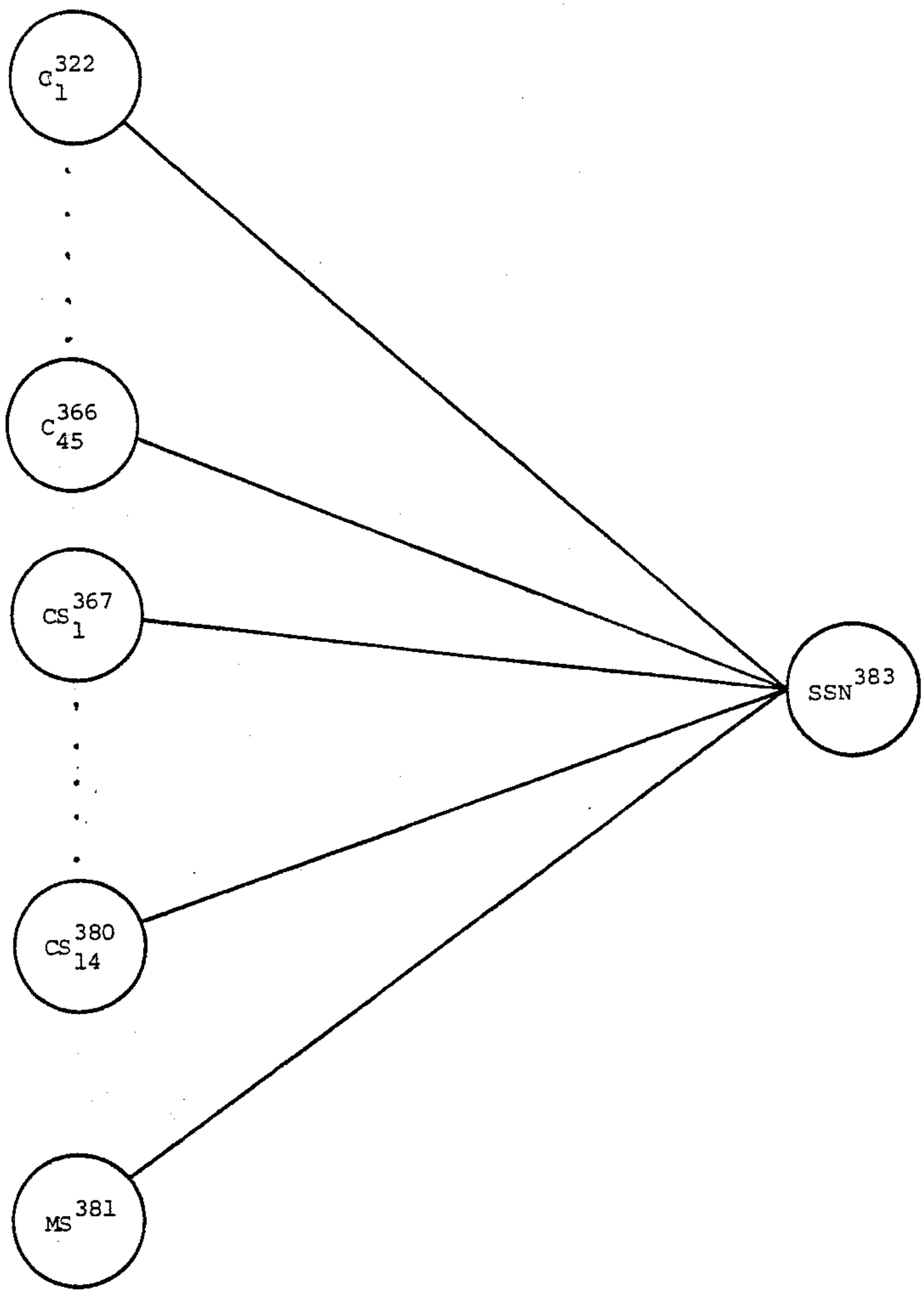
Milk manufactured and used in Class II and Class III is treated more simply than packaged milk. First, there are no consumption centers for manufactured milk as there are for fluid milk. Instead an aggregate Class II and III demand is established at an artificial node called the manufacturing sink. Figure 10 shows the manufacturing sink and its links to the manufacturing nodes. Manufacturing center capacities for single and multiple manufacturing nodes are set as upper bounds on the arcs between these manufacturing nodes and the manufacturing sink. Since there is no geographic location relevant to the manufacturing sink; there is no cost assigned on any arc to the manufacturing sink.

The Demand for Milk Products

There is a demand for fluid milk products in each of the 45 federal order areas (Table 6) and 14 state regulated areas (Table 3). Consumption requirements for each area are set as equality constraints on arcs connecting consumption nodes and the manufacturing sink to another artificial node called the super sink. There are no costs on these arcs, as the super sink is a modeling device having no economic significance. This portion of the network is shown in Figure 11.

The demand for Class I milk is computed for each state and federal order area. The demand functions have the same functional form as the supply functions and the following arguments: consumption and retail price in the base period, the current retail price, and exogenous factors, including population, demographic characteristics and real income. When exogenous factors are held constant, the demand function can be expressed as follows:

Figure 11. Consumption and the Manufacturing Sink to the Super Sink, a Cross-Section of Stage One of DAMPS



prices in each area. The Class II demand function is analogous to the Class I demand function. A separate index is used to vary Class II consumption if exogenous factors are allowed to vary. This index is listed in the base data (13).

Computed more simply than Class I retail prices, retail prices of Class II products are equal to the sum of the Class II price and a margin reflecting manufacturing and other marketing costs, multiplied by a percentage retail markup, which reflects retail merchandising costs.

Class III demand is simply the residual of total production and Class I and II consumption. If the computed Class II consumption exceeds total production less Class I consumption in any area, then Class II consumption is the residual. There is no reserve requirement for Class II or III products. [For further details, see Banker (3, pp. 45, 50, 84-85, and 121-122).]

The Class II and III consumption figures used and computed in stage one of DAMPS are only used for blend price computations needed within that stage. New calculations for Class II and specific Class III products are made in stages two and three of DAMPS. Although the first stage is not inconsistent with the latter two, it represents only a part of total U.S. consumption of manufactured products.

THE UNREGULATED GRADE A MILK SUBSECTOR - STAGE ONE

The unregulated Grade A milk subsector is divided into nine regions, shown in Figure 12. These regions, also used for Grade B milk production regions, are the dairy production regions used by the U.S. Department of Agriculture. Compared with the other subsectors, the unregulated Grade A milk subsector is treated rather summarily in DAMPS. Unregulated Grade A milk represents only about two percent of the dairy sector, and there is a paucity of data for the subsector. Production data must be inferred from data on total Grade A milk production and production in regulated subsectors. There is no data whatsoever on consumption, processing activities, or prices in unregulated Grade A milk regions.[6/]

Production of raw milk and consumption of fluid products in unregulated regions is calculated in DAMPS, but processing is ignored entirely, and there is no interregional movement of raw milk or milk products. Raw milk in excess of fluid consumption enters the manufacturing milk market; this is discussed in the section on the Grade B milk subsector.

Although data are not available to test it, the assumption that there is no interregional movements among unregulated markets is probably reasonable. First, the regions used in DAMPS are large geographic areas.

6/ For the sake of expedience, the unregulated Grade A milk subsector will be referred to as the unregulated subsector, although it should be remembered that the Grade B milk subsector is also unregulated.

Insofar as unregulated areas tend to be small and isolated, interregional movements seem unlikely; in fact, the intraregional movements implied by the aggregation of the many small unregulated areas into the large regions chosen probably requires a stronger assumption. Regardless of the size of the unregulated regions, these regions tend to be self-sufficient in meeting local fluid demand, and they probably do not typically have much milk in excess of fluid demand.

The Supply of Raw Milk

The supply of raw milk in unregulated regions is patterned after supply in regulated areas. The quantity produced is a function of production and the farm price in the base period, the farm price in the current period, the direct cost of production and productivity. More specifically, when exogenous factors are held constant, the supply function can be expressed as follows:

$$UNS_{r,q,y} = \frac{UNS_{r,q,b}}{UNGBP_{r,q-1,b}^{SE_r}} \; UNGBP_{r,q-1,y}^{SE_r}$$

where:

r denotes the unregulated region.

q denotes the quarter; q=1, ..., 4; if q=1, then q-1=4 and y=y-1.

y denotes year.

b denotes base year.

UNS = production of unregulated raw milk.

UNGBP = farm price.

SE = price elasticity of supply (Table 4).

All data, other than milk production, must be based on some other, closely related, observed variable. The farm price of milk is based on class prices in regulated areas. An unregulated "Class I" price is calculated for each region as a simple average of Class I prices in regulated areas located in that region (see Table 5). This price is intended to reflect the price paid for milk used for fluid purposes in unregulated regions. The Class III price is used to reflect the price paid for surplus milk in unregulated regions. While it is difficult to verify that this is a reasonable assumption, the dominance of regulated subsectors in the Grade A milk market suggests that prices set in regulated areas would affect prices in nearby unregulated areas. At the least, it is assumed that price movements in unregulated regions follow price movements in regulated areas.

Table 7. Grade B Supply Regions and Production-Manufacturing Centers Used in DAMPS

Supply Region	Production-Manufacturing Center
Northeast	Elmira, NY
Corn Belt	Peoria, IL
Lake	Eau Claire, WI
Southeast	Macon, GA
South Central	Little Rock, AR
Prairie	Mitchell, SD
Mountain	Vernal, UT
Southwest	Fresno, CA
Northwest	Ontario, OR

Table 8. Manufactured Milk Products Demand Regions and Consumption Centers Used in DAMPS

Demand Region	Consumption Center
Northeast	Elmira, NY
South	Atlanta, GA
North Central	Chicago, IL
West	Amarillo, TX
Pacific	San Francisco, CA

regulated markets. A transportation formulation is used (rather than a transshipment approach) because it is assumed that manufacturing facilities are located in producing regions and that sufficient capacity exists in a region to manufacture all of the milk available for manufacturing in that region. This assumption is made because of a lack of data on manufacturing plants outside of the federal order system and because the regions, being much larger than any regulated market area, are believed to have sufficient manufacturing capacity to support the assumption. In fact, there is little interregional movement of manufacturing milk; because it is more difficult to recover transportation costs, given the lower value of the milk. The effect of this assumption on the formulation of the network is simply that intermediary nodes are omitted; production nodes are linked directly to consumption nodes.

The Grade B subsector is split into primary and residual products markets and formulated as two models or networks, the second and third stages of DAMPS. In the first network, the market for Class II products, cheese, and miscellaneous Class III products is modeled. The second network deals with the market for butter and nonfat dry milk. In stage two, quantities are measured in thousands of pounds of raw milk equivalent. In stage three, thousands of pounds of product weight are used.

The Grade B milk subsector has some characteristics unlike Grade A milk subsectors. This is reflected in the stage two and three networks. Most strikingly, in addition to production and consumption nodes, there are nodes for beginning stocks of storable products (cheese, butter, and nonfat dry milk) and imports of importable products (all Class III products).

Stage Two

The second stage of DAMPS is illustrated in Figure 14. In this stage, surplus Grade A milk from stage one is aggregated according to Grade B regions and added to Grade B milk production to get the total milk available for manufacturing. The total amount of milk available for manufacturing can be used to make perishable manufactured products, cheese, or miscellaneous storable products. Manufacturing is not modeled in the same detail as processing is in regulated areas, due to insufficient data. It is assumed that manufacturing takes place in the same location as production and that there is no interregional movement of raw milk. In fact, there has been little movement of milk for manufacturing purposes because transportation costs cannot be recovered as they can under order provisions.

In addition to the products manufactured from raw milk in a given quarter, there are commercial and government stocks of cheese and imports of cheese and miscellaneous storable products.[7/] Total supplies are allocated to meet consumption requirements for the three manufactured

---

7/ Stocks of miscellaneous, storable products are relatively minor and are ignored.

products groups. The supplies in excess of manufactured products consumption requirements are first used to meet desired ending commercial and government cheese stock levels. The remaining "residual" supply of manufacturing milk is available for making butter and nonfat dry milk.

Node labels, numbers, and definitions for stage two are provided in Table 9. A schematic of the network is given in Figure 15. Unlike the network in stage one, there are no arcs omitted because of excessive shipping distance or for any other reason. This reflects the national scope of the Grade B subsector. In terms of Figure 15, this implies that the arc shown linking an S node and a CC node, for example, represents arcs linking all nine S nodes to all five CC nodes.

The Sources of Milk and Manufactured Products

As in stage one, a super source node is used to put the quantities supplied into the network. These quantities appear as equality constraints on arcs from the super source to the appropriate production node. There are no costs on these arcs; since the super source is a modeling device and has no economic significance. There are production nodes for raw milk (S), cheese and miscellaneous Class III imports (SIC and SI III), and commercial and government stocks of cheese (CSC and GSC).

Raw Milk for Manufacturing

The S nodes represent regional raw milk production centers. Milk is available for manufacturing from two sources--surplus Grade A milk and Grade B milk. Surplus Grade A milk is Grade A milk not used for fluid consumption. The surplus is aggregated by Grade B regions (Table 5) and added to the production of Grade B milk in each region. Grade B milk supply functions in DAMPS are analogous to the Grade A milk supply functions. The quantity of Grade B milk supplied is a function of production and price in the base period, price in the current period, and exogenous factors including direct cost of production and productivity. The federal order Class III price equals the Grade B farm price. The mathematical form of the supply function, when exogenous factors are held constant, is as follows:

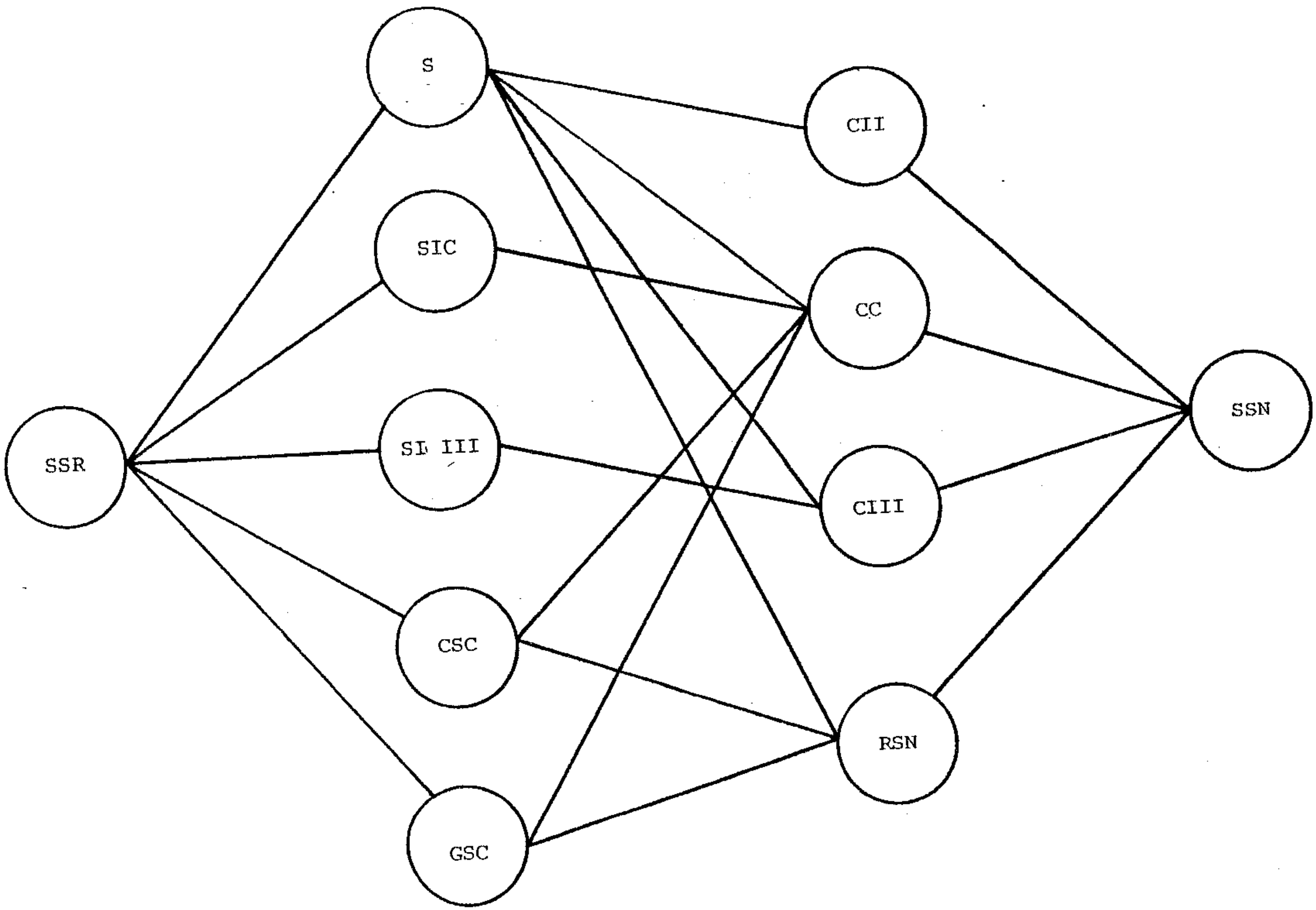
$$BS_{r,q,y} = \frac{BS_{r,q,b}}{C3P_{q-1,b}^{SE_r}} \; C3P_{q-1,y}^{SE_r}$$

where:

r denotes region.

q denotes quarter, q=1, ..., 4; if q=1, q-1=4 and y=y-1.

Figure 15. An Outline of the DAMPS Network, Stage Two



All arcs to consumption nodes have a transportation cost attached to them, measured in cents per hundredweight of raw milk. Transportation cost is a linear function of distance between supply and demand centers. Distances and intercept and slope parameters of the function are listed in the base data (13). In addition to the transportation cost, a one cent cost is attached to arcs between milk production nodes and cheese consumption nodes. This cost is arbitrary and intended only to encourage the model to choose cheese stocks over milk supplies in the same location when satisfying cheese consumption. This procedure is used to discourage an unnecessary accumulation of stocks and encourage the cycling of stocks on a first in-first out basis.

The Demand for Manufactured Products

All demand functions take quantity demanded as a function of consumption and retail price in the base period, retail price in the current period, and exogenous factors. As with fluid products, cross-price effects are ignored. In some instances, there is little evidence of cross-price effects; for butter and, to a lesser extent, cheese, cross-price effects could be expected. In those cases where cross-price effects may be measurable, the demand model used is chosen because of the lack of data to do otherwise. It can be argued that the omission of cross-price effects is not likely to cause serious problems given the short time period simulated by the model[8/] and the fact that the analyses are intended to compare relative impacts of various policies, all done under the same assumptions.

The mathematical demand function, when exogenous factors are held constant, is as follows:

$$C_{r,q,y} = \frac{C_{r,q,b}}{RP_{q-1,b}^{DE_r}} RP_{q-1,y}^{DE_r}$$

where:

r denotes region.

q denotes quarter, q=1, ..., 4; if q=1, then q-1=4 and y=y-1.

y denotes year.

b denotes base year.

C = manufactured product consumption.

8/ In other words, over a short time period, changes in the consumption of butter associated with changes in the price of margarine, for example, may be small.

Table 10. Manufactured Milk Products Demand Elasticities in Stages Two and Three of DAMPS, by Region

	Class II	Cheese	Butter	Nonfat Dry Milk	Miscellaneous Class III
Northeast	-.45	-.55	-.30	-.70	-.75
South	-.45	-.55	-.30	-.70	-.75
North Central	-.45	-.55	-.30	-.70	-.75
West	-.45	-.55	-.30	-.70	-.75
Pacific	-.45	-.55	-.30	-.70	-.75

tapped to bring the stock up to the desired level. All such calculations are done on a regional basis; that is, residual stocks in one region cannot be used to replace milk set aside in another region. Unlike commercial cheese stocks, government cheese stocks will not necessarily equal the desired level. Residual stocks may exceed the desired level; or if residual stocks plus residual milk is less than the desired level, government stocks could be less than the desired level. In practice, government stocks are rarely below the desired level and occasionally greater than the desired level.

Stage Three

Butter and nonfat dry milk markets are modeled in stage three, which is illustrated in Figure 16. It is assumed that all "residual" milk for manufacturing is manufactured into butter and nonfat dry milk. As with cheese, there are also beginning commercial and government stocks and imports of butter and nonfat dry milk. The totals of these butter and nonfat dry milk supplies are used to satisfy butter and nonfat dry milk demands. Again, the least cost allocation of butter and nonfat dry milk supplies can be computed. As with cheese, ending commercial stocks are computed based on desired stock levels and the amount of butter or nonfat dry milk left after consumer demands are satisfied. Any remaining butter and nonfat dry milk is assumed to enter government storage.

Node labels, numbers, and definitions for stage three are given in Table 11. The network is depicted in Figure 17. As with the stage two network, there are no arcs omitted due to maximum shipping distances. In Figure 17, this means that an arc between SB and CB, for example, implies that all nine SB nodes are linked to all five CB nodes. The stage three network can be divided into two halves; one half deals with butter; the other deals with nonfat dry milk. For this reason, all quantities are measured in thousands of pounds on a product weight basis. Only the stage three residual sink is connected to both butter and nonfat dry milk nodes, but, as in stage two, the residual sink is only a modeling device to provide an outlet for butter and nonfat dry milk supplies in excess of the quantities of butter and nonfat dry milk demanded, respectively.

The Sources of Butter and Nonfat Dry Milk

As in stages one and two, a super source node is used to put the quantities supplied into the network. These quantities appear as equality constraints on arcs from the super source to the appropriate supply node. There are no costs on these arcs; since the super source is a modeling device, devoid of economic significance. There are supply nodes for product supply (SB and SNFDM), imports (SIB and SINFDM), beginning commercial stocks (CSB and CSNFDM), and beginning government stocks (GSB and GSNFDM).

Table 11. Labels, Numbers and Definitions of Nodes in Stage Three of DAMPS

Label	Identification Number	Number of Nodes	Definitions
SB	1-9	9	Butter production center
SIB	10-11	2	Butter import center
CSB	12-20	9	Commercial butter storage center
GSB	21-29	9	Government butter storage center
SNFDM	30-38	9	Nonfat dry milk production center
SINFDM	39-40	2	Nonfat dry milk import center
CSNFDM	41-49	9	Commercial nonfat dry milk storage center
GSNFDM	50-58	9	Government nonfat dry milk storage center
CB	59-63	5	Butter demand center
CNFDM	64-68	5	Nonfat dry milk demand center
RSN	69	1	Residual sink
SSR	70	1	Super source
SSN	71	1	Super sink

Butter and Nonfat Dry Milk Production

The SB and SNFDM nodes represent regional production centers for butter and nonfat dry milk produced from raw milk in the current period. The raw milk used to produce butter and nonfat dry milk is the "residual" milk from stage two. Butter and nonfat dry milk are produced jointly in fixed proportions (given a partricular fat and nonfat solids content in milk). It is assumed that all "residual" milk from stage two is made into butter and nonfat dry milk. Butter can also be produced from excess cream resulting from fluid product and cheese production.[9/] Based on fluid milk production in stage one and cheese production in stage two, butter produced from residual cream is also estimated and added to the butter produced jointly with nonfat dry milk from raw milk. The proportions used to convert "residual" raw milk into butter and nonfat dry milk were first approximated based on the average fat and solids-not-fat content of butter, nonfat dry milk, and raw milk. Among other things, this approximation fails to account for any slippage or shrinkage in production; hence the first approximation was adjusted until the factors used contributed to a satisfactory model simulation of the base period.

Imports of Butter and Nonfat Dry Milk

Imports of butter and nonfat dry milk, like cheese imports, are set by the model user (12). An annual percent change in imports is specified in the base data (13). Imports can be increased by this percentage as a once and for all change or as a cumulative, year-to-year change.

Stocks of Butter and Nonfat Dry Milk

As with cheese, there are beginning commercial stocks and beginning government stocks of butter and nonfat dry milk. Ending stocks from the previous period equal beginning stocks in the current period. This figure enters the network as an equality constraint between the super source and the appropriate stocks node.

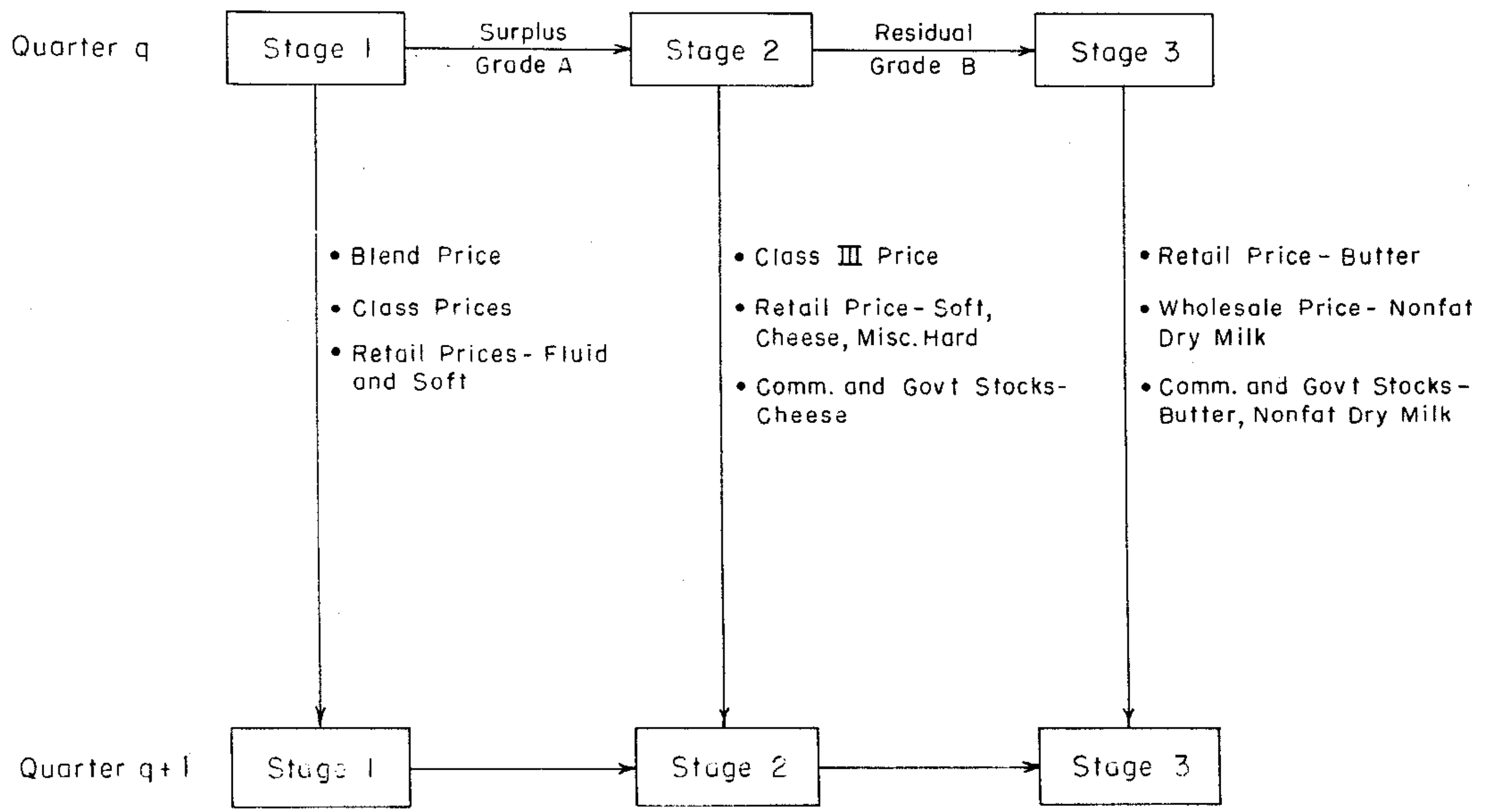
Movements from Supply Centers to Consumption Centers

All supply nodes are linked to all of their corresponding consumption nodes. All nodes, except the import nodes, are linked to the residual sink. The residual sink in stage three serves a purpose similar to

---

9/ Fat and nonfat solids come in fairly constant proportions in milk, especially in the short run for the U.S. average. Fat, or cream, has typically been the component in greatest abundance given the demand for dairy products in recent years. This trend is expected to continue. Thus, it is appropriate to recognize that there is excess cream associated with the production of lowfat fluid milk products and cheese. This cream is typically manufactured into butter, a dairy product that is relatively easy to store.

Figure 18. Sequential and Recursive Solution Procedure for DAMPS.



BIBLIOGRAPHY

1. Babb, E. M., D. E. Banker, O. Goldman, D. R. Martella, and J. E. Pratt, Economic Model of Federal Milk Marketing Order Policy Simulator--Model A, Station Bulletin No. 158, Agricultural Experiment Station, Purdue University, April, 1977.

2. Babb, E. M., D. E. Banker, O. Goldman, D. R. Martella, and J. E. Pratt, User's Manual for Federal Milk Marketing Order Policy Simulator--Model A, Station Bulletin No. 157, Agricultural Experiment Station, Purdue University, April, 1977.

3. Banker, David E., "A Model for the Analysis of Alternative Pricing Policies in Federal Milk Marketing Orders," Ph.D. Thesis, Purdue University, 1977.

4. Banker, D. E., E. M. Babb, O. Goldman, D. R. Martella, and J. E. Pratt, Computer Program Documentation for Federal Milk Marketing Order Policy Simulator--Model A, Station Bulletin No. 164, Agricultural Experiment Station, Purdue University, June, 1977.

5. Boehm, William Thomas, "An Econometric Analysis of the Household Demand for Dairy Products," Ph.D. thesis, Purdue University, 1974.

6. Boehm, W. T., The Household Demand for Fluid Milk in the United States with Regional Consumption Projections Through 1990, Res. Div. 120, Virginia Polytechnic Institute and State University, December 1976.

7. Boehm, W. T. and E. M. Babb, Household Consumption of Beverage Milk Products, Station Bulletin No. 75, Agricultural Experiment Station, Purdue University, March 1975.

8. Bradley, G. H., G. C. Brown, and G. W. Graves, Design and Implementation of Large-Scale Primal Transshipment Algorithms, Report NPS-55 BZBW 87901, Naval Postgraduate School, Monterey, California, September 1976.

9. Martella, D. R., D. E. Banker, E. M. Babb, and J. E. Pratt, Computer Program Documentation for Federal Milk Marketing Order Policy Simulator-- Model B, Station Bulletin No. 172, Agricultural Experiment Station, Purdue University, October, 1977.

10. Novakovic, Andrew Milovan, "An Economic Analysis of the U.S. Dairy Price Support Program and Alternate Policies," Ph.D. thesis, Purdue University, 1979.

11. Novakovic, A. M., E. M. Babb, D. R. Martella, and J. E. Pratt, A Computer Program Documentation of the Dairy Market Policy Simulator (Model A), Staff Paper 79-4, Department of Agricultural Economics, Cornell University, May 1979.

References

Barnum, M.N. and L. Squire. "An Econometric Application of the Theory of the Farm Household." Unpublished paper, 1977.

Bennett, M.K. The World's Food. New York: Harper and Row, 1954.

Burk, M.C. and E.M. Pao. "Methodology for Large-Scale Surveys of Household and Individual Diets." Home Economics Research Report No. 40, Washington: USDA-ARA, 1976.

Chayanov, A.V. The Theory of Peasant Economy. Homewood, Illinois: American Economic Association Translation Series, 1966.

Collinson, M.P. Farm Management in Peasant Agriculture: A Handbook for Rural Development in Africa. New York: Praeger, 1972.

Ferber, R. "Consumer Expenditure and Price Data: An Overview." Annals of Economic and Social Measurement, 3:2, 1974

Ferroni, M. "Consultation on Bolivian Rural Household and Food Consumption Survey." Report submitted to Nutrition Economics Group, OICD/USDA, August 1978 (mimeo).

-- "The 1979-81 Bolivian Rural Household Survey." Report submitted to Nutrition Economics Group, OICD/USDA, August 1979 (mimeo)

-- The Urban Bias of Peruvian Food Policy: Consequences and Alternatives. Ph.D. Dissertation, Dept. of Agricultural Economics, Cornell University, Ithaca, N.Y., January 1980 (mimeo).

Flinn in Kearle, B. (ed.) Field Data Collection in the Social Sciences. New York: Agricultural Development Council, 1976.

Joy, L. and P. Payne. "Food and Nutrition Planning." Nutrition Consultant Report Series No. 35. Rome: FAO, 1975.

Lau, L.J., W.L. Lin and P.A. Yotopoulos. "The Linear Logarithmic Expenditure System: An Application to Consumption-Leisure Choice of Agricultural Households in the Province of Taiwan." Stanford: Food Research Institute Discussion Paper No. 1975-1, 1975.

Lechtig, A., C. Yarbrough, R. Martorell, H. Delgado, R. Klein. "The One-Day Dietary Survey: A review of its usefulness to estimate protein calorie intake." Archivos Latinoamericanos de Nutricion, 26:3, 1976.

McWhinney, I. and H.E. Champion. "The Canadian Experience with Recall and Diary Methods in Consumer Expenditure Surveys." Annals of Economic and Social Measurement, 3:2, 1974.