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BOVINE SOMATOTROPIN:

ITS IMPACT ON THE SPATIAL DISTRIBUTION OF THE U.S. DAIRY INDUSTRY

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by

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Biotechnologically manufactured bovine somatotropin (bST) is awaiting approval for commercial use by the U.S. Food and Drug Administration. Trial results indicate that bST may increase the lactation-based yield of milk per cow by as much as 25 percent, well in excess of additional feed requirements. Adoption of bST by U.S. dairy farmers will change some of the industry's basic production parameters. Such changes may lead to a reallocation of productive resources among agricultural industries in general. Because of the differences in physical characteristics of the country's production regions, such reallocation might affect the regional comparative advantage of each of the industries, including dairy. It is the object of this study to investigate the regional impacts of bST on the dairy industry.

For this purpose, a ten region price-endogenous spatial equilibrium programming model of the U.S. agricultural sector, optimizing producers' and consumers' surplus for all regions, was constructed. Scenarios were specified for alternative bST impacts on milk yields and feed requirements reflecting the expected physiological effects and adoption levels of bST. In addition, the effects of alternative bST prices, the level of manufacturing milk price support, and mandatory Class I milk price differentials were analyzed.

Model results show that the bST impact on regional dairy distribution is dependent on prevailing policy conditions. If both price support and classified pricing parameters remain at base year levels, bST will increase the share of the industry in the western regions, at the expense of all others and at an enormous government expenditure. If classified pricing remains in effect while price support is phased out, bST will cause a relative increase of dairy activity in the Northeast and the Corn Belt, mostly at the expense of the Lake States. Government expenditure will be negligible. If both policies are phased out, there will be a relative increase in the Lake States. Results also show the main participants in the above shifts to be the regions that have a sizeable dairy product manufacturing industry.

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INTRODUCTION[1]

As of January 1988, there were about 150,000 dairy farmers in the U.S., milking approximately 10.3 million cows (Economic Research Service, 1988b). Geographically, U.S. dairy farms are dispersed throughout the 48 contiguous mainland states, under a wide range of climatic and other production-influencing conditions. Due to developments in product preservation and transportation technologies, the original dependence of the dairy industry on the location of its markets is continually being reduced. This trend underlines the importance of regional comparative advantage in determining the industry's geographical distribution.

Today, 28 percent of U.S. milk is produced in the Lake States region[2], which consumes only eight percent of all dairy products. At the other extreme, the Southeast[3] consumes ten percent of all dairy products, but only accounts for three percent of U.S. milk production (National Agricultural Statistics Service, 1988).

At the same time, the dairy industry is subject to various policy measures. Under a program designed to maintain the farm price of milk at or above a targeted support level, the government has recently removed between five and ten percent of total dairy production from the market annually. To make such a price support program viable, the government also, through a system of quotas and tariffs, tightly restricts dairy imports. Furthermore, under a system of classified raw milk pricing originally designed to stimulate the local supply of fluid milk, a specific differential between the prices of fluid and manufacturing grade milk is imposed for each milk marketing order area.

Dairy farmers, the same as other market-oriented producers, are striving to lower their short-run costs by influencing production function relationships. This endeavor normally involves a change in technology. The potentially most significant technical innovation to affect dairy farming since the advent of artificial insemination, and also one of the first to involve the application of biotechnology, is the use of commercially produced bovine somatotropin.

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[1]The investigation reported in this monograph is based upon the Ph.D dissertation of Jork Sellschopp, with Robert Kalter serving as thesis advisor. Complete documentation of the study is provided by the dissertation (Sellschopp 1989).

[2]Michigan, Wisconsin, Minnesota.

[3]South Carolina, Alabama, Georgia, Florida.

Bovine somatotropin (bST) is a hormone, instrumental in metabolism control, which is naturally secreted by the bovine pituitary gland. Today, it can be produced industrially by a fermentation process sustained by genetically engineered bacteria. Application trials have shown that supplementary bST injected into the bloodstream of a lactating cow can increase milk production by as much as 25 percent on a lactation basis while feed requirements increase by considerably less (Bauman et al., 1985). There also are available preliminary estimates of the production cost of bST (Kalter et al., 1985). Based on such information, one may reasonably expect that the commercially produced hormone will cause a decrease in the production cost of milk. Not only will it reduce the fixed or long-run cost, represented by the expenses of raising and maintaining a dairy cow, but, through a more efficient feed conversion, the variable or short-run cost as well. Presently, the commercial use of synthetic bST is awaiting approval by the Food and Drug Administration (FDA). Availability of the product in the U.S. is expected in 1990 (Fallert et al., 1987).

The developments outlined above raise a number of economic issues. They primarily concern the dairy industry but, indirectly, they also involve the agricultural sector as a whole and other productive sectors of the economy. Ultimately, all consumers and taxpayers will be affected. One of the crucial issues to be raised is that of the dairy industry's spatial distribution.

The spatial distribution of milk production is pivotal in a wide range of economic questions about the adoption of bST. The main question at the farm level is the effect of bST on the output and the production cost of raw milk, and thereby, on the short-run profitability of existing dairy enterprises. At the industry level, the main interest is in the price effect of a bST-induced change in total milk supply and its impact on the long-run profitability of dairying. An additional question is the reallocation of land and labor among agricultural industries, due to bST-induced profitability changes. This reallocation of agricultural resources also is of concern to input suppliers to the agricultural sector, such as the chemical and the utilities industries. Dairy processors, such as fluid milk distributors and producers and retailers of manufactured dairy products, are concerned about changes in the pattern of regional availability for their input. And, through the markets for final dairy commodities, bST-induced changes may have an effect on the entire consumption side of the economy.

Due to the importance of the spatial distribution of the dairy industry and the potential impact of bST on this distribution, this study was designed to investigate the probable changes which will come about as a result of bST's commercial introduction. The objective is to determine the responses of economic variables, especially those related to the dairy industry, to different levels of bST-induced increases in milk yield and feed requirements, of bST cost, of dairy price support, and of mandatory milk price differentials. It was recognized that in order to lead to realistic and plausible conclusions, such an investigation must focus on the dairy industry at an appropriate level of spatial disaggregation.

Also, since dairy is closely linked to other agricultural industries, these linkages must be included. There is required, then, an analysis of spatially disaggregated variables, spanning a substantial portion of the agricultural sector.

Section II

THE U.S. DAIRY INDUSTRY

In the context of this study, the U.S. dairy industry includes all raw milk producers in the country and all enterprises dedicated to the processing of raw milk into intermediate or final products. It also includes the reprocessors and all enterprises engaged in the handling, transporting, storing and distributing of dairy commodities.

OVERVIEW

In 1987, 142.5 billion pounds of milk was produced in the U.S. Of this total, 3.4 billion pounds was used on the farm or sold directly by producers to final users. The largest portion, 123.8 billion pounds, was sold as Grade A milk which is produced on farms qualifying, by their level of sanitation, to supply the fluid milk market. The remainder, 15.3 billion pounds, was marketed as Grade B milk, eligible for being processed into manufactured dairy products (National Agricultural Statistics Service, 1988).

The handling of practically all Grade A milk is subject to public regulation. Of the 123.8 billion pounds, 98.2 billion was handled under federal and most of the remaining 25.6 billion under state law. Regulated handlers may buy Grade A milk either for distribution in the form of fluid milk products, in which case it becomes Class I milk, or for manufacturing, in which case it becomes Class II or, in some instances, Class III milk. In 1987, 52.2 billion pounds of Grade A milk was bought as Class I, the remaining 71.6 billion pounds going into manufacturing, along with all of the milk from Grade B producers (Agricultural Marketing Service, 1988).

In the same year, 52.2 billion pounds of whole milk equivalent[1], was bought by domestic consumers as fluid milk products, while 80.2 billion pounds of equivalent was purchased by domestic consumers, exporters, and the operators of privately held stocks as manufactured dairy products. The equivalent of an additional 6.7 billion pounds of whole milk, roughly five percent of production, was removed from the market by the federal government in the form of butter, American cheese, and non-fat dried milk (NFDM) (Economic Research Service, 1988a). Figure 1 is a flow diagram of the movements of dairy commodities across primary and secondary markets.

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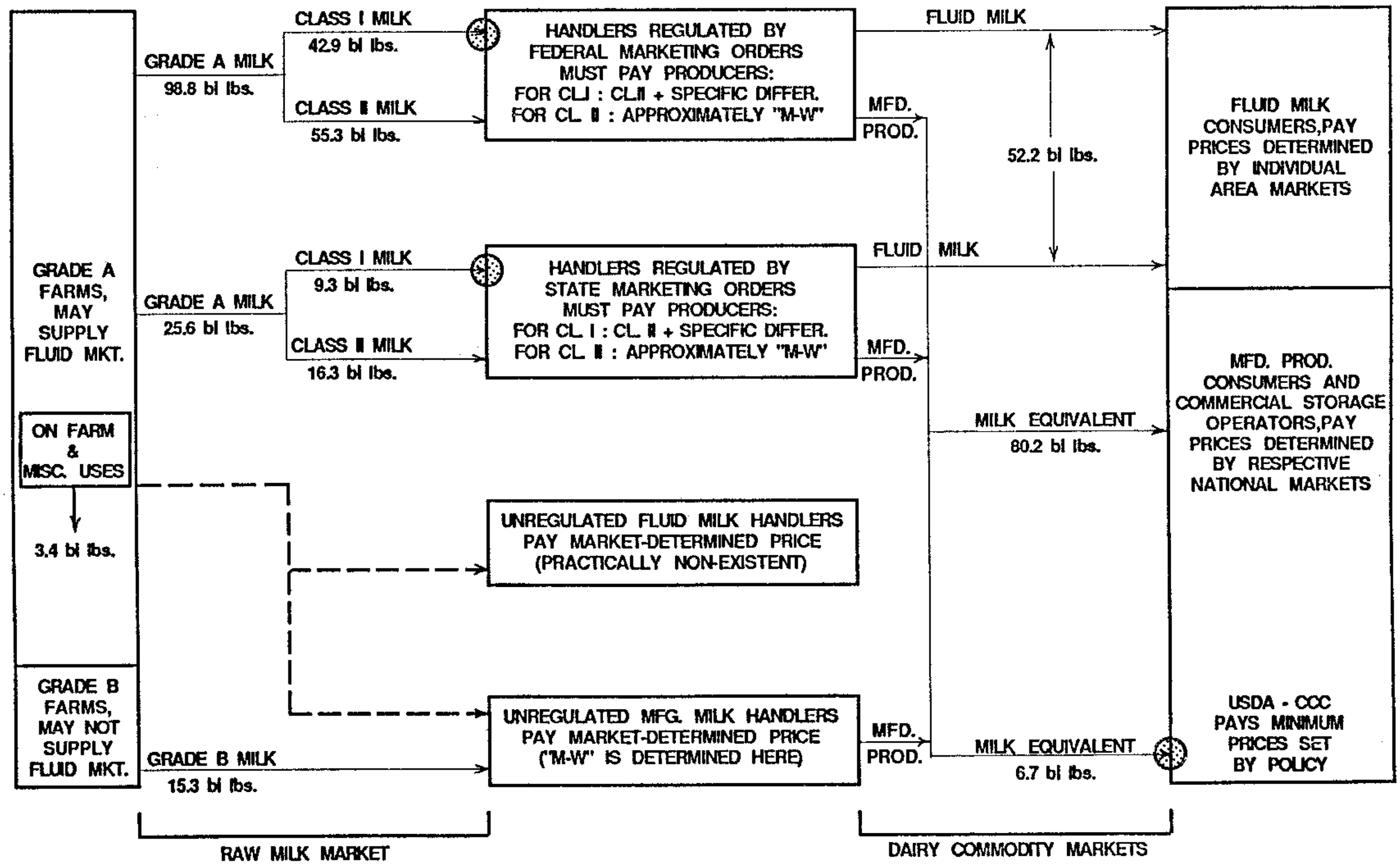
[1]The whole milk equivalent of a given quantity of dairy product is the amount of milk which, at a 3.7 percent butterfat content, would contain the same amount of fat solids.

**FIGURE 1: FLOW OF RAW MILK AND DAIRY PRODUCTS ACROSS U.S. MARKETS
(Numbers Refer to 1987 Quantities, Shaded Areas are Points of Policy Impact)**



Government purchases of butter, American cheese, and NFDM are intended to increase the farm level demand for manufacturing milk in order to support its price at or near a predetermined target level. Another policy measure involves the marketing of Grade A milk through a system of classified pricing. Federal and state authorities have approved such practice by setting minimum regional Class I milk price differentials. The producer price for Class I milk must exceed that for Class II or manufacturing grade milk by the respective differential, which is to be paid by the milk handler. A third policy measure is the control and virtual elimination of dairy product imports through the use of quotas and tariffs.

STRUCTURE

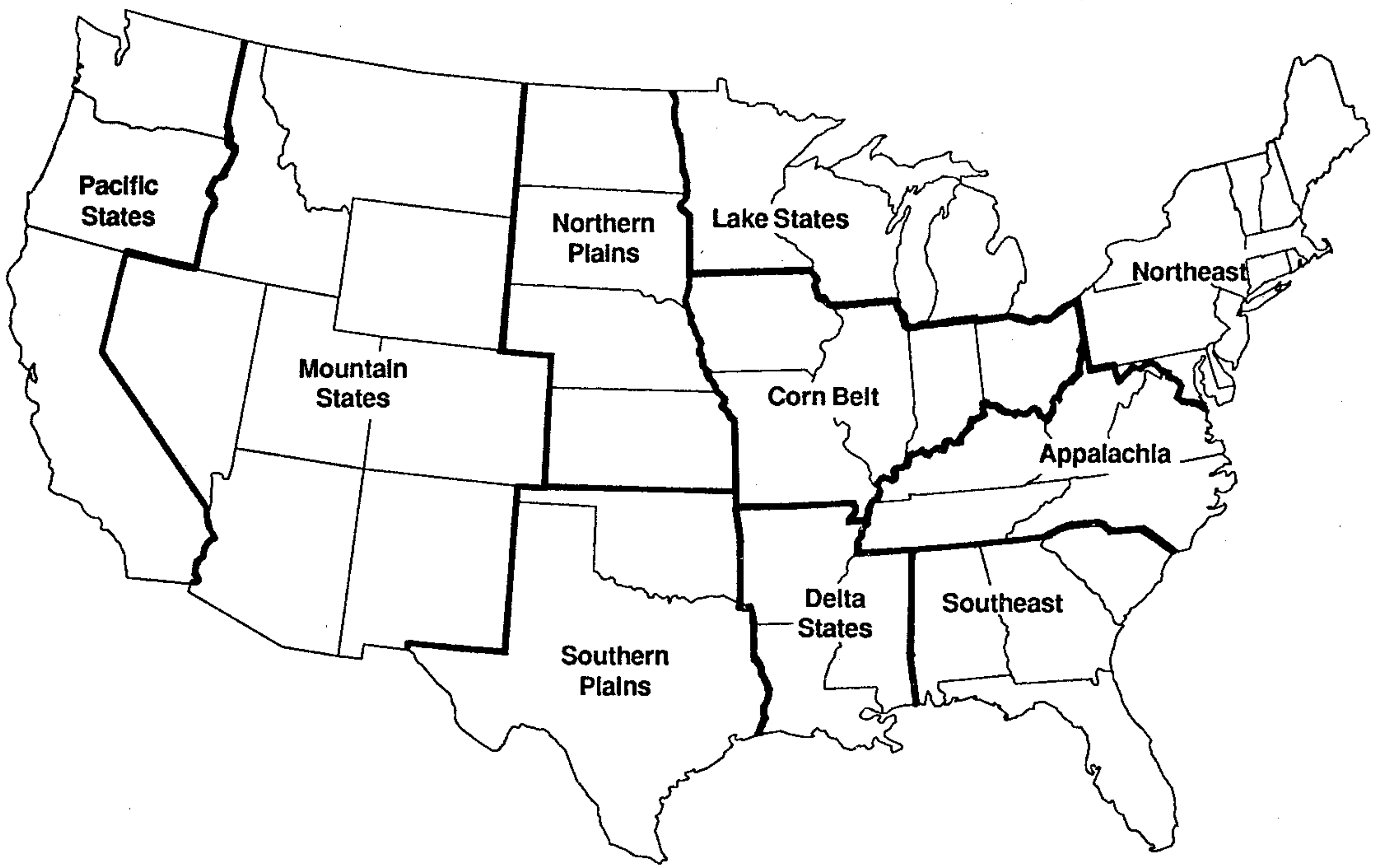
The structure of an industry is generally characterized by frequency distributions of its basic units across one or several suitable classifications. Classification criteria generally include enterprise size and may extend to additional industry-specific aspects. It is difficult to characterize the structure of an agricultural industry in a country the size of the U.S. without introducing the criterion of geography. Land, the chief resource in agricultural production, is fixed, which implies a local capacity constraint on outputs. In addition, there is a regionally uneven distribution of comparative advantages of production, due to the diversity of physical conditions and management practices. The distribution of comparative advantages is different for each combination of agricultural commodities and is likely to change over time.

One of the most widely used definitions of regions for purposes of studying comparative advantage is the one created by the Economic Research Service (ERS) of the U.S. Department of Agriculture for handling general crop production data. It groups the 48 contiguous continental states into ten production regions, as shown in Figure 2.

Raw Milk Production

It is apparent from Table 1 that four of the ten regions, Northeast, Lake States, Corn Belt, and Pacific States, produce over 75 percent of all milk, possess over 70 percent of all cows, and have more than 65 percent of all dairy farms. Whereas average herd size, as shown in Table 2, is approximately the same for the first three regions and for the entire U.S., for the Pacific States it is two and one half times as large. The size of the herd containing the median cow in the Northeast, assuming an ordered array of herd size classes and a linear distribution of cows within each class, is approximately equal to that in the U.S. For the Lake States and the Corn Belt it is slightly smaller, but for the Pacific States, it is five times as large. Average milk production per cow in the

FIGURE 2: AGRICULTURAL PRODUCTION REGIONS OF THE U.S.



Source: Economic Research Service, 1985

Table 1

U.S. DAIRY FARMS, DAIRY COWS, AND MILK PRODUCTION BY REGION, 1982.

Region	Dairy Farms	Dairy Cows	Milk (million pounds)
Northeast	46,634	2,127,627	27,358
Lake States	77,413	3,090,297	38,824
Corn Belt	45,789	1,371,561	16,747
Northern Plains	18,616	501,385	5,483
Appalachia	31,746	805,112	8,784
Southeast	7,588	431,597	4,669
Delta States	9,503	283,162	2,681
Southern Plains	13,225	431,060	4,935
Mountain States	15,561	538,770	7,115
Pacific States	11,535	1,255,589	19,041
U.S.	277,610	10,836,160	135,637

Source: USDA, Agricultural Statistics 1984.

first three regions is near the national average, whereas in the Pacific States the national average is exceeded by 20 percent. Tables 3 and 4 show the distributions of farms and cows for all regions and herd sizes. Table 5 shows the distribution of milk produced by region and grade.

The regional trends in relative milk production and population over the past four decades are shown in Table 6. Similar relative trends in a region's milk production and population may indicate that the influence of

Table 2

COWS PER FARM AND MILK PER COW, 1982

Region	Average Herd Size	Size of the Herd Containing Median Cow[a]	Average Milk Yield (#/cow - year)
Northeast	45.62	77.77	12,858
Lake States	39.92	49.15	12,563
Corn Belt	29.95	58.29	12,210
Northern Plains	26.93	55.47	10,936
Appalachia	25.36	76.00	10,910
Southeast	56.88	417.81	10,818
Delta States	29.80	96.81	9,468
Southern Plains	32.59	207.94	11,449
Mountain States	34.62	113.87	13,206
Pacific States	106.25	435.63	15,165
U.S.	39.03	74.86	12,517

[a]Assuming ordered array of herd size classes and linear distribution of cows within each class.

Source: U.S. Department of Commerce, 1984.

population in determining milk production has outweighed all other influences, including that of the comparative advantage of dairying. This applies to the Southeast, the Mountain States, and the Pacific States, where both relative population and milk production are increasing. It also applies to the Corn Belt, the Northern Plains, Appalachia, and the Delta States where both population and relative milk production are declining. Opposing trends in

Table 3

U.S. DAIRY FARMS BY REGION AND HERD SIZE, 1982
(percent)

Region	Herd Sizes in Number of Cows					All Herd Sizes
	1-29	30-69	50-99	100-499	500-	
Northeast	5.92	4.70	4.79[a]	1.37[b]	.01	16.80
Lake States	10.42[b]	9.74[b,a]	6.55[b]	1.18	.01	27.89
Corn Belt	9.47	3.35[b]	3.06	.61	.00	16.49
Northern Plains	4.20	1.22[a]	1.03	.25	.00	6.71
Appalachia	8.09	1.29	1.41[a]	.65	.01	11.44
Southeast	1.96	.07	.24	.41[a]	.05	2.73
Delta States	2.29	.28	.57[a]	.28	.00	3.42
Southern Plains	3.42	.25	.57[a]	.50	.01	4.76
Mountain States	4.19	.35	.56[a]	.47	.05	5.61
Pacific States	2.35	.15	.43	.99[a]	.23[b]	4.15
U.S.	52.31	21.40	19.21	6.70	.38	100.00[c]

[a]Largest size class share of this region, excepting the 1-29 cow class.

[b]Largest regional share of this herd size class.

[c]Detail may not add to total due to rounding.

Source: U. S. Department of Commerce, 1984

Table 4

U.S. DAIRY COWS BY REGION AND HERD SIZE, 1982
(percent)

Region	Herd Sizes in Number of Cows					All Herd Sizes
	1-29	30-69	50-99	100-499	500-	
Northeast	1.77	4.91	7.91[a]	4.83	.21	19.63
Lake States	4.15[b]	10.57[a,b]	10.22[b]	3.50	.09	28.52
Corn Belt	2.31	3.15	5.27[a]	1.87	.06	12.66
Northern Plains	.89	1.24	1.73[a]	.72	.06	4.63
Appalachia	1.34	1.16	2.34	2.46[a]	.13	7.43
Southeast	.10	.05	.41	1.80[a]	1.62	3.98
Delta States	.18	.28	.91	1.17[a]	.08	2.61
Southern Plains	.24	.15	.97	2.32[a]	.30	3.98
Mountain States	.48	.48	1.46	2.18[a]	.38	4.97
Pacific States	.18	.30	.81	5.37[a,b]	4.93[b]	11.59
U.S.	11.64	22.51	31.89	25.97	7.99	100.00[c]

[a]Largest size class share of this region, excepting the 1-29 cow class.

[b]Largest regional share of this herd size class.

[c]Detail may not add to total due to rounding.

Source: U. S. Department of Commerce, 1984 and National Agricultural Statistics Service, Milk Production, 1984 Summary.

Table 5

MILK PRODUCTION BY REGION AND GRADE, 1982
(percent)

Region	Grades of Milk: Grade A	Grades of Milk: Grade B	Both Grades of Milk
Northeast	20.10	.07	20.17
Lake States	21.05	7.57	28.62
Corn Belt	9.92	.43	12.35
Northern Plains	2.25	1.79	4.04
Appalachia	5.78	.70	6.48
Southeast	3.43	.01	3.44
Delta States	1.89	.09	1.98
Southern Plains	3.57	.07	3.64
Mountain States	3.79	1.46	5.25
Pacific States	13.51	.53	14.04
U.S.	85.37	14.63	100.00[a]

[a]Detail may not add to total due to rounding.

Source: U. S. Department of Agriculture, 1984.

Table 6

MILK PRODUCTION AND POPULATION BY REGION, 1940-1982
(percent)

Region	Milk Produced				Population			
	1940	1960	1978	1982	1940	1960	1978	1982
Northeast	16.8	20.0	20.5	20.2	29.0	26.9	24.8	22.5
Lake St.	23.8	27.0	28.8	28.6	8.5	8.5	8.3	8.1
Corn Belt	21.0	18.0	12.8	12.4	18.7	17.6	16.2	15.9
North. Pl.	8.5	5.8	4.3	4.0	3.0	2.7	2.4	2.4
Appalachia	6.6	7.2	6.8	6.5	11.0	10.0	9.8	9.7
Southeast	2.8	3.1	3.6	3.4	7.4	8.2	9.4	10.2
Delta St.	2.9	2.5	2.1	2.0	4.9	4.1	4.0	4.1
South. Pl.	6.0	3.5	3.7	3.6	6.6	6.6	7.3	8.0
Mount. St.	4.0	3.9	4.4	5.3	3.2	3.9	4.8	5.3
Pacific St.	7.5	9.0	12.8	14.0	7.4	11.5	13.1	13.9
U.S.[a]	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a]Detail may not add to total due to rounding.

Source: R. E. Jacobson, 1980 and U. S. Department of Commerce, various years.

relative milk production and relative population may indicate that the influence of population on milk production is outweighed by some other influence, probably that of the comparative advantage of dairying. This applies to the Northeast and the Lake States, where relative population is declining but relative milk production is increasing, and to the Southern Plains, where the reverse is true.

The 1982 regional distribution of manufactured dairy products is shown in Table 7. The fact that the regional distribution of dairy product manufacturing is different from that of total milk production appears to confirm the dependence of regional raw milk markets on at least two distinct downstream markets. This coincides with the existence of two distinct markets for final dairy commodities, that for fluid milk, and that for manufactured dairy products. Fluid milk markets, due to the high ratio of transportation cost to commodity value, are of a local or regional nature, with physical distances between population centers serving as virtual barriers between them. An increase in population will, normally, directly translate into an increased regional production of fluid milk. Markets for manufactured dairy products, due to a lower transportation cost to value ratio, do not have the same barriers. An increase in national demand for manufactured dairy products will translate into an additional regional production only if, in the respective region, dairying holds a position of sufficient comparative advantage. Changes in the regional alignment of milk production during the past four decades can then be explained to some extent by changes in conditions affecting the respective fluid and manufacturing milk markets.

In the Lake States, the absolute and relative increase in milk supply indicates that the decrease in fluid milk demand caused by the relative loss of population was outweighed by the combined effects of an increase in the demand for manufactured dairy products and by a strong comparative advantage of dairying. In the Corn Belt, the relative decrease in milk supply may be seen as the combined effect of a relative loss in population and the lack of comparative advantage of dairying with respect to other activities. In the Pacific States, the effect on fluid milk demand of the absolute and relative population increase may well mask any positive or negative influence of the regional comparative advantage position on the production of manufactured products for the national market.

Corresponding milk production changes in the remaining regions can be interpreted in a similar way. While it is not the object of this study to analyze past trends in dairy industry structure, the above interpretation may be suitable as a working hypothesis regarding regional shifts in milk supply. One might even be led to expand that hypothesis in the sense that regions dominated by the fluid milk market are characterized by larger herd sizes, higher yielding cows, and a higher proportion of Grade A milk than regions which are engaged in dairying mainly because of the benefit its comparative advan-

Table 7

REGIONAL OUTPUT OF MANUFACTURED DAIRY PRODUCTS, 1982
(million pounds)

Region	Ice Cream	Soft Cheese Products	Hard Cheese Products	Butter
Northeast	1,297	402	348	254
Lake States	403	613	1,635	523
Corn Belt	439	367	226	108
Northern Plains	87	89	163	28
Appalachia	276	35	62	27
Southeast	288	--	--	--
Delta States	84	26	11	--
Southern Plains	269	--	--	12
Mountain States	152	55	174	28
Pacific States	540	202	133	277
U.S.	3,835	1,789	2,752	1,257

Source: U. S. Department of Agriculture, 1983

tage is yielding them through the manufactured dairy product markets. A higher return on investment in the former might be a plausible explanation.

Raw milk production is carried out by about 150,000 dairy farmers. A large part of them are also involved in activities well beyond the farm gate through dairy farmers' cooperatives. About 75 percent of all milk produced in the U.S. is marketed through cooperatives, of which there are about 500 (Quinn and Wasserman).[2]

Fluid Milk Distribution

This segment of the dairy industry includes all enterprises engaged in converting farm gate Grade A milk into fluid milk products and placing them at the reach of the consumer. The most important fluid milk products are whole milk, cream, low-fat and skim milk, buttermilk, and flavored milk drinks.[3] Industrial processing, however, is only a secondary aspect of this segment of the industry. Primarily, fluid milk distribution consists of the materials handling operations of packaging and transportation, carried out on a perishable liquid of relatively low value per unit of volume.

The nature of the product and the fact that it must be collected from dispersed rural sources and delivered to a central urban destination suggest that the structure of the fluid milk distribution industry developed according to the laws of location theory.[4] For the distribution areas around the major U.S. urban centers, it is not unreasonable to assume that their development took place according to this theory and that individual milk sheds developed within the profitable range of distances from the distribution center, as a function of the prevailing means and costs of transportation.

The development within each of these isolated milk markets was, however, far from quiet and orderly. Cyclicality, a pattern of seasonal fluctua-

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[2]These cooperatives assume many functions in all phases of the dairy industry, from processing to retailing. One function is that of bargaining agent for the producer, a function based on the Capper-Volstead Act of 1922. Whereas anti-trust law generally forbids producers to "act together in association", that Act provides an explicit exemption for agricultural cooperatives. An additional important function of dairy cooperatives at the producer level is that of providing a market for temporary production in excess of commercially contracted quotas. This function results in a reduction of producers' price risk.

[3]The growing demand for fluid milk products with lower fat content is making it increasingly difficult to account for those products on a raw milk basis. Cream, separated from raw milk processed into a low-fat fluid milk product, might go into the manufacturing of butter, with the buttermilk, again, ending up among fluid milk products. Such flows of individual components are blurring the traditional system of raw-milk-based accounting.

[4]This theory, originally formulated in the early 19th century by Johann Heinrich von Thuenen, states that in an area where a single central market is surrounded by agricultural land of uniform quality, a concentrical pattern will develop in the allocation of such land to the production of different commodities. This pattern is a function of the margin that can be obtained from production per unit of land at the central market. In the case of neighboring markets, the boundaries between the areas supplying each of them would be constituted by the minimum margin troughs.

tions of supply and demand, was caused by the spring peak of production and the fall peak of consumption. Balancing, by increasing milk demand for the manufacturing of butter and cheese, neutralized such instability only to a limited degree.[5] In addition, long lead times for production decisions, as well as a growing disparity between the number of producers and the number of distributors created considerable instability in the availability and prices of fluid milk. The situation was finally brought under control by the introduction of milk marketing orders, in the wake of the Agricultural Adjustment Act of 1933 (Spencer and Blanford).

A milk marketing order is a set of rules governing producer sales of Grade A milk to first handlers. These rules are agreed upon by the majority of producers supplying a specific fluid milk distribution area. Upon government approval, they become binding for that area -- which is then called a milk marketing order area (MMOA). The two objectives of milk marketing orders are spelled out as "insuring an adequate supply of pure and wholesome fluid milk" to consumers, and "promoting and maintaining orderly marketing conditions" for producers, particularly with respect to price inequalities and revenue fluctuations (Masson and Eisenstat).

The first objective is achieved by classifying, according to use, all Grade A milk bought by the handlers of a marketing order area, and stipulating, for all fluid use purchases, the payment of a positive price differential with respect to the "M-W series".[6] The second objective deals with handlers' unequal relative demands for Class I (fluid use) and Class II (manufacturing use) milk, and with producers' seasonal supply fluctuations. The price inequalities due to different use shares of handlers are eliminated by pooling the proceeds from all Class I and Class II sales within a MMOA and paying each producer an average or "blend" price per unit of milk.[7] The seasonal revenue fluctuations that would be caused by seasonal supply fluctuations, even on such an equalized market, are often reduced by the implementation of seasonal price incentive plans, in terms of either the area's blend price (the "Louisville Plan") or a basic producer quota (the "Seasonal Base Plan").

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[5]The spring peak of production is related to the sudden and plentiful availability of green pasture in May and June and to the practice of scheduling calving for this time of the year. In the early 1920's, this could mean an excess supply of 40 percent. Today, with demand balancing, modern storage technology, and improved management, the excess is around 15 percent. The fall peak of consumption is related to the beginning of the school year in September.

[6]The "Minnesota-Wisconsin series" is the market price for manufacturing milk in those states. This price also is the object of government support policy through manufactured dairy product purchases.

[7]Originally many orders were "handler pools" which provided for "blend" prices to be established on the basis of the milk delivered by producers to a single handler.

Dairy Product Manufacturing

This segment of the industry includes any enterprise engaged in converting Class II milk from Grade A producers and any milk from Grade B producers into manufactured dairy products ready for final use. According to their keeping qualities, these products are classified into soft and hard. The first group includes ice cream, yogurt, and soft cheese products; the second includes hard cheese, butter, and non-fat dried milk (NFDM). Soft dairy products, much like fluid milk, are produced in direct response to demand, often in plants which also handle fluid milk. They are largely sold on local markets. Hard products are less perishable than soft ones and also have a lower transportation cost per unit value. That makes them especially suitable for the exploitation of favorable production conditions at some distance from major consumption centers. Hard manufactured dairy products, also, are instrumental in the Federal Dairy Price Support Program, as they constitute the commodities purchased by the government in the implementation of its policy. This, indeed, is the outlet for a significant portion of NFDM, produced as a byproduct in butter making.

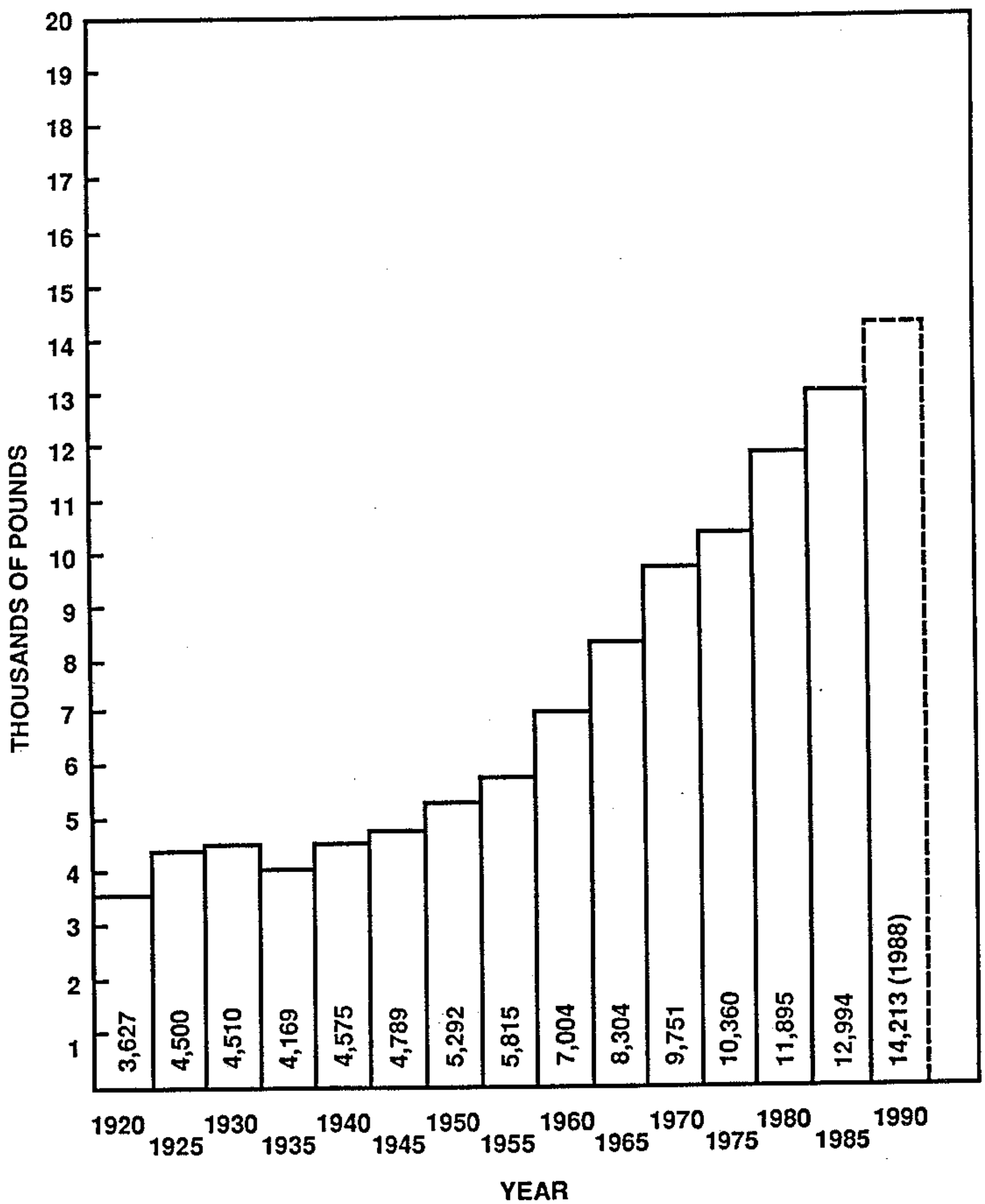
The manufacture of hard dairy products has its longest tradition in regions which, besides offering a cheap supply of raw milk sufficiently removed from major fluid milk markets, also offer climatic and environmental advantages for the manufacturing process, such as reasonably cool temperatures for the curing of cheese and an abundance of fresh water. It falls to the manufacturing of hard dairy products to balance seasonal and any other variations in raw milk supply. Due to the nature of the respective manufacturing processes, however, this applies more to butter and NFDM production than to cheese making.

Cooperatives not only play an important role in raw milk marketing, but they also are active in fluid milk distribution and dairy product manufacturing. Presently, they dominate in marketing raw milk and in manufacturing butter and NFDM. They are engaged to a limited degree in fluid milk distribution and cheese manufacturing, the latter two being dominated by proprietary companies.

STRUCTURAL RESPONSE TO TECHNICAL INNOVATION

Just as the primary effect of resource endowment is felt across geographical regions, the primary influence of technology is felt along the axis of time. The decline in the total number of U.S. dairy cows between 1955 and 1975, from 21 to 11 million, is a case in point. This decline was caused by an unprecedented increase in the production of milk per cow. A graphical representation of this change appears in Figure 3. Such an increase is, of course, not

FIGURE 3: AVERAGE YIELD OF MILK PER COW IN THE U.S., 1920-1985



Source: U.S. Department of Agriculture, Agricultural Statistics, Several Issues the result of a single discrete change in technology, but of a series of innovations gradually taking place at all process levels. In the above case, changes happen to be reflected in the concept of yield, measurable in annual pounds of milk per cow. The very nature of technology determines that all changes will eventually be reflected in the concept of cost of production. This implies that changes in technology will cause the size and shape of an industry to be different at one point of time from another.

By affecting, although in a secondary way, some characteristics which are primarily determined by geographical conditions, technical innovation may influence the regional or structural alignment of an industry. One example of this influence is the progressive equalization of regional average milk yields that took place in response to the decreasing reliance of breeders on local bulls, due to the almost universal adoption of artificial insemination. Another example is the concentration of dairy product manufacturing in the Northeast and the Lake States, in response to increased national market integration due to more efficient transportation technology. Likewise, large scale milk production by enterprises which do not grow sufficient roughage of their own would be unthinkable without the technology that facilitates the operation of well developed feed markets. Thus, just as technical innovation may cause changes over time in some national characteristics of the dairy industry, it may also cause changes in its regional or structural alignment. Generally, the effect of any one innovation, however, cannot be traced beyond the trend to which it contributes, and most of these trends will be defined only "a posteriori".

The impending introduction of bST may be an exception to this pattern. The associated yield increase promises to be sufficiently large -- and adoption after FDA approval sufficiently quick -- to permit the tracing of its effects through a substantial part of the economy. The analysis of these effects, over time as well as over geographical regions, offers the unique opportunity of a theoretical study with significant real life verification.

Section III

BOVINE SOMATOTROPIN (bST)

In 1937, the production-enhancing effect of an injection of bovine pituitary gland extract into lactating cows was first reported. Subsequent investigations led to the identification of somatotropin, one of the substances produced by the gland, as the agent responsible for the observed increase in milk secretion (Bauman et al., 1985). Somatotropin of a similar type has been isolated in many other species, among them swine, goats, sheep, poultry, and also man. In all cases, it can be related to the partitioning of nutrients among the productive functions of the body. Since the principal productive function in young individuals is growth, or more precisely, the growth of lean tissue, somatotropin became known as growth hormone. In adult individuals, productive functions differ by species and the action of somatotropin may take very specific forms. In the case of lactating cows, it enhances the secretion of milk.

Until less than ten years ago, all bovine somatotropin needed for physiological tests or production enhancement experiments had to be extracted from the pituitary glands of slaughtered animals.

GENERAL CHARACTERISTICS

Bovine somatotropin (bST) is a protein whose molecular structure consists of 192 amino acid blocks (Martial). Its release from the bovine pituitary gland into the blood stream is monitored by releasing agents, the presence of which depends on, among other things, the genetic make-up of each animal (Peel). The production-enhancing action of supplementary bST in the mature dairy cow has been found to express itself at two interrelated levels of control. At a primary level, it increases the amount of tissue available for nutrient metabolism and milk synthesis. At a secondary level it influences the process of nutrient partitioning, increasing the mammary blood flow and milk synthesis to insure steady state conditions for the altered body structure (Boyd and Bauman). Knowledge of the mechanisms by which bST influences bovine physiology are still far from complete. Detailed studies of its effects on the carbohydrate, protein, and lipid metabolisms are presently underway, a considerable amount of information having recently become available (Peel and Bauman).

MANUFACTURE BY RECOMBINANT DNA TECHNOLOGY

For well over a century, achievements in the area of chemistry have made it possible to actively influence certain processes in most forms of life. However, until very recently, the hereditary characteristics of these forms could be influenced only passively, by selecting individuals with desirable traits after nature's periodic acts of genetic recombination through sexual reproduction. A change was triggered in the 1950's by Crick's and Watson's discovery of the molecular structure of Deoxy-ribonucleic Acid (DNA), the basic component of all genetic material. This discovery opened the way for the mapping of genes on the species-specific strands of DNA or chromosomes. Knowledge about the location of encoded instructions for the synthesis and release of specific proteins became the key to altering hereditary characteristics in life forms. In some of the lower forms, mapping progressed at an especially fast pace, and soon it became possible to insert pieces of DNA with species-exogenous codes into the genetic material of certain bacteria.

Simultaneously, there were unveiled the secrets of replication, transcription, and translation, the processes by which protein is synthesized according to DNA codes, and by which coded DNA for specific proteins can sometimes be reconstituted (Nester et al.). In the late 1970's, the gene for bST synthesis was reconstituted and isolated from bovine pituitary material and successfully inserted into the genetic material of a common bacterium, Escherichia coli (E. coli), one of the emerging work horses of biotechnology. The process was appropriated by pharmaceutical and chemical firms, able to grow the genetically altered bacteria in fermentation vats and to extract the bST from the subsequently processed cell material.

The driving force behind this development had, of course, been the idea of applying bST to commercial milk production. As soon as the supply of a reasonable amount of recombinant bST was assured, arrangements emerged between animal science departments of about a dozen universities and some of the potential bST manufacturers, with the objective of applying the product in full scale trials. These trials have been underway since 1983. Their results constitute the basis for ongoing physiological research and for technical and economic evaluations. Simultaneously, the public health aspects of bST are being studied by the Food and Drug Administration (FDA). Commercial application of the product is awaiting final FDA approval.

RESULTS OF APPLICATION TRIALS

The trials can be grouped by several criteria. These include the source of bST, the institution conducting the trial, the duration of the trial, and the method of bST application used. The principal groups by duration are long and short-term trials. With respect to the production pattern of an entire lactation, bST slightly raises the initial amount of milk produced per day but, more significantly, it delays the yield decline that normally starts approximately 90 days after calving. As the important increases in production are, thus, being achieved during the middle and the latter part of the lactation, little seems to be gained by applying bST during the early part of the cycle. Full-lactation or long-term trials generally start between 30 and 100 days post partum and continue almost to the end of the approximately 300 day lactation. Trials of less than this duration are considered short-term.

The fact that bST is a protein rules out its application by dietary intake, since it would be broken down, along with other proteins, in the cow's digestive tract.[1] Therefore, direct application to the blood stream is indicated. This can be done by either subcutaneous or intramuscular injection, or by a sustained release mechanism. Initially, all exogenous bST was applied by daily injection. To reduce the cost of application, sustained release vehicles (SRV) were developed. They permit intervals between injections of up to 28 days. In the application trials, both the daily injection and the SRV alternative are represented.

In Tables 8 and 9, results of the long-term application trials of bST, reported in the U.S., Canada, and the U.K. during the past four years (ADSA Proceedings), are summarized. A complete set of results, from both short-and long-term trials, appears in Appendices A-1 through A-7.

Of the 35 trials reported, 24 can be considered long-term. Of the latter, fifteen were based on the daily injection of bST, and nine on a sustained release method. A total of 638 cow-lactations were involved in the long-term daily injection trials. Twenty six of these cows were participating for the second consecutive lactation (U. of Minnesota, 1987). The long-term sustained release trials, the first of which were reported in 1987, involved a total of 813 cow-lactations, and included 38 cows which were receiving their second consecutive treatment (Monsanto, 1988)[2]. The focus in the long-term trials has been chiefly on the effect of the dose of bST on lactational performance and, in some cases, on feed consumption and feed efficiency.

The 11 short- and medium-term trials, on the other hand, were focused mainly on the influence exerted on the bST-induced increase in milk yield by different physiological and management conditions. Some of these conditions were the joint applications of bST and insulin, the application of extra

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[1]BST is also broken down in the human digestive system, a fact which is of interest in the evaluation of the consumer safety of milk produced by bST-treated cows.

[2]These totals include control animals and cows tested with pituitary bST. They are listed in the Appendices A-1 through A-7 but are not included in Tables 8 and 9.

Table 8

BST-INDUCED INCREASES IN MILK PER COW
(Long-Term Trials, Daily Injection)

Institution	Year	Cows/ Treatment	Milk[a] /Lactation (% increase)				
Monsanto (13.5, 27.0 and 40.5 mg of bST/da, respectively)							
Cornell U.	1985	6			14.36[b]	22.31	25.40
U. of Missouri	1986	6			7.81	1.36	2.73
Mississippi St. U.	1986	6			18.92	16.58	11.83
Wt. Ave.					13.70	13.42	13.32
Am. Cyanamid (6.25, 12.5, 25.0, 40.0, and 50.0 mg of bST/da., respectively)							
U. of Kentucky	1986	8	--	13.98	11.51	--	17.99
U. of Pennsylvania	1986	8	--	16.03	19.27	--	26.94
U. of Minnesota	1986	9	--	8.66	25.90	--	20.30
U. of Minnesota	1987	8,7,3	--	5.11	20.03	30.60	--
U. of Florida	1987	9	18.71	22.91	34.82	--	--
U. of Guelph	1987	10,10,9	--	12.10	15.34	--	13.13
Animal/Grassland I.	1987	10[c]	--	14.15	19.78	--	18.16
Animal/Grassland I.	1987	10	--	19.86	20.54	--	22.33
Wt. Ave.			18.71	14.33	20.91	30.60	19.72
Am. Cyanamid (10.3, 20.6, 30.9, and 41.2 mg of bST/da., respectively)							
Ohio St. U.	1988	9		-.87	4.80	--	13.52
U. of Pennsylvania	1988	30		2.66	3.33	3.33	--
Wt. Ave.				1.85	3.67	3.33	13.52
Upjohn & Others (5.0, 10.0, 15.0, 20.0, and 25.0 mg of bST/da., respectively)							
Pennsylvania St. U.	1988	16	--	--	--	--	6.70
U. of Georgia	1988	8	2.04	17.12	19.38	14.10	--
South Dakota St. U.	1988	8	8.37	.75	8.37	15.23	--
Wt. Ave.			5.21	8.94	13.88	14.67	6.70

[a] 3.5% fat corrected.
[b]Reported results converted from treatment period to 305 day lactation.
[c]Cows per treatment not reported, total divided by number of treatments.
Source: Appendices A-1 through A-3.

Table 9

BST-INDUCED INCREASES IN MILK PER COW
(Long-Term Trials, Sustained Release)

Institution	Year	Cows/ Treatment	Milk[a] /Lactation (% increase)		
Monsanto 14 da. Sustained Release (averages 36.7, 107 and 179 mg of bST/da., respectively)					
Monsanto	1988	16	23.46[b]	--	--
Monsanto	1988	16	18.88	--	--
Monsanto	1988	20[c]	28.83	35.83	32.69
Monsanto	1988	10[c]	23.94	28.20	44.50
U. of Vermont	1988	22[c]	25.98	--	--
Cornell U.	1988	40[c]	9.42	--	--
U. of Arizona	1988	40[c]	6.94	--	--
Utah St. U.	1988	36	12.15	--	--
Monsanto	1988	63[c]	18.01	--	--
Wt. Ave.			16.31	33.29	36.63
American Cyanamid 14 da. Sustained Release (averages 10, 25 and 50 mg of bST/da., respectively)					
Clemson U.	1988	9[c]	10.32	8.41	9.25
Lilly 28 da. Sustained Release (averages 11.4, 22.9, and 34.3 mg of bST/da., respectively)					
North Carolina St. U.	1988	48[c]	8.42	13.30	14.62

[a]3.5% Fat corrected.

[b]Reported results converted from treatment period to 305 day lactation.

[c]Cows per treatment not reported, total divided by number of treatments.

Source: Appendices A-4 and A-5.

high bST concentrations, and different frequencies of feeding and milking. A total of 164 cows were involved in short-term trials based on the daily injection, and a total of 108 in those based on the sustained release method. With respect to the present study, the long-term trials, obviously, are of greater interest.

In all but one of the long-term trials, supplementary bST had a positive effect on the output of milk per cow. There was, however, a wide range of increases, even among trials of similar dose, method of application, and duration of treatment. Converting the results from a treatment to a lactation base lessens this variation to some degree. The relationship between yield increases and application rates across trial groups is shown in Figure 4. It is apparent that comparable increases in milk yield can be obtained with either of the two methods of bST application.

Cyclical production patterns, parallel to the injection cycles, have been reported for some treatments based on a SRV. This phenomenon points to an accelerated use of bST by the organism during the first part and an insufficient supply during the latter part of the application interval (Bauman et al., 1989). The feed use figures indicate that dry matter ingested per cow also is increased by supplementary bST, although to a lesser degree than the output of milk. This implies a lower overall input of feed per unit of milk, reflecting the cost diluting effect of a constant maintenance requirement. The results reported by the University of Minnesota in 1987 and by Monsanto in 1988 indicate that cows treated for the second consecutive lactation respond to bST just as well as in their initial treatment.[3] The effect of some additional parameters, such as shade, frequency of feeding, and different rations, are also evident from the short-term results.

Qualitatively, an increase in milk produced per cow and a somewhat smaller increase in milk produced per unit of feed can be registered as the main effects of the application of supplemental bST. However, any type of quantitative projection of these results onto a national scale can only be made on the basis of a carefully formulated set of assumptions.

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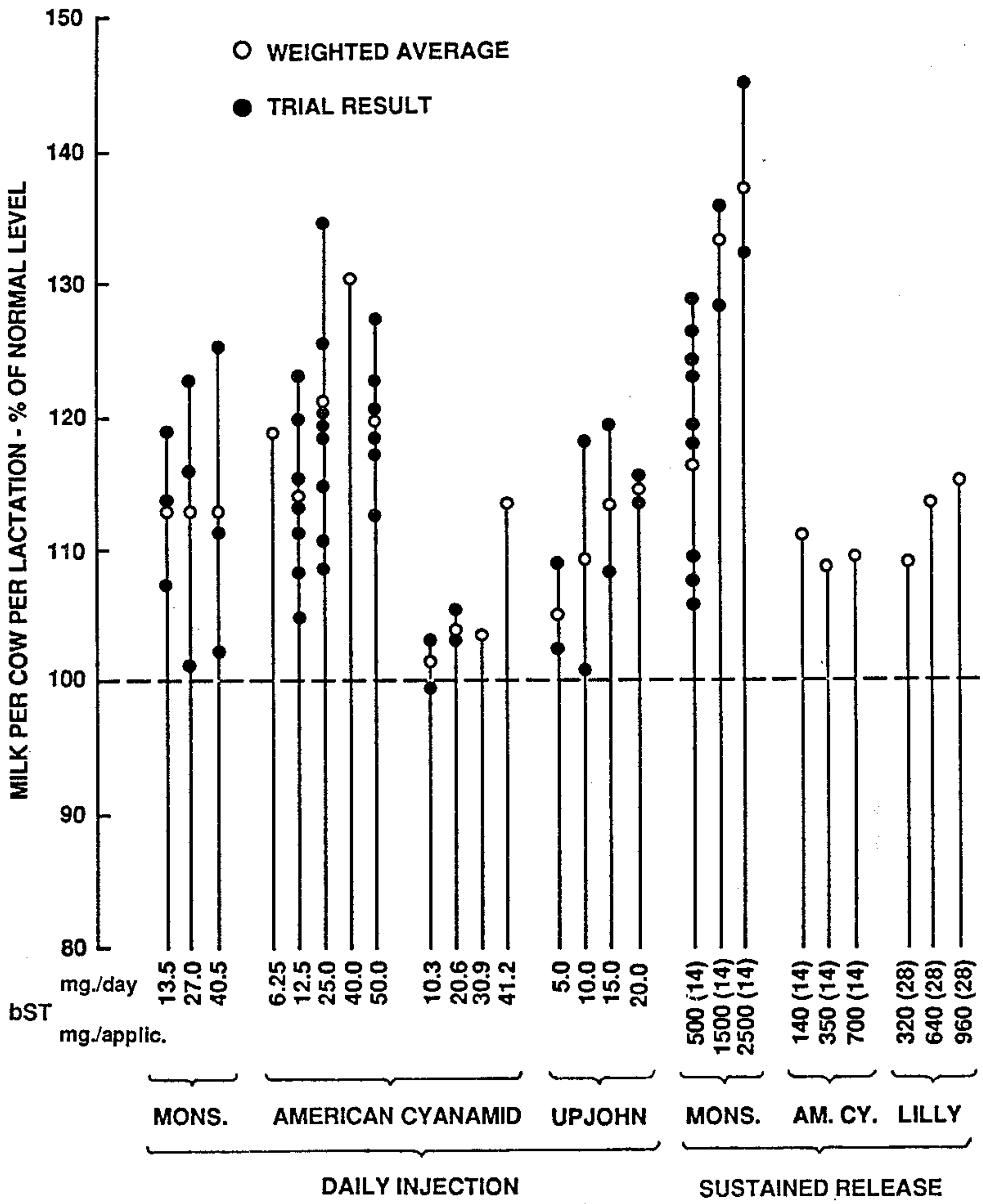
[3]Reports of lower responses to bST by first-calf heifers are probably due to the more constant performance over time by animals in their first lactation. As bST slows the decline in the daily output of milk throughout the lactation, such effect must necessarily be smaller where there is less of a decline (Bauman, personal communication).

FIGURE 4: RESPONSE OF MILK YIELD TO bST AT DIFFERENT APPLICATION RATES



Source: Tables 8 and 9

CURRENT ECONOMIC IMPACT STUDIES

The prospect of the commercial availability of bST and of its adoption by dairy producers prompted the appearance of a series of studies addressing the economic implications of such an innovation. As issues are being raised at different levels of economic aggregation, and as the resulting studies include many different economic relationships, a diversified body of literature on the economic impacts of bST is gradually emerging. There follows a summarized cross section.

Additional bST Parameters

While changes in production parameters may be derived from the trial results presented in the first part of this Section, indications as to the cost and the eventual adoption process for bST have to be obtained from separate studies.

Cost of bST. A portion of the bST study done by Kalter et al. (1985) focused on the feasibility of commercial production. Production costs in this study were estimated on the basis of engineering data. The possible returns for a potential bST industry and the necessary prices were based on plausible demands and justifiable margins and derived by a discounted cash flow simulation model. Given the lack of empirical data, no additional studies have been forthcoming in this area. The results of Kalter et al., presented in the form of likely wholesale prices of bST at different levels of demand, are used here as they have been by most investigators of the economics of bST.

BST adoption. While determining the cost of bST at different output levels essentially amounts to specifying a bST supply function, a bST demand function is specified by determining, under different profitability conditions, the level of bST adoption by the dairy industry. This level of adoption is defined in terms of the fraction of dairy producers which, under a certain scenario of technical and financial assumptions, would adopt bST as part of their production process. Since the assumptions are stated in terms of the cost-reducing or profit-enhancing potential of bST, a boundary of economic feasibility in a two-coordinate system of adoption levels and bST costs may be visualized. Such a boundary may be defined by using the subjective responses of a sample of dairy producers confronted with hypothetical bST scenarios or by objectively setting a point of economic feasibility of bST application for a known distribution of producers.

The first method was employed by Kalter et al.[4], Marion et al. and Zepeda, while the second was also used by Marion et al..[5] In the case of the first two studies, based on potential adopter surveys, the time aspect of the bST adoption is explored through the survey questionnaire. The results are presented either in a descriptive manner, as in Marion et al. and Zepeda, or in terms of a mathematical formula, as in Kalter et al. The latter used a diffusion model based on the sigmoid logistic growth curve. An important aspect of all three surveys is the classification of response groups by social and economic attributes. In the study by Marion et al., based on an objectively defined point of feasibility, the time aspect is introduced by the use of price and quantity predictions for specific future periods.

Kalter et al. predict an adoption level of 85 percent of all cows at the end of three years and Marion et al. one of 40 percent, with no time interval specified. No final adoption level nor time interval is predicted by Zepeda. Using the second method, Marion et al. predict the application of bST to 40 percent of all cows at the end of four years.

Impact on the Individual Dairy Producer

Kalter et al. also analyzed the effects of bST on three representative New York dairy farms.[6] Parameters were drawn from the experimental production results of bST application trials, balanced least-cost rations for correspondingly extrapolated feed requirements, and optimal rotation patterns for forage and feed grain production. The analysis was carried out for each farm at different conditions of initial milk yield per cow, yield response to bST, feed intake pattern, on-farm production of feed, and the producer price of raw milk. The results are expressed as returns in excess of variable costs per cow for each scenario specified. Break-even prices of milk were calculated for several scenarios. The results show that at all combinations of initial milk yield, bST response, and feed intake pattern tested, the farms producing all of their own feed stand to profit more from the application of bST than those producing forage only. At all raw milk prices tested, the break-

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[4]See also Lesser et al., 1986.

[5]The first three of these studies are based on state level surveys, realized in New York, Wisconsin, and California, respectively. A total of 173 producers were questioned by Kalter et al., 271 by Marion et al., and 146 by Zepeda. Marion et al. also used a method based on production level and production cost statistics of Wisconsin dairy farms.

[6]See also Milligan and Kalter, 1985.

even point for the first type of farm is considerably lower than that for the second.[7]

Impact on the Industry at the State Level

Kalter et al. also solved for post-adoption equilibrium quantities and prices of milk in the State of New York.[8] This analysis was based on cross-sectional production data from 147 randomly selected dairy farms and on existing milk price and quantity conditions. The reported results are percentage changes in the price and quantity of raw milk as well as in the number of farms and cows. A time dimension was added to the study by assuming bST adoption to take place according to the logistic diffusion equation estimated as part of the same study.

Alternatively, Kalter et al. developed another solution for the post-bST equilibrium in the New York State dairy industry. It is based on a mathematical programming rather than on an econometric approach.[9] It includes 18 possible farming activities, varying in bST use, yield response, initial milk yield, and type of feed production. The relative levels of the activities are constrained by resource limits which are representative of those encountered by typical New York dairy farms. The results reported are the relative levels of each of these activities, as well as the price and quantity of raw milk. The solutions are calculated with and without price supports being in effect.

Following the approach of the above study, Magrath and Tauer (1986) investigated the effects of bST on the price and quantity of raw milk in New York under various assumptions of yield response, bST cost, and manufacturing milk support price. The results, which are long-term equilibrium solutions, show that under the application of bST, profits in dairying will be very dependent on the level of price support and on the cost of bST.

Marion et al. calculated the impact of bST on the Wisconsin dairy industry. The study focuses on the feasibility of the adoption of bST among Wisconsin producers at various levels of yield response, milk price, bST cost, and the additional margin required by farmers to entice them to adopt bST. The empirical data of this study consist of the distribution of Wisconsin dairy cows by milk yield and by herd size. Results are presented as the level of bST

[7]Most studies on the economic impact of bST involve the use of mathematical models. Since at this point the focus is on the level and scope of the studies and on the results obtained, major attention is not paid to the details of such models here. Some of the studies mentioned are quoted again in Section IV, in a specific mathematical modeling context.

[8]See also Magrath and Tauer, 1985.

[9]See also Tauer, 1985.

adoption, in percentage of total cows, and the corresponding volume of milk produced. A time dimension was introduced by the use of plausible non-bST productivity increases and predicted changes in price support policy. The effect of bST on the income of dairy farmers, on consumer benefits, and on the structure of the Wisconsin dairy industry was then calculated assuming various reduced levels of the manufacturing milk support price.

Impact at the National Level

With milk supply being determined predominantly by regional production conditions and with milk demand depending on regional markets, at least in its fluid portion, it is federal dairy policy which has the greatest influence the structure of the dairy industry. Because of this, many studies on the impact of bST have focused on variations in dairy policy.

An example of this is provided by Kaiser and Tauer. The milk yield effects of bST were incorporated into national supply and demand conditions, as captured in an econometric model. This model, by simulation, projected equilibrium solutions for the number of cows, the price and quantity of milk, and farm profits over ten consecutive years. Scenarios were specified by adjusting the manufacturing milk price support and implementing a cow removal program through government-paid herd buy-outs. The results show that the most satisfactory trade-off between producer profits and government expenditure was obtained by using a combination of the two instruments. Similar studies, but with different methodological approaches, were carried out by Tauer and Kaiser, and by McGuckin and Ghosh.

Multi-Regional Impact on the Dairy Industry

A number of studies on the economic impact of bST have also taken into account the regionally differentiated nature of the dairy industry. The first of these was the 1985 report of the U. S. Congressional Office of Technology Assessment (OTA), the ninth chapter of which is dedicated to developments predicted for the dairy industry. Based on projections of representative farm studies for the main dairy producing regions, it established relationships between the production cost of milk and average herd size, and between average herd size and a long-term rate of return. BST-induced developments in the regional distribution of the dairy industry were then projected on the basis of the returns on investment for the regional representative farms. The returns were highest for farms in the Pacific and the Southwestern regions. Although this study had the merit of being the first to introduce the spatial dimension into the evaluation of the economic impact of bST, its conclusions were not accepted unanimously. Jesse and Cropp published a vigorous rebuttal of the implication of a dwindling competitiveness of the Wisconsin dairy industry, while Stanton (1987) did the same on behalf of the Northeast.

The study carried out by Fallert et al. at the Economic Research Service (ERS) of the U.S. Department of Agriculture is the most comprehensive of all economic bST studies published. Its results are based on the combined use of an industry analysis at the national level and an analysis of various regionally representative farms. Cow and dairy farm numbers for the U.S. as well as for seven different dairy production regions were projected with and without the use of bST, under four different policy scenarios, over eight one year periods. The results suggest that bST will decrease milk prices and the total number of cows, the lowest price level and cow number being associated with the scenario featuring the lowest support price. The results also suggest that bST has little effect on the regional distribution of the dairy industry under any policy scenario. The policy scenarios do not include any alterations of the mandatory fluid grade milk price differentials. No distinction is made between regions with respect to their dairy product manufacturing capacity. Also, interregional shipping of commodities is not considered.

Whereas Fallert et al. limited themselves strictly to dairy-oriented variables, Boehlje and Cole also included other livestock activities in their study. Thereby they were able to partially capture the interdependence between dairy and other agricultural production activities. Just as Fallert et al., they carried out two simultaneous analyses at different levels, one of them involving the national dairy industry. The other analysis, however, instead of involving regional representative farms, involved the regional livestock sectors. The results include total and regional production levels of milk, manufactured dairy products, and beef calves. They are calculated at no bST application and at two milk yield response levels of bST projected over six consecutive one year periods. Reported also are interregional shipments of milk, presumably the milk equivalent of manufactured dairy products. In terms of changes in the regional distribution of the dairy industry brought about by bST, Boehlje and Cole projected increases in milk production for the Eastern Corn Belt, the Southeast, the Southern Plains and the Pacific Northwest. Decreases were foreseen for the North Central Region and the Northern Great Plains, while practically no changes were projected for the Northeast and the Pacific Southwest.

Section IV

METHOD OF ANALYSIS

Quantitative analysis of bST's impact on the spatial distribution of the dairy industry requires a well defined modeling system. The conceptual framework for such a system is provided by neo-classical economic theory. It demonstrates how an economy, by constantly moving towards equilibrium in all its markets, allocates its resources to the production of goods and services, while distributing production factor returns as household income (Samuelson, 1947). Such a framework is tightly bound to welfare theory, which states that, ideally, the allocation of resources is economically efficient, and the distribution of factor returns equitable (Boadway and Wildasin).

The essential aspects of any analysis system are its economic linkages. Due to the interdependence of consumption, production, resource allocation, and income, all sectors of an economy are linked, and the effect of a change in one will eventually be transmitted to all others. Only rarely, however, is it practical to include all of these linkages in one analysis system. Usually, a trade-off between comprehensiveness and relevance has to be made. Agricultural industries are linked to each other rather closely through production factor and intermediate commodity markets, while linkages between agricultural industries and other productive sectors are much weaker. Thus, for an analysis of bST's impact, the entire agricultural sector suggests itself as the appropriate system.

This system covers most of the linkages relevant to the bST analysis. It, nevertheless, leaves out the linkage between factor payments and consumption expenditure. Strictly speaking, inclusion of that linkage, which closes the circular flow of goods and money, is the distinguishing characteristic of a general equilibrium system, all other systems being partial equilibrium only. However, in this particular case, where the system encompasses an entire sector of the national economy, a more relaxed usage of terminology will be followed. The label of general equilibrium will be applied even though the circular flow is not closed.[1]

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[1]Technically, the assumption of independence between demand of consumption commodities and supply of production factors in agricultural systems seems entirely reasonable (Hazell and Norton), given that the fraction of national income actually accruing to the owners of agricultural production factors is small, and that the rate at which a change in this fraction will be reflected in the national consumption function is slow.

QUANTITATIVE RELATIONSHIPS IN ECONOMIC SYSTEMS

The insight that, under the assumptions of neo-classical theory, an economy will always tend towards equilibrium was first formulated by Walras in the 1870's. It has since become the foundation for static economic analysis. Walras' insight implies that a system of equations, formulated using empirical parameters to represent a real economy will, upon solution, yield actual price and quantity variables. Solution, of course, is subject to the condition that supply equal demand. The solution values for the original conditions can then be used as a state of reference with respect to solutions obtained after changing, or "perturbing", one or several of the original parameters.

Mathematical Modeling

Static economic models, based on the above principle, have been devised under two different sets of assumptions. Under the first, equilibrium is taken as being determined by the interplay of impersonal forces which are part of the social environment (Chiang). The system includes general market clearing as well as empirically specified behavioral equations. The basic solution is defined in terms of coefficients relating prices and quantities to each other. Analysis is carried out by changing some of the exogenous variables in the behavioral equations, leaving the coefficients unchanged, and comparing the new and the original solution levels of the endogenous variables. This approach constitutes the basis for the conventional econometric technique of quantitative analysis.

Under the second approach, equilibrium is taken as being determined by the intervention of decision-making economic agents, households or firms, consciously optimizing their respective goals within budget or resource constraints (Chiang). The model includes an objective function representing these goals, and equations modeling any transformation process involved. The optimizing conditions of the objective function act as equilibrium conditions. The solution is defined in terms of endogenous variables, while coefficients and exogenous variables are taken as given, based on prior econometric estimation or technical information. Analysis is carried out by changing some coefficients or exogenous variables and observing the change in the equilibrium levels of all endogenous variables. This approach is the basis for the technique of constrained optimization, leading to mathematical programming (MP).

The above two approaches to quantitative analysis complement each other with respect to the different types of existing analytical problems. The ease with which quantitative relationships between variables can be estimated by econometric models, independently of any given function, makes them very suitable for systems about which technical detail is scarce. Such is the case with most problems involving household utility or consumption functions, and macroeconomic relationships. On the other hand, the ease with which specific information on transformation functions can be incorporated into optimization models gives the latter a great advantage in the case of production problems.

Static models are not the only available method for the analysis of economic change. Dynamic models also exist. Their application, however, is restricted to systems which possess well defined linkages between successive time periods, such as between income in one year and investment in the next for an individual firm. In a sector context, few of these linkages are known (Hazell and Norton) which is the reason why static models are predominant. The use of static models should be accompanied, however, by an awareness of the dynamic influences they do not capture.

Mathematical Models and the Impact of bST

As was indicated in Section III, the economic studies spawned by the prospect of the introduction of bST encompass a wide range of economic relationships and levels of aggregation. Useful methodological starting points for a quantitative analysis of the economic impact of bST were provided by the existing farm level and dairy industry models, in both econometric and MP formulations (Thraen).

A farm level linear programming model in which experimental bST results are introduced to modify the technical coefficients was used by Kalter et al. to solve for the optimal allocation of productive resources on three representative New York dairy farms after the adoption of bST. The analysis of the impact of bST on representative farms, either by econometric or programming models, has also been employed as a basic component in several bST studies at higher levels of aggregation, including reports by the OTA and Fallert et al.

Both an econometric and a programming model of the dairy industry were used by Kalter et al., to solve for post-adoption equilibrium conditions in the state of New York. In the econometric model, the raw milk demand function is based on current price and quantity data which are combined with several assumed elasticities. The model has a raw milk supply function based on the concept of Marshall's "Particular Expense Curve", an ordering of costs by producers, from most to least efficient. It is adjusted in the intercept term by increments which reflect the technological effects of bST. The programming model is based on the optimization of social welfare, defined as the sum of consumers' and producers' surplus. The optimization is made possible by the exogenous calculation of the area between a demand curve, taken from the econometric study above, and a supply curve, implicitly specified through the constraints on a series of production activities of decreasing efficiency. The bST effect is incorporated into the coefficients defining these activities. The segmentation of both curves allows the solution of the quadratic programming problem by a linear algorithm.

An example of a bST study exclusively relying on an econometric dairy industry model at national level is supplied by Kaiser and Tauer. In it, the effect of different time paths of policy adjustment is analyzed through the use of a series of static solutions. Subsequently, Tauer and Kaiser carried out a study in which the policy adjustment scenarios are no longer compared on the basis of a sequence of static solutions but on the basis of a single dynamic solution.

Up to now, whenever it was required to analyze simultaneously the response of national policy parameters and regional production levels to bST, models at two different levels have been used. The most notable example of such endeavor is the comprehensive study by Fallert et al. An econometric model of the dairy industry at the national level, incorporating the bST-induced increases in production, solves for the overall price and quantity values. An econometric model at farm level, also incorporating the effects of bST, responds to the industry prices in terms of cow numbers, according to regional production cost conditions, herd size, milk yield per cow, and farm debt. The results of both models are brought into agreement for each scenario by adjusting the number of cows in the industry model. While an abundance of results is obtained from this combination, the synchronization of the two models is difficult and somewhat arbitrary, as the authors themselves admit. The true comparative advantage position of an industry in a particular region can only be captured through the modeling of resource constraints and competing production activities. This is not possible with econometric models of representative regional farms but requires a MP approach.

The study by Boehlje and Cole, even though much less comprehensive than that of Fallert et al., and even though still depending on the econometric dairy model for national commodity volumes and prices, contains such constraints through its use of a regional linear programming model of all livestock activities. Kalter and Milligan, in an article about the economic and policy implications of emerging agricultural technologies, strongly recommend a general equilibrium type analysis.

A review of the literature on the economic impacts of bST led to the conclusion that, for this investigation, the general equilibrium method would be the most appropriate approach. The analysis would involve a single model that, on the one hand, would furnish production totals and responses to policies on a national level and, on the other hand, allocate regional resources among dairy and the remaining agricultural production activities.

Recent developments in static MP justified the pursuit of such a model in that area. As an unavoidable trade-off for eliminating the two-model analysis, however, individual farm unit operating results would not be obtained. Also, the short and intermediate term solutions would be less relevant since, in a MP approach, solutions primarily are obtained for a long term general equilibrium.

MATHEMATICAL PROGRAMMING (MP)

Constrained mathematical optimization problems are formulated in the language of differential calculus and solved by the Lagrangean method. When this "classical programming" method is used in an economic context, the optimum, achieved either at maximum profit or at minimum cost for the decision-making producer, can be equated with economic equilibrium. Optimum conditions are defined by the vanishing first partial derivatives of the objective function and by the appropriate sign in the determinant of the bordered Hessian matrix. This method was one of the main quantitative tools in economics for many years. However, it also proved to be the source of serious limitations, since it required the objective function and the constraints to be continuously twice differentiable, and only admitted equality constraints throughout. Mathematical solutions were limited to rather abstract systems of few equations and variables.

The Development of MP Solutions

The solution of large scale realistic systems became possible with the introduction of MP. The differentiability requirement of classical programming disappeared and inequalities could be used in formulating the system of equations. In MP, in place of a single-point solution, there exists an opportunity set, a space within which solutions are feasible. Among all feasible solutions, the final one then has to be found by iteratively improving the objective function.

In linear programming (LP), the objective function and the constraints are limited to being linear equations.[2] As opposed to classical programming, the opportunity set is not described by a continuous production possibility frontier but by a discontinuous set of resource availability constraints. Each resource enters the discrete production activities of LP at a fixed rate. The variables of the system are represented by the activity levels while the objective function is made up of the sum of profit or cost contributions of the activities. Strict non-substitution of inputs and constant returns to scale are

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[2] LP was the only operative version of MP for about 20 years.

necessary assumptions for this method. There are no "a priori" optimum conditions and, as is the case with all MP problems, the LP problem has to be solved iteratively.

Since only as many variables can be admitted into solution as there are constraints, each iteration is an attempt to improve the objective function by exchanging one of the solution variables. If no further improvement can be accomplished the optimal solution has been reached. At that point the duality theorem and the complementary slackness theorem hold true. They can be understood as an "a posteriori" formulation of optimum conditions.[3]

Availability of the LP algorithm and electronic computers initiated the era of large scale economic modeling. Such modeling can be applied to any system allocating limited resources among fixed-input and constant-return-to-scale production activities. Agricultural models were specified to solve for cost minimizing or profit maximizing activity levels. The solutions were subject to the known availability limits of land and labor. The models were based on realistically defined input-buying, commodity-producing, and output-selling activities and on specifically derived input usage and output yield coefficients. Models were specified for typical farms and for state and regional agricultural systems. Eventually, the agricultural sector of an entire country was represented in a single model (Kutcher et al.).

At this point, the issue of regionalization had to be addressed. Supply of most agricultural commodities varies with the geographical distribution of

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[3] With every primal(P) problem of LP, there is associated a dual(D) problem:

(P) MAX.: $c'x$ S.T.: $Ax \leq b$ (D) MIN.: $w'b$ S.T.: $w'A \geq c$

where c = Vector of primal objective function coefficients (l)
x = Vector of primal solution variables (l)
A = Matrix of technical coefficients (k,l)
b = Vector of primal constraint values (k)
w = Vector of dual solution variables (k).

The duality theorem states that primal and dual either have the same optimal solution or none at all

$$c'x^* = w'b^*.$$

The complementary slackness theorem states that, at the optimal solution, an inequality in any of the constraint equations implies a zero in the corresponding dual variable. It also states that, at the optimal solution, a positive value in any of the variables implies an equality in the corresponding dual constraint equation

$$(A_k x - b_k)w_k = 0$$
$$(w'A_l - c_l)x_l = 0\,.$$

comparative advantage for their production. Demand is dependent on the distribution of either final consumers or processing industries. The result is a separate set of markets, with its own inter-market boundaries, for each commodity. The right degree of aggregation of markets for each commodity and the appropriate combination of such aggregates into model regions has to be decided according to the specific purposes of each model. In an agricultural sector model, there may be different regional subdivisions for production, processing, and consumption, but not for factors or commodities linked through the same markets.

One of the serious limitations with which first generation LP agricultural sector models were burdened was their missing link to economic equilibrium. Whereas, in firm or farm models, fixed factor and commodity prices are a realistic assumption, this is not true in models at the level of the entire economy. Simple minimization of the production and delivery cost of exogenously specified quantities of commodities, as stated in the objective functions of LP models, does not constitute a condition of economic equilibrium. Commodity supply functions can be derived from implicit factor supply functions which are based on the opportunity costs of factors in alternate production processes. But no economic equilibrium can be guaranteed unless supplies are equated to demands through price dependent demand functions.

The theoretical basis for the eventual elimination of this shortcoming was found in the fact that the equilibrium point of price and quantity which maximizes the joint benefit to buyers and sellers in the classical market model also maximizes the difference between the areas under the linear demand and supply curves. These areas may be thought to represent consumers' and producers' surplus respectively. This result, presented by P. Samuelson in 1952, was first applied to mathematical programming by T. Takayama and G. G. Judge in 1971. The areas under the demand and supply curves, when expressed in terms of the demand and supply variables and indirect linear demand and supply functions, appear as quadratic terms. The introduction of the difference between these terms to the objective function of an otherwise linear model was the beginning of quadratic programming (QP) in economics.

In a QP model, the maximization of total social welfare, represented by the sum of differences between the areas under the linear demand and supply curves, will solve for the equilibrium levels of the respective buying and selling activities. In accordance with the demand and supply functions, specified as part of the model, equilibrium prices in the corresponding markets also will be determined endogenously.[4] As no computer algorithm for the

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[4] Although these functions may not actually be linear, they are estimated and specified that way as a matter of convenience.

solution of QP models existed at the time, approximations with LP algorithms, on the basis of convex separable programming, were undertaken. The most prominent was the grid linearization process used in 1973 by J. H. Duloy and R. D. Norton in their solution of CHAC, an agricultural sector model of Mexico.

Theoretical work on the concept of nonlinear programming (NLP) had been initiated by H. W. Kuhn and A. W. Tucker in 1951. Their set of first order conditions is sufficiently general to include classical, linear, and quadratic programming, all as special cases (Intriligator). The Kuhn-Tucker conditions make provision for the possible corner solutions due to the non-negativity constraints that had already been introduced to classical programming, as well as for the possible extreme point solutions due to the inequality constraints first used in the opportunity sets of LP models. They are based on the assumption that the feasible region of NLP is a convex set. This implies the need for the qualification of constraints at their boundary values. It has been established that, if the feasible region is a convex set formed by linear constraints only, such as occurs in QP, then the above constraint qualification will always be met and the Kuhn-Tucker conditions will hold at an optimal solution (Chiang).

Lately, computer algorithms have become available by which it is possible to directly solve mathematical programming problems of any degree of nonlinearity in either the objective function or the opportunity set. This includes QP models such as represented by price endogenous agricultural sector models.

MP Models of the U.S. Agricultural Sector

In MP models applied to agriculture, the very nature of the sector imposes fairly predictable forms on most of the elements. Model dimensions are geographical units, land and labor classifications, crop and livestock production technologies, and intermediate and final commodities. The endogenous variables represent the activity levels of factor supply, and of commodity production, transportation, and demand. The objective function in LP models, typically, is total costs or total net profits to producers, while in QP models, typically, it is social welfare, defined as the sum of consumers' and producers' surplus. A MP model of the agricultural sector normally has a strictly linear opportunity set, defined by equalities which balance either factors or commodities, and by inequalities which limit either factor supply or commodity demand.[5]

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[5] Its technical coefficients are the factor and intermediate commodity usages and the intermediate and final commodity yields of production and processing activities. Its so-called right-hand-side (RHS) parameters include the levels of land and farm labor constraints and

Application of MP to the agricultural sector in the U.S. started in 1955 when a basic LP model of the production of three types of grain in 104 production regions was built at Iowa State University. There, at the Center for Agricultural and Rural Development (CARD), the basic model was subsequently expanded and adapted to the analysis of resource use, production capacity, and agricultural policy. In 1975, it encompassed over 10,000 equations and 75,000 variables.[6]

The CARD model objective function minimizes total producer cost. The endogenous variables are the levels of crop and livestock production, labor, water, and fertilizer use, and commodity transportation. Its technical coefficients and constraint parameters constitute an enormous data base.[7] Although it is possible to adapt the CARD model to a detailed study in one part of the modeling matrix while aggregating technologies and balances in all others, it was not considered for studying the effect of bST. The detail with which its technical coefficients would have to be modified is not warranted by the limited information available on the actual effects of bST.

In 1983, a package for modeling the U.S. agricultural sector was presented by B. L. Chattin, B. A. McCarl, and H. S. Baumes Jr. at Purdue University. The dimensions in the resulting models include primary and secondary production regions, types of land, labor, and national inputs, primary and secondary production technologies, and agricultural commodities. Land and labor are assigned as fixed endowments to a number of production regions. In each region, supplies of these resources are characterized by linear supply functions. Resource demands exist in the form of derived demands, based on the demands for final commodities. All commodity demands are characterized by linear demand functions. The package provides for the formulation of a QP model which allocates the regional resource

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any possible constraints on demand. (In LP models, where the levels of commodity demand are not determined by endogenous market functions, these have to be specified exogenously as RHS vectors.) Objective function parameters include production and transportation costs and factor and commodity prices. (In LP models, all of them are specified directly. In QP models, prices are specified by parameters for the respective linear supply and demand functions.).

[6] The CARD model space varies with the specific application. In different combinations, there have been up to 223 production regions, 30 domestic consumption regions, 51 water supply regions, nine land classes per production region, two types of crop and five types of livestock management, 17 commodities, and 458 transportation routes (Heady and Nicol).

[7] The nature of the constraint parameters in the CARD model points to one of the serious limitations of LP. They include constraints for regional factor supply and commodity demand activities, but also for many of the production activities. Practically every increase in model realism, obtained through the introduction of alternative production technologies, makes it necessary to constrain the levels of the newly added activities. Otherwise, production of a commodity would be concentrated in the least-cost activity.

endowments to the production of commodities, maximizing the sum of producers' and consumers' surplus. The model variables are levels of land, labor, and national input use of primary and secondary production (or processing), and commodity demand for domestic consumption, export, and private stocks.

Any actual model based on this package will then be solved by a LP algorithm, through the use of convex separable programming. The large number of endogenous variables created by the segmentation of every supply and demand activity is one of the procedural drawbacks of this modeling approach. A structural disadvantage, especially for the study of spatial equilibrium effects, is the single domestic consumption region and the consequent lack of provision for commodity transportation. Nevertheless, the Purdue package has become a useful point of departure for further modeling work.

In 1985, R. M. House of the Economic Research Service (ERS) at the USDA presented USMP, a QP agricultural sector model. It was formulated to be solved by the Modular In-core Non-linear Optimization System (MINOS), one of the new non-linear programming algorithms. Thus, the large number of variables dictated by the separable programming method was obviated. Model dimensions of USMP are essentially the same as described for the Purdue package.[8] In addition to the geometric representation of producers' and consumers' surplus, the objective function includes a quadratic term for producers' risk. The model does not include any commodity transportation activities. Technical coefficients are based on data from the Firm Enterprise Data System (FEDS) assembled by the Economic Research Service of the U. S. Department of Agriculture (1979-82). Regional land and labor constraints, as well as the parameters for their linear supply functions, are based on information from a number of other agencies within the USDA, as are parameters for the linear commodity demand functions. The objective function contributions of production activities are expressed as a residual cost, specified as total revenue less total cost, both evaluated at base year prices. The translation of the model from user formulation to algorithm input continues to be done by a matrix generator, the same way as in the traditional LP solutions. The intended primary application of USMP is in policy analysis.

In 1987, T. L. Hickenbotham of ERS presented SPATEQ, a QP agricultural sector model developed to analyze the spatial impacts of a general energy price increase and a possible federal subsidization of vegetable oil production on the use of vegetable oil as diesel fuel. SPATEQ has ten production regions. Availability constraints are specified regionally for labor and on a state basis for land. Otherwise, the production sector is not unlike that of

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[8] There are ten regions for production and one for domestic consumption, two types each of land and labor, 23 national inputs, 26 primary and 33 secondary production technologies, two irrigation and two price support program participation alternatives, and 36 commodities.

USMP. In the consumption sector, however, there are ten domestic regions instead of one. There also are two kinds of transportation activities. One of them models the transport of intermediate commodities between production regions, and the other that of final commodities between production and consumption regions. The transportation cost coefficients constitute a significant empirical contribution of this model. Since the general structure of SPATEQ goes back to the Purdue package, the grid linearization or convex separable programming method is employed in its solution. The translation between user and algorithm takes place through a matrix generator and report writer program.

THE AGTEC MODEL

For the analysis of the impact of bST, an effort was made to formulate a model which would combine the strengths of QP with the use of the MINOS algorithm and the SPATEQ interregional transportation submodel, and which, at the same time, would substitute the cumbersome traditional matrix generator program with one of the recently developed modeling languages. The Agricultural Sector Spatial Equilibrium Model for the Analysis of Technical Change (AGTEC) is the result of this effort.

The system being modeled by AGTEC is assumed to have two types of economic agents, owners of production factors and users of final commodities. The agents are assumed to be operating in perfectly competitive markets and to behave in accordance with explicitly specified linear factor supply and commodity demand functions.[9] This condition implies that there are no decision-making intermediate agents and that all production and transportation activities are taking place at equilibrium conditions, which is at minimum cost. It is assumed that there are no imports of agricultural commodities.

In AGTEC, the objective function is defined as total welfare or gross social surplus, the sum of factor-owning producers' and commodity-using consumers' surplus. The remaining endogenous variables are constituted by the activity levels of factor supply and commodity demand, primary and secondary production, and transportation between spatially differentiated points of supply and demand. The model indices, parameters, and variables are listed in Tables 10 through 12, respectively.

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[9] The factor demand and commodity supply functions needed to complete the characterization of these markets are implicitly specified by commodity demand, factor availability, and the Leontief type production functions contained in the technical matrix.

Table 10 (Continued)

Primary Production Technologies (pt):	
Dryland Cotton Growing	Irrigated Silage Growing
Dryland Soybean Growing	Irrigated Hay Growing
Dryland Wheat Growing	Hay to Silage Conversion
Dryland Sorghum Growing	Dairy Farming
Dryland Corn Growing	Beef Raising 1
Dryland Barley Growing	Beef Raising 2
Dryland Oats Growing	Farm Feeding of Beef 1
Dryland Silage Growing	Farm Feeding of Beef 2
Dryland Hay Growing	Farm Feeding of Beef 3
Soy-Wheat Double Cropping	Farm Feeding of Beef 4
Irrigated Cotton Growing	Feedlot Feeding of Beef 1
Irrigated Rice Growing	Feedlot Feeding of Beef 2
Irrigated Soybean Growing	Feedlot Feeding of Beef 3
Irrigated Wheat Growing	Feeder Pig Raising
Irrigated Sorghum Growing	Farrow-to-Finish Operation
Irrigated Corn Growing	Feeder Pig Finishing
Irrigated Barley Growing	

Secondary Production Technologies (st):	
Soybean Crushing 1	Raw Milk to Class I Milk
Soybean Crushing 2	Raw Milk to Class II Milk
Dairy Supplement Mixing 1	Class I Milk to Fluid Milk
Dairy Supplement Mixing 2	Class II Milk to Ice Cream
Dairy Supplement Mixing 3	Class II Milk to Soft Cheese
Dairy Supplement Mixing 4	Class II Milk to Hard Cheese
Dairy Supplement Mixing 5	Class II to Butter and NFDM
Dairy Supplement Mixing 6	Dairy Calves to Calves for Slaughter
Low Protein Beef Suppl. Mxg 1	Beef Calves to Calves for Slaughter
Low Protein Beef Suppl. Mxg 2	Dairy Cows to N-F Beef for Slaughter
Low Protein Beef Suppl. Mxg 3	Beef Yrlgs to N-F Beef for Slaughter
Low Protein Beef Suppl. Mxg 4	Beef Cows to N-F Beef for Slaughter
Feed Grain Mixing 1	Fed Beef for Slaughter to Fed Beef
Feed Grain Mixing 2	Calves for Slaughter to Veal
Feed Grain Mixing 3	N-F Beef for Slaughter to N-F Beef
Feed Grain Feeding to Cattle	Culled Sows to Pork
High Protein Beef Suppl. Mxg	Hogs for Slaughter to Pork
High Protein Swine Suppl. Mxg	Prod. of Poultry and other LS
Feed Grain Feeding to Swine	

Table 12

AGTEC VARIABLES

GSS	Gross Social Surplus
$XSFCL_i$	Farmer-owned Cropland Supply Activity
$XSHCL_i$	Rented Cropland Supply Activity
$XSFPL_i$	Farmer-owned Pasture Land Supply Activity
$XSHPL_i$	Rented Pasture Land Supply Activity
$XSWPL_i$	Western Pasture Land Supply Activity
$XSFLB_i$	Family Labor Supply Activity
$XSBHLB_i$	Bottom Tier Hired Labor Supply Activity
$XSVHLB_i$	Variable Wage Hired Labor Supply Activity
$XP_{ii,pt}$	Primary Production Activity
$XS_{st,i}$	Secondary Production Activity
$XTP_{i,l}$	Commodity to Production Transfer Activity
$XQP_{i,j,l}$	Comm. Production to Prod. Transportation Activ.
$XQC_{i,j,l}$	Comm. Prod. to Consumption Transport. Activity
$XQE_{i,f,l}$	Comm. Export Transportation Activity
$XTPST_{i,l}$	Comm. to Private Stock Transfer Activity
$XTGCP_{i,l}$	Comm. to Government Transfer Activity
$XDCON_{l,j}$	Consumption Demand Activity for Commodity
$XDEXP_{l,f}$	Export Demand Activity for Commodity
$XDPST_l$	Priv. Stock Demand Activity for Commodity
$XDGCP_l$	Government Demand Activity for Commodity

The mathematical formulation of AGTEC is stated in Table 13. The objective function (1) includes all variables which influence the level of gross social surplus. Because of the specification of factor and commodity prices by linear demand and supply functions, it is a second degree equation. Objective function coefficients include transportation and production activity costs and the parameters defining factor supply and commodity demand functions. The opportunity set is defined by three groups of linear equations: factor market clearing rows and constraints (2-11), commodity production and transportation balances (12-14), and commodity market clearing rows and constraints (15-18). The technical coefficients specify the usage of factors in primary, and

Table 13 (Continued)

$XSFPL_i \le FPLMX_i$;	for all i	(9)
$XSFLB_i \le MAXFLB_i$;	for all i	(10)
$XSBHLB_i \le BHLBMX_i$;	for all i	(11)
$\Sigma_{ii}\Sigma_{pt}YP_{i,ii,pt,l}XP_{i,ii,pt}+\Sigma_{st}YS_{st,i,l}XS_{st,i}-XTP_{i,l}+\Sigma_j XQP_{i,j,l}$ $+\Sigma_j XQC_{i,j,l}+\Sigma_f XQE_{i,f,l}+XTPST_{i,l}+XTGCP_{i,l} = CIPST_{i,l}$;	for all i, l	(12)
$\Sigma_{pt}YSIL_{ii,pt}XP_{ii,pt} = 0$;	for all ii	(13)
$XTP_{j,l}-\Sigma_i XQP_{i,j,l} = 0$;	for all j	(14)
$\Sigma_i XQC_{i,j,l}-XDCON_{l,j} = 0$;	for all l, j	(15)
$\Sigma_i XQE_{i,f,l}-XDEXP_{l,f} = 0$;	for all l, f	(16)
$\Sigma_i XTPST_{i,l}-XDPST_l = 0$;	for all l	(17)
$\Sigma_i XTGCP_{i,l}-XDGCP_l = 0$;	for all l	(18)

the usage and yield of commodities in primary and secondary production activities.[10] All opportunity set coefficients not belonging to the technical matrix are unity. Equations containing a right hand side (RHS) value are either constraints or balance rows with non-zero beginning levels. Equations without RHS values are either market clearing rows or zero beginning level balances. Figure 5 is a representation of AGTEC in tableau form.

AGTEC is formulated in the General Algebraic Modeling System (GAMS) which allows it to be solved directly by MINOS. A modeling language, such as GAMS, essentially consists of prefabricated programming elements which, when used according to specific rules, will enable the user to

[10] It should be noted that no production inputs other than land, labor, and intermediate commodities are modeled. The prices of such general inputs as fertilizer, fuel, and electric power are assumed to be unaffected by demand from the agricultural sector and are included directly as a component of production activity costs.

directly produce an appropriate input for the solution algorithm (Bisschop and Meeraus). A version of GAMS was developed specifically for MINOS (Kendrick and Meeraus) which in turn had to be adapted to GAMS in a special version. This was the origin of the GAMS-MINOS user package, then in its experimental stage. A listing of the complete GAMS formulation of the model may be obtained from the authors.

economic context, this amounts to verifying whether the Kuhn-Tucker conditions of the problem imply competitive economic equilibrium. Such verification constituted the third step of the procedure.

The fourth and final step was the validation of the model, the comparison of base year solution values with observed base year prices and quantities. In the remainder of this chapter, several key aspects of the AGTEC model and its development are highlighted.

BASIC STATEMENT OF THE MODEL

In Tables 10 through 12, the dimensions, parameters, and variables of the model were displayed. The mathematical formulation of AGTEC was shown in Table 13.

Dimensions

Ten geographical regions are used as spatial units in production and, likewise, in domestic consumption. They are the crop producing regions defined by ERS which are shown in Figure 2. Other countries to which U.S. agricultural commodities are exported are combined into a single foreign region. There are 43 commodities which include all major intermediate and final outputs from crop and livestock activities. Not included are vegetables, fruits and nuts, sugar crops, and tobacco. Commodities may be inputs to either further processing or final demand activities, in any of the domestic or foreign regions. The three factors of production are cropland, pasture land, and agricultural labor. There is a set of 33 primary production technologies, essentially following the Firm Enterprise Data System (Economic Research Service, 1979-82) listing, and a set of 37 secondary production or processing technologies.

Assumptions in Technical Coefficient Specification

The parameters of AGTEC are grouped by convention into technical coefficients, right-hand-side (RHS) values, and objective function contributions. Although primarily conveying quantitative information, they also carry assumptions about inter-dimensional relationships of the model. This is true especially in the case of the technical coefficients. A mapping of commodities into production technologies is shown in Figure 6. The assumption is that no relationship between elements of the two sets will exist outside of this mapping. Any parameter change to be imposed in the course of static analysis will be confined to this particular commodity yield and usage space.

FIGURE 6: (Continued)

Secondary Livestock Technologies

	101-COTTON	102-RICE	103-SOYBNS	104-WHEAT	105-SORGHM	106-CORN	107-BARLEY	108-OATS	109-SILAGE	110-HAY	201-SBMEAL	202-SBOIL	211-PRSUPD	221-LOPRCT	222-HIPRCT	223-CORNCT	232-HIPRSW	233-CORNSW
81-PLTYOLS				+	+	+	+	+										
72-HOG-PRK																		
71-SOW-PRK																		
69-NSL-NBF																		
68-CSL-VEA																		
67-FSL-FBF																		
65-CBC-NSL																		
64-BYL-NSL																		
63-CDC-NSL																		
62-BCF-CSL																		
61-DCF-CSL																		
56-CL2-BTP																		
55-CL2-HCP																		
52-CL2-SCP																		
51-CL2-ICR																		
45-CL1-FLU																		
42-RAW-CL2																		
41-RAW-CL1																		

Primary Livestock Technologies

	101-COTTON	102-RICE	103-SOYBNS	104-WHEAT	105-SORGHM	106-CORN	107-BARLEY	108-OATS	109-SILAGE	110-HAY	201-SBMEAL	202-SBOIL	211-PRSUPD	221-LOPRCT	222-HIPRCT	223-CORNCT	232-HIPRSW	233-CORNSW
73-PGFIN											+						+	+
72-FTFIN											+						+	+
71-FDRPG											+						+	+
69-FDLT3															+	+		
68-FDLT2					+				+	+					+	+		
67-FDLT1					+				+	+					+	+		
66-FCTL4									+	+					+	+		
65-FCTL3										+					+	+		
64-FCTL2									+	+					+	+		
63-FCTL1										+					+	+		
62-BFCEN							+	+	+	+					+	+		
61-BFCCF									+	+				+		+		
41-DAIRY									+	+			+					
35-HAYSI									-	+								

Columns 101–110: Primary; columns 201–233: Secondary

Crop Commodities

Figure 7 provides a mapping of primary production technologies into states, while the mapping presented in Figure 8 is one of secondary production or processing technologies into regions. It is assumed that primary and secondary production activities take place only within the confines of these mappings, and that the model will provide no solution values for any activity outside of these combinations. Analysis shocks may cause the levels of these activities to vary within the respective regions and states or to vanish completely. They may not, however, cause activities to appear in states or regions where they are not foreseen by the above mappings.

Opportunity Set Parameters

Technical coefficients and RHS values jointly constitute the opportunity set parameters. The coefficients of the technical matrix express usages of production factors and yields, as well as usages of commodities in all transformation activities. Since factors have price-dependent supply functions, the factor usage of an activity influences the activity's entry into the final solution.

Technical coefficients. The usage of total and irrigated cropland, pasture land, and agricultural labor in primary production activities is specified by the coefficients UCLDP, UIRCP, UPLDP, and ULABP. Since secondary production activities, by definition, express only the processing of primary commodities, land is not among their inputs. The labor employed in secondary production activities is assumed to be of the industrial type, supplied from an unlimited national pool. Because of this, wages in secondary production are not a function of the quantity of labor used, and labor costs can implicitly be included with net production activity costs. Thus, no production factor usage coefficients for secondary production or processing activities need to be specified.

In the model formulation of Section IV, commodity yields and usages in primary and secondary production are specified by the three-dimensional coefficients YP and YS. Jointly, factor usage, and commodity yield and usage coefficients specify the constant-proportion production functions of the model's primary and secondary production activities.[2]

The factor usages as well as the commodity yields and usages associated with primary production activities are specified on a state basis. The commodity yields and usages associated with secondary production activities, on the other hand, are specified by region. The outputs of state level primary as well

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[2]As a matter of convention, activity inputs carry a positive and activity outputs a negative sign.

FIGURE 8: SECONDARY PRODUCTION TECHNOLOGIES BY REGION ("*" Indicates an assignment from SPATEQ, "o" indicates a new assignment)

	NE01	LS02	CB03	NP04	AP05	SE06	DL07	SP08	MN09	PA10
01-SOYCR1	*	*	*	*	*	*	*	*	*	*
02-SOYCR2	*	*	*	*	*	*	*	*	*	*
11-PRSUPD1	*	*	*	*	*	*	o	*	o	*
12-PRSUPD2	*	*	*	*	*	*	o	*	o	*
13-PRSUPD3	*	*	*	*	*	*	o	*	o	*
14-PRSUPD4	*	*	*	*	*	*	o	*	o	*
15-PRSUPD5	*	*	*	*	*	*	o	*	o	*
16-PRSUPD6	*	*	*	*	*	*	o	*	o	*
17-LOPRCT1	o	o	*		*	*	*			
18-LOPRCT2	o	o	*		*	*	*			
19-LOPRCT3	o	o	*		*	*	*			
20-LOPRCT4	o	o	*		*	*	*			
21-FEEDGR1	*	*	*	*	*	*	*	*	*	*
22-FEEDGR2	*	*	*	*	*	*	*	*	*	*
23-FEEDGR3	*	*	*	*	*	*	*	*	*	*
26-CORN-CT	*	*	*	*	*	*	*	*	*	*
29-HIPRCTO	*	*	*					o	o	o
33-HIPRSWO	*	*	*	*	*					
36-CORN-SW	*	*	*	*	*					
41-RAW-CL1	*	*	*	*	*	*	o	*	o	*
42-RAW-CL2	*	*	*	*	*	*	o	*	o	*
45-CL1-FLU	o	o	o	o	o	o	o	o	o	o
51-CL2-ICR	o	o	o	o	o	o	o	o	o	o
52-CL2-SCP	o	o	o	o					o	o
55-CL2-HCP	o	o	o	o					o	o
56-CL2-BTP	o	o	o	o					o	o
61-DCF-CSL	*	*	*	*	*	*	o	*	o	*
62-BCF-CSL	o	o	*	*	*	*	*	*	*	*
63-CDC-NSL	*	*	*	*	*	*	o	*	o	*
64-BYL-NSL	o	o	*	*	*	*	*	*	*	*
65-CBC-NSL	o	o	*	*	*	*	*	*	*	*
67-FSL-FBF	*	*	*					o	o	o
68-CSL-VEA	*	*	*	*	*	*	*	*	*	*
69-NSL-NBF	*	*	*	*	*	*	*	*	*	*
71-SOW-PRK		*	*	*	*	*				
72-HOG-PRK		*	*	*	*	*				
81-PLTYOLS	*	*	*	*	*	*	*	*	*	*

constraint levels are based on statistics from the U. S. Department of Agriculture (1984). Pasture land constraint levels for the six eastern regions are based on the same source. Those for the four western regions were calculated by Hickenbotham in animal-unit-months (AUM)[6]. Family labor constraints are based on an adjusted version of the data used in SPATEQ, which, in turn, were taken from the 1985 Report on Farm Labor (Statistical Reporting Service). The adjustments consisted in converting the regional totals of hours worked to hours worked on activities actually modeled, and in including overhead labor. The adjustments were based on statistics from the Economic Research Service (1987).

Private commodity stock beginning inventories were taken from the 1980 total ending inventories reported in the supply and disappearance tables of Agricultural Statistics 1984. For all commodities except manufactured dairy products, government stocks are included in private stock levels. Base year government purchases of dairy commodities were taken from Dairy Situation and Outlook Report (Economic Research Service, 1988b). They were used, however, for model calibration only. Private commodity stocks are assumed to be physically located in the main producing as well as in some of the main processing and consuming regions.

Supply and Demand Function Parameters

Factor and final commodity prices in AGTEC are assumed to be determined in competitive markets for which linear functions of factor supply and final commodity demand are explicitly specified. Such functions are typically expressed in terms of base year prices and quantities, and the respective price elasticities. Since the formulation of the AGTEC objective function requires that factor and commodity prices be expressed in terms of price axis intercepts and slopes, the above parameters must be transformed accordingly. The price elasticities used in factor supply and commodity demand are summarized in Table 14.

Supply of production factors. The regional cropland and pasture land supply functions relate the amount of land in use to yearly rental prices per acre. Following SPATEQ, pasture land in the four western regions, much of which is public grazing land, is assumed to be supplied at a single and constant price. The regional hired labor supply functions relate manhours worked per year to hourly wages.

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[6]Hickenbotham defines an AUM as the forage (land) required to sustain one animal unit (AU) for one month, where an AU is one mature (1000 lbs) cow or equivalent.

For cropland and pasture land, price elasticities of supply are less than unity. This implies the possibility of negative prices at small total land quantities. To avoid such a situation, each of the supply functions in AGTEC was subdivided into a constant price and a variable price portion, called "farmer-owned" and "rented", respectively. The "farmer-owned" portions are assumed to be earning inducement prices only, whereas the "rented" portions are assumed to be paid according to the market, at or above inducement prices. A similar subdivision was introduced in the labor market where, otherwise, there might arise a situation of hired labor being remunerated below the reservation wage. Family labor is assumed to earn the reservation wage throughout. In the case of hired labor, there was defined a "bottom wage" category, assumed to earn a constant wage slightly above the reservation level while a category, designated "variable wage", is assumed to earn market wages.

The base year supply function parameter values for all cropland are taken from SPATEQ, as are those for pasture land in the eastern regions. Due to the nature of the objective function, a change in the constant pasture land price for the western regions alters neither the amount of land used nor the final value of the objective function. For reasons of convenience, the price was set at $1.00 per AUM. Parameter values for hired labor supply functions also were taken from SPATEQ but were adjusted with respect to base year quantities in the way described for family labor constraint levels. SPATEQ base year wages are based on 1985 Report on Farm Labor, (Statistical Reporting Service) and elasticities on H. S. Baumes' model (Hickenbotham).

Demand for agricultural commodities. By their destination, agricultural commodities can be divided into intermediate and final ones. Intermediate commodities serve as inputs to other production or processing activities, their quantities being determined by the levels and commodity usage coefficients of the activities to which they are destined. The quantities of final commodities, on the other hand, are determined by demand functions which, similar to the factor supply functions, are specified in terms of base year prices, quantities, and price elasticities. Elasticities are defined strictly as own-price elasticities. Cross-price elasticities of agricultural commodities are assumed to be insignificant. This assumption, whose validity was justified for agricultural sector programming by Hazell and Norton, makes it possible to avoid parameters for which information is incomplete, as well as computational complexity. Of the three markets for final commodities, domestic consumption, exports, and privately operated commodity stocks, the first is by far the most important. A fourth, non-market destination for commodities is represented by government purchases at a fixed price. It serves as an instrument for price support policy in certain commodities.

the respective commodity prices. The specification of AGTEC transportation activity costs is based on the assumption that the average transportation costs between production regions and production and consumption regions equal the transportation costs between the regional production and consumption centroids.

Transportation between production regions is assumed for eleven commodities (soybeans, wheat, sorghum, corn, barley, oats, Class I milk, Class II milk, beef calves, beef yearlings, and soybean meal). Within a production region, all commodities are assumed to move freely and at no cost, the exception being silage, which is assumed not to be transported at all, not even between states of the same region. Transportation from production to consumption regions is assumed for 18 commodities (cotton, rice, wheat, corn, barley, oats, soybean oil, fluid milk, ice cream, soft cheese products, hard cheese products, butter, NFDM, fed beef, veal, non-fed beef, pork, and poultry). Of these, cotton, poultry, fluid milk, and ice cream are assumed not to be transported interregionally at all but intraregionally only, the first two at zero cost.[7]

AGTEC transportation parameter values are based entirely on SPATEQ. Four main sets of costs, for transportation by rail and by highway, from production to production and production to consumption region respectively, were calculated by Hickenbotham. For some routes, rail costs for different train lengths, barge costs, and costs of a barge and rail combination were also calculated. All of these costs are based on engineering data about each of the major components, and on the assumption that the transportation market is efficient.[8] The rail costs are used for bulk grain, the cost of each particular crop being determined with the help of the respective specific weight. The truck costs are used for live animals, processed feeds, liquid products, and all solid processed commodities.

<u>Cost of production activities</u>. These costs are calculated by AGTEC as residuals which include all activity costs not explicitly modeled plus an activity profit. The two assumptions justifying this procedure have already been stated, namely the realization of all production at minimum cost and the price constancy of all inputs other than the ones modeled. The calculation is done

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[7]Since cotton is the input to an industry whose output is distributed in a national rather than in regional markets, local processing as well as the absorption of transportation costs by the producer are assumed. Poultry products, fluid milk, and ice cream are final commodities, produced largely in the regions in which they are consumed. The average poultry transportation cost is included in the producer price. Any necessary interregional transportation of fluid milk could take place in the form of Class I milk.

[8]Due to their nature, these costs were not affected by the trucking rate deregulation of 1984 which, if anything, may have brought real rates closer to the calculated ones (Hickenbotham).

Dairy Commodity Balances and Dairy Production Activities

To have primary dairy production represented in all ten AGTEC production regions, the dairy production activities adopted from SPATEQ had to be supplemented by activities for at least one state each in the Delta and the Mountain States regions. To be selected, a state had to contain more than one quarter of the regional dairy herd in the base year of 1982.[9] Louisiana and Idaho emerged to represent the missing two regions, while Florida was designated an additional dairy state due to the relative size of its herd within the Southeast. Under the indicated criterion, primary dairy production, although distributed across the ten production regions, needed to be specified for a total of only 15 states.

No separate specification of technologies for the production of Grade A and Grade B milk was carried out. Even though two distinct regimes of production exist, the bST effect on both should be similar. Moreover, the volume of Grade B production is comparatively small (see Table 5), such that in the model any distinction due to grade may safely be ignored. On the other hand, modeling the partition of all raw milk into Class I and Class II, according to its final destination, was seen to be essential. This partition constitutes the basis for classified raw milk pricing. Therefore, regional balances for both classes of milk and for their respective derived products were created. Also, the technologies to transform Class I into fluid milk and Class II milk into manufactured dairy products were defined.

Secondary dairy production activities for transforming Class I into fluid, and Class II milk into ice cream were specified for all ten regions. The processing of Class II milk into butter and cheese, however, was specified to take place in six regions only (Northeast, Lake States, Corn Belt, Northern Plains, Mountain States, and Pacific States). This decision was based on the assumption that since no dairy product manufacturing of any consequence had ever taken place in the remaining regions, the comparative advantage of manufacturing within those regions would not be strengthened sufficiently, even after the introduction of bST, for it to prevail. Consumption demands for the six final dairy products, fluid milk, ice cream, soft cheese products, hard cheese products, butter, and NFDM, were specified for each of the ten regions. Private stock demands for hard cheese products, butter, and NFDM were specified nationally, as were export demands for the above and for soft cheese products.

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[9]Examination of the distribution of U.S. dairy cows by state showed that one state, or at most two, in each region are the primary dairy producers. In order to make the AGTEC dairy section representative across all regions as well as simple with respect to computations, the one-quarter criterion was adopted.

price support program was the calibration of AGTEC, to respond to a specification of base year CCC prices with the observed base year government purchases. This was achieved by slightly varying hard cheese and butter prices in the domestic consumption, export, and private stock demand functions, and also in the production activity cost calculations, while the price of NFDM was held constant at the base year CCC intervention level. The cheese and butter prices were varied in fixed proportions, based on the CCC price formulas. In the case of consumption demand, average transportation allowances of 1.65, 4.85, and 1.35 cents per pound of cheese, butter, and NFDM, respectively, were added to the adjusted prices.[13] In Figure 9, the calibration is shown in terms of a price-quantity diagram of supply and demand. The procedure involves raising and lowering the domestic consumption, export, and private stock demand schedules for hard dairy products (D) along the respective implicit supply functions (S), by slightly altering the respective prices in the base year demand curve specifications (P_b). P_b^* puts D^* into exactly the position at which the aggregate of all CCC purchases equals the total base year amount.[14]

Regional Classified Raw Milk Pricing

A mandatory differential between the prices of Class I and Class II milk is set for each milk marketing order area. It applies to all Class I milk sold for fluid use within that area. Payment of the differential is an expense incurred by the first handler who passes it on as part of the Class I milk price. Eventually, it is extracted from the fluid milk consumer. To ascertain the influence of mandatory Class I milk price differentials on the distributional impact of bST it was necessary to include them, as well as the linkages through which they affect economic equilibrium, in the AGTEC formulation.

Equilibrium in AGTEC is determined in the final commodity markets. Demand functions of final commodities are specified explicitly. Final

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Make allowances used are those in effect during the base year. Revenue fractions of butter and NFDM in the butter and powder activity output were calculated at base year quantities and prices.

[13]These allowances are based on the respective average production-to-consumption transportation costs as determined at base year conditions.

[14]Incidentally, the very small difference between the marginal social surplus derived from the purchase of either cheese or butter causes the solution values for government purchases to toggle between 100 percent of one and 100 percent of the other commodity. To prevent this, a fractional constraint was introduced, locking the two solution variables into a fixed proportion, equal to that existing between the two base year purchases. This is the only constraint used in modeling government purchases of manufactured dairy commodities.

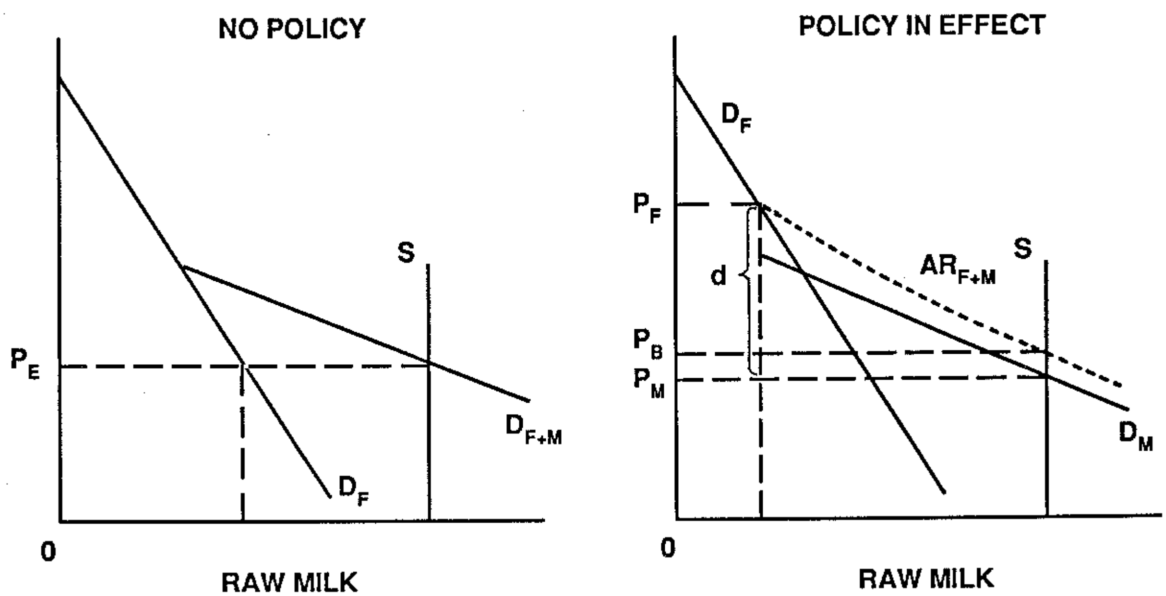
commodity supply functions, on the other hand, are specified implicitly only, by the supply functions of production factors, technical coefficients of transformation activities, and the costs of such activities. These costs are calculated as the residual of the value of activity outputs and explicitly modeled activity inputs. The calculation requires constant prices of production factors and intermediate and final commodities. Whereas such prices are available for production factors and final commodities from base year supply and demand function specifications, they need to be specified separately for intermediate commodities. Since the Class I milk price differential is a component of the price of Class I milk and since Class I milk is an intermediate commodity, the price differentials can be modeled at this point. From here, they influence the fluid milk markets through the implicit regional fluid milk supply functions described above.

As part of such modeling, activities had to be defined and activity costs specified for the regional transformations of raw milk into Class I and Class II milk, and that of Class I into fluid milk. With base year price differentials in effect, the unit costs of the first two of these activities are equal to the differences between raw and Class I, respectively Class II milk prices. The regional raw milk prices received by producers, the so-called blend prices, were available from Agricultural Statistics 1983. For Class II milk price, the Minnesota-Wisconsin price for manufacturing milk, the "M-W series", was used for all regions. Regional Class I milk prices were derived by adding the appropriate price differential to the "M-W" price of Class II milk.

In AGTEC, consumption demand for all commodities, including fluid milk, is specified in terms of consuming regions. Class I differentials, on the other hand, are imposed in terms of milk marketing order areas. Thus, a set of regional price differential equivalents had to be calculated for use in the determination of regional Class I prices. These equivalents are based on a mapping of all milk marketing order areas, or fractions thereof, into the AGTEC consuming regions. They were calculated as consumption-weighted regional averages. The actual base year price differentials by milk marketing order area, as well as the above calculations, are shown in Appendix B. The unit cost of the activity transforming Class I into fluid milk is based on regional Class I prices described above and on the national average fluid milk price taken from SPATEQ.

Under the hypothetical conditions of removed Class I differentials, the extra cost incurred by the first handler would vanish and the prices of raw, Class I, and Class II milk would equalize, presumably somewhere slightly above the "M-W" level. Costs of the transformation activities yielding Class I and Class II milk would be zero. To maintain unaltered the cost of the activity transforming Class I into fluid milk, which contains real processing and distribution costs, the Class I differential equivalent would also have to be subtracted from the price of fluid milk. In terms of the activity cost for

FIGURE 10: AGTEC MODELING OF THE REMOVAL OF CLASS I MILK PRICE DIFFERENTIALS



S	Raw Milk Supply Function
D_F	Class I Milk Demand Function
D_M	Class II Milk Demand Function
D_{F+M}	Raw Milk Demand Function
AR_{F+M}	Raw Milk Average Revenue Function
P_F	Price of Class I Milk
P_R	Price of Class II Milk
P_B	Blend Price
P_E	Raw Milk Equilibrium Price
d	Mandatory Class I Milk Price Differential
e_F	Class I Milk Price Elasticity of Demand
e_M	Class II Milk Price Elasticity of Demand

$$P_E = P_M + d\,(e_F/e_M)$$

Table 15

DAIRY ACTIVITY LEVELS IN AGTEC BASE YEAR SOLUTION

Region	Million Cows		Percent[a]	
	Observed	AGTEC	Observed	AGTEC
Northeast	2.200	2.265	19.98	20.59
Lake States	3.131	3.370	28.43	30.64
Corn Belt	1.457	1.201	13.23	10.92
Northern Plains	.498	.154	4.52	1.40
Appalachia	.797	.604	7.24	5.49
Southeast	.429	.650	3.90	5.91
Delta States	.283	.297	2.57	2.70
Southern Plains	.435	.497	3.95	4.52
Mountain States	.521	.735	4.73	6.68
Pacific States	1.224	1.227	11.12	11.15
U.S.	11.012	11.000	100.00	100.00

[a]Detail may not add to total due to rounding.

Source: Appendix C-3.

Examining observed and calculated resource prices shown in Appendix C-1, the two sets are reasonably close. Exceptions are pasture land prices in the Northeast and Southeast, and wages in the Lake States, the latter deviating from the observed value by almost 50 cents per hour. The first two instances are most likely related to the underestimation of beef raising activities in

Section VI

SCENARIO SPECIFICATION

Comparative statics presuppose a series of equilibrium solutions of the same model at various levels of the parameter being analyzed. If several parameters are subjected to a change of their levels jointly, it becomes necessary to specify a series of scenarios, each one capturing a relevant combination of parameter levels among all combinations possible. This section presents the specifications of the AGTEC scenarios for the bST analysis. The specifications are preceded by a discussion of the individual parameters.

PARAMETERS SUBJECT TO CHANGE

The most important parameters are those which express the technical and economic relationships directly affected by the introduction of bST. These are the average milk yield, the average feed consumption, and the average cost of bST per cow. Their effect on model equilibrium is greatly influenced by the prevailing dairy policy situation which is subject to discrete and sudden changes. Hence, price support levels for manufactured dairy products and the terms of the classified pricing of raw milk constitute a second important group of analysis parameters. In addition, there are several parameters that will enter scenario specifications only under special conditions.

Milk Yield Coefficients

The AGTEC opportunity set parameters most prominently affected by the introduction of bST are the average coefficients for milk yield. They represent the most important dimension in the analysis. The increase in output of milk per cow and year directly dilutes all cost items associated with the raising and maintaining of an animal.

The yield data discussed in Section III are based on 28 full-lactation trials, involving a total of less than 1,000 cows treated with bST. Because of the small sample size, it would be statistically questionable to use these data to estimate coefficients expressing the yield effect of bST as a function of dosage and other application variables. The trial results can be used, however, to define the range of a hypothetical average yield increase. Several levels within this range can then be analyzed.

In the reported trials, daily application of bST ranged from 6.25 to 179 mg per animal, the most frequently used rates being those between 20 and 30 mg. A weighted average for the 250 cows treated at the rates within this range

Feed Usage Coefficients -- The BSTFEED Program

Milk output and feed intake in dairy cows are closely related, so any independent change in milk yield will have an effect on feed requirements. All nutrients taken up by an animal are partitioned into maintenance and production portions (Milligan et al., 1981). In the case of an exogenous change in milk yield, such as the one induced by bST, it is primarily the production requirement that will be affected (Bauman et al., 1985). Thus, in the production of additional milk, additional nutrients are required only to support that production. The cost of the fixed maintenance portion of the ration, per unit of milk produced, is diluted. This dilution and the reduction in cost of raising and maintaining cows for the national herd (due to the requirement for fewer animals) are the two principal economic impacts of bST.

If the nutrient requirements for maintenance and production at a given milk yield are known, and also the relationship between production requirement changes and yield changes, the total nutrient requirements for any other yield can be calculated. If, in addition, the nutrient content of feed ingredients and current ingredient prices are known, the corresponding least-cost ration can be determined. In this analysis, the total nutrient requirements corresponding to the bST-related average milk yields of 100, 105, 110, 115, and 120 percent of base year conditions, and the respective least cost rations, are calculated by BSTFEED. This is a program created especially for supplying the appropriate dairy feed parameters to AGTEC.

BSTFEED contains the instructions by which a set of total nutrient requirements for each of the AGTEC dairy states at each of the selected average milk yield levels are calculated. It also contains a LP model in which these requirements are used as constraints and in which the least-cost ingredient usages for each of the above state and yield combinations are determined. The resulting usage levels are then incorporated into AGTEC as alternative feed usage coefficients. BSTFEED is formulated in GAMS, which allows the individual LP problem to be solved directly by the MINOS algorithm. The elements and the mathematical formulation of the LP problem appear in Tables 16 and 17.

For the calculation of total nutrient requirements, it is assumed that base year requirements are satisfied exactly and at least cost by the 1982 FEDS state level dairy rations. These rations also constitute the AGTEC feed usage coefficients. The assumption applies to the minimum levels of energy and protein as well as to the maximum level of dry matter. Also, it is assumed that production requirements for energy and protein are related linearly to the average yield of milk and that such linearity also prevails with respect to the production portion of the dry matter maximum.

Table 17

MATHEMATICAL FORMULATION OF BSTFEED

MINIMIZE FEEDCOST, where:

$FEEDCOST_{s,p} = \Sigma_i c_{s,i} X_{s,p,i};$ (Objective Function)	for all s, p
SUBJECT TO:	
$\Sigma_i a_{i,s,n} X_{s,p,i} \leq b_{s,p,n};$ (Dry Matter Constraint)	for all s, p n = Dry Matter
$\Sigma_i a_{i,s,n} X_{s,p,i} \geq b_{s,p,n};$ (Nutrient Requirements)	for all s, p n = Protein, Energy
$\Sigma_i (a_{i,s,n'} - .15 a_{i,s,n''}) X_{s,p,i} \geq 0;$ (Fiber Ratio Constraint)	for all s, p n' = Fiber n" = Dry Matter
$X_{s,p,i} = u_{s,i};$ (Pasture Land Usage Constraint)	for all s, p i = Pasture Land
$X_{s,p,i} \geq 0;$ (Non-negativity Constraint)	for all s, p, i

level throughout.[6] Its objective function coefficients are the regional ingredient prices of the AGTEC base year solution. They are assumed to remain constant over the various milk yield increases. The LP solution values are incorporated into AGTEC, jointly with the corresponding milk yield coefficients.

In addition to determining least-cost rations for specific yield increases, BSTFEED also defines the relationship between feed intake and the output of milk. In several of the bST trials, the ratio of milk produced to dry matter fed has been established empirically, as shown in Appendix E-3. In Appendix E-4, it has been calculated for the analysis conditions of AGTEC. Both sets of ratios are shown in Figure 11. Even though higher ratios were determined for the trials, the rate of increase is about the same in both cases. The absolute difference between the ratios may be related to the average efficiency conditions assumed for AGTEC and the above-average conditions prevailing in the bST trials.

The direct linkage between milk yield and feed usage allows the parameters of both to share the same dimension in the analysis. In the specification of scenarios and the discussion of results, any reference to the bST-induced changes in average milk yield automatically extends to the corresponding bST-induced changes in average feed usages.

Exogenous Commodity Prices

Equilibrium in AGTEC is established in the factor and final commodity markets with their explicit linear supply and demand functions. Any technology-related change in the production cost of a commodity entering such a market, either directly or indirectly (as an input to another commodity), must be transmitted to that market. This is done through the net activity costs of the transformation activities involved. To transmit a change in commodity cost, it is necessary to explicitly specify the changes in exogenous commodity prices with respect to their base year levels, not only for the commodity whose cost is undergoing the change but also for those to which it becomes an input.

The bST-induced changes in dairy activity coefficients cause a technology-related change in the production cost of raw milk. This change is equal to the difference between the dairy activity margins calculated before and after the bST-induced coefficient changes, using the original exogenous activity input and output prices in both instances. The change in the price of raw milk can be determined from this difference. It is then incorporated into the commodity price parameter for all derived products, in direct proportion to

[6] The last constraint was included according to personal recommendation by R. A. Milligan.

their raw milk content. With these changes in exogenous commodity prices, a technology-induced change in equilibrium conditions is specified completely.

Cost of bST

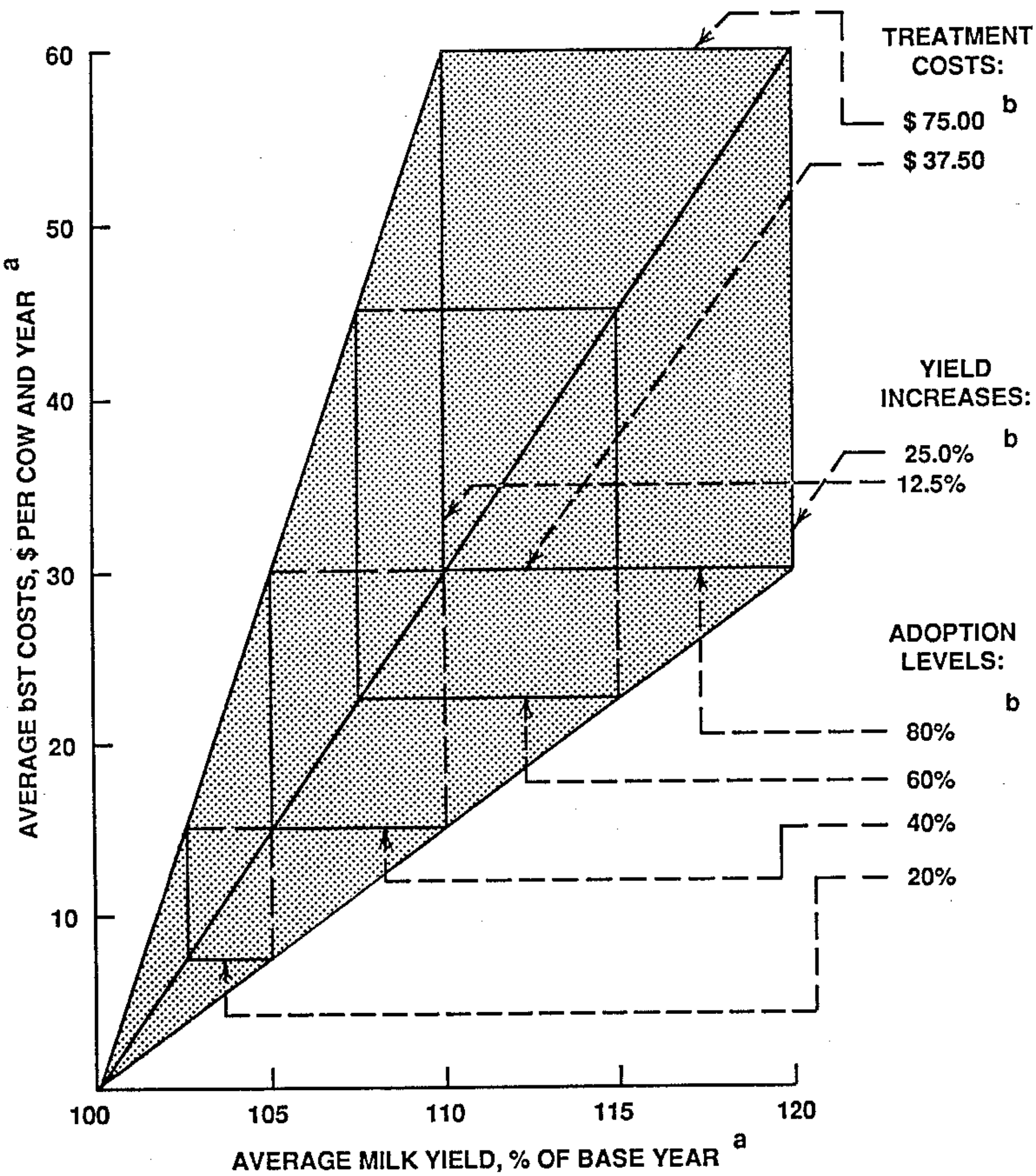
While it is possible to obtain in advance realistic data on the application of recombinant bST, this is not the case with respect to bST manufacture. There, such data will be available only after laboratory scale production has been replaced by a fully commercial process. Nevertheless, several useful bench mark values can be taken from an engineering type study of the economics of bST production (Kalter et al.). Its point of departure is a plant which, through the use of scale factors, is designed for the economic production of 75 kilograms of high purity product per day. With an assumed load factor of 90 percent and 360 operating days per year, such plant would produce 25,000 kilograms annually. Cost calculations, based on engineering data for comparable processes, and a financial evaluation, based on the conditions required to attract capital to bST production, show that a wholesale price of $3.17 per gram of bST is required for economic feasibility. Changes in the economic plant design show this price to rise to $4.23 at an annual production of 5,000 kilograms and to decline to $1.97 at 70,000 kilograms.

To establish a range of average bST costs for this study, a treatment period of 200 days per year and a range of daily application rates between 25 and 50 mg per cow are assumed. These assumptions imply yearly bST requirements of between five and ten grams per cow. At an annual bST demand of about 45,000 kilograms,[7] the wholesale price of bST, if manufactured in a single plant, would be about $2.50 per gram. The price of the annual bST requirement per cow at the two limiting application rates would, thus, be $12.50 and $25.00 respectively. An assumed 300 percent markup to allow for bST production in several plants rather than in a single one, for marketing, intermediate handling, and actual application, would bring the annual farm cost of bST to between $37.50 and $75.00 per cow. These costs, along with the lower and upper levels assumed for bST adoption and for the increase in milk yield per cow are listed in Table 18.

Figure 12 maps average milk yield and average bST cost to an area containing all realistic combinations of those two parameters. It indicates that for a five percent average increase in milk yield the average bST cost may lie between $7.50 and $30.00. For a ten percent increase the range lies between $15.00 and $60.00, and for a 20 percent increase between $30.00 and $60.00. If the average bST cost does not enter the analysis, default levels of $15.00, $30.00, $45.00, and $60.00, corresponding to average yield increases of 5, 10, 15,

[7]At the base year total of 11 million dairy cows, this demand would correspond both to a daily dose of 25 mg at an 80 percent adoption level and to a dose of 50 mg at a 40 percent level.

FIGURE 12: MILK YIELD AND bST COST COMBINATIONS IN AGTEC



a ANY COMBINATION INSIDE SHADED AREA IS FEASIBLE
b FOR RELATIONSHIP BETWEEN MODEL ASSUMPTIONS AND PARAMETERS SEE TABLE 18

On the one hand, it would increase fluid milk consumption along the regional fluid milk demand curves. On the other hand, the reduced supply of manufacturing milk would raise the manufacturing milk price along the national manufacturing milk demand curve. In terms of the price of raw milk, this rise in the manufacturing milk price would partly offset the Class I milk price reduction.

The AGTEC mechanism by which these policy-imposed changes in intermediate commodity prices are transmitted to final commodity and factor markets is the same as the one described for the transmission of technology-related changes in production costs: a change in the exogenous commodity prices used for net activity cost calculations. If classified pricing is abolished, the decreases in both Class I and fluid milk prices and the increases in the prices of manufacturing milk and all manufactured dairy commodities, will have to be incorporated into the respective parameters. Due to the largely "ad hoc" structure of the Class I milk price differentials, this policy instrument does not lend itself to the modeling of gradual variations from its base year condition. In AGTEC, only a "yes or no" alternative is considered. A special case can be created by assuming that the entire nation is a single milk marketing order area with a single Class I differential.

Parameters for Special Conditions

A set of special conditions expands the basic objectives of the analysis. These special conditions were introduced because they capture some very realistic and plausible situations and, at the same time, provide further opportunity to apply spatial general equilibrium sector analysis to technical innovation. The additional parameters include a set of average milk yield increases by region, the technical coefficients for reducing the volume of raw milk by reverse osmosis (RO) prior to transport, and the coefficients for increasing the feed efficiency in the pork industry by the use of porcine somatotropin (pST). The parameters for the latter two conditions are related to two pending innovations. No technical or statistical basis exists, on the other hand, for the assignment of different bST-induced relative increases in milk yield to geographical regions. Thus, a functional relationship between such increases and the regional herd size distribution was assumed.

Milk yield increases by region. In this study, the bST-induced increase in average milk yield is analyzed at four hypothetical levels. It is assumed throughout that any yield increase will apply uniformly throughout all regions. In one group of scenarios, nevertheless, this assumption was changed to the effect that the increase in each region is a function of herd size distribution. For this purpose, it is assumed that the average increase in milk yield, which is the product of the bST adoption level and the yield increase

Table 19

REGIONAL AVERAGE MILK YIELDS AND bST COSTS BASED ON REGIONAL HERD SIZE DISTRIBUTIONS, AS ASSUMED FOR SPECIAL SCENARIOS

Region	Weighted Average Yield Increase[a] (%)	Av. Regional Yield (RYH)[b] (%)	Av. Regional bST Cost (RCH)[c] $/Cow
Northeast	9.18	109	27.00
Lake States	7.34	107	21.00
Corn Belt	7.72	108	24.00
Northern Plains	7.64	108	24.00
Appalachia	9.25	109	27.00
Southeast	16.03	116	48.00
Delta States	11.32	111	33.00
Southern Plains	12.86	113	39.00
Mountain States	11.52	112	36.00
Pacific States	16.28	116	48.00

[a]Based on the distribution in Table 4 and on the following weighting:

Herd Size	Av. Yield Increase
1- 29	0
30- 49	5%
50- 99	10%
100-499	15%
500+	20%

[b]RYH = 100 + weighted average yield increase.

[c]RCH = Treatment cost x $\frac{\text{Weighted Av. Yield Incr.}}{\text{Yield Inc. Per Cow}}$

Assuming $75.00 treatment and 25.0% increase or $37.50 treatment and 12.5% increase per cow.

SELECTION OF SCENARIOS

The specification of AGTEC equilibrium conditions by changing the values of the indicated parameters and constraints implies the possibility to analyze the impact of any such change on each of the model variables. The "ceteris paribus" assumption, which is essential in such analyses, implies that all parameters not explicitly changed continue at their base year values. A schematic layout of all the scenario specifications is shown in Table 20.

The analysis layout described lacks the dimension of time. The long-run equilibrium at any of the conditions specified is attained by the complete and instantaneous adjustment of all solution variables. Nevertheless, the regional dairy activity levels can be constrained to remain at their base year levels. This would model a short-run equilibrium, where the response to a parameter change would be restricted to prices, while the production activity levels would remain unchanged.

In the long-run situation, all endogenous prices and quantity variables adjust freely. The scenarios specified for this time frame are divided into a group of basic and a group of special scenarios. The basic scenarios are a representative selection of the large number of scenarios obtained by independently varying the four dimensions of the analysis, average milk yield, average bST cost, manufacturing milk support price, and the status of classified raw milk pricing. The special scenarios are subdivided into three separate sets. The first one is characterized by average milk yields on a regional basis, assumed to be functions of the respective regional herd size distributions. In the second, the commercial use of RO is assumed. In the third set, the scenarios model the adoption of pST. Each of these three special conditions is analyzed separately, at various combinations of average milk yield, manufacturing milk support price, and Class I milk price differentials.

In the short-run situation, the number of dairy cows is held constant at its base year level. The time horizon of this frame is assumed to be one year, the first year after the introduction of bST. Dairy producers are assumed to be awaiting first year operating results before deciding about any production level adjustment. All other activity levels are assumed to adjust freely.[10] Average milk yields and the manufacturing milk support price are limited to realistically small changes. Classified raw milk pricing is not changed at all. The average bST cost, however, is perturbed extensively, as this corresponds to a real life uncertainty about the market price of bST.

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[10]It would be realistic to extend the adjustment constraint to all primary commodity producers, holding them to their initial production decisions and letting only prices adjust. Unfortunately, in a model of the specifications of AGTEC, holding constant more production activities than those of a single technology will jeopardize the existence of a feasible region.

Section VII

RESULTS

In this section, there are presented and discussed AGTEC solution values corresponding to the different analysis scenarios. The scenarios were specified by introducing into the base year conditions of the model the parameter changes listed in Table 20. Among all possible combinations of such changes, only those required to provide a clear picture of the relationship between analysis parameters and key solution variables were selected. Following the short-run results, the long-run results are presented.

SHORT-RUN SOLUTIONS

Table 21 shows the specifications and key results of the short-run scenarios. Class I milk price differentials are maintained at base year levels throughout. The average milk yield is specified at its base year level as well as at a five percent bST-induced increase. The manufacturing milk support price is specified at its base year level of $13.10 and at $12.50. The average cost of bST per cow is specified at $7.50, $15.00, and $30.00.[1] The results shown are limited to four solution variables. A more complete set of results may be found in Appendices F-1 and F-2. Cow numbers are fixed at their base year levels by the definition of short-run equilibrium and, thus, are not included among the solution variables.

The average price of raw milk varies with average milk yield as well as with manufacturing milk support price. An increase in milk yield will shift the raw milk supply curve to the right, thereby lowering the raw milk equilibrium price. A decrease in the manufacturing milk support price will shift downward one of the components of the demand curve and, thus, also decrease the equilibrium price. This interpretation is corroborated by the solution values for raw milk going to the CCC, the smaller amount being purchased at the lower support price. Given fixed cow numbers, the system will adjust to short-run equilibrium by changes in the average raw milk price and the volume of CCC purchases. However, adjustments also occur through the interregional transportation of Class II milk. This takes place from non-manufacturing regions to regions whose dairy product manufacturing plants offer a more favorable outlet for raw milk than the non-manufacturing regions' depressed fluid markets. The total of these flows, which vary directly with milk yield and support price, are shown as the third solution variable. The last variable displayed is the approximate change in net welfare, a term

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[1]These three points cover the plausible range identified for a five percent yield increase (see Figure 12 and Table 18).

Table 22

MODEL RESULTS FOR LONG-RUN SCENARIOS: CLASSIFIED RAW MILK PRICING IN EFFECT

Analysis Parameters			Key Solution Variables			
Av. Yield %	Support Price $/Cwt	bST Cost $/Cow	Total Nr. of Cows Mill.	Av. Price Raw Milk $/Cwt	M.Equiv. to CCC Bill.Lbs.	Net Welf. Change[a] Mill. $
100[b]	13.10	0.00	11.000	13.75	15.0	(459,590)
	12.50	0.00	9.813	13.76	.1	2,219
	11.90	0.00	9.773	13.76	.1	2,301
105	13.10	15.00	17.714	13.64	116.4	-13,901
	12.80	15.00	11.070	13.52	22.7	-650
	12.50	7.50	9.453	13.51	.1	2,626
		15.00	9.438	13.56	.1	2,551
		30.00	9.408	13.68	.1	2,404
110	13.10	30.00	20.484	13.64	165.8	-20,345
	12.55	30.00	11.215	13.30	31.8	-1,490
	12.50	15.00	14.305	13.19	77.1	-7,492
		30.00	10.117	13.34	14.6	861
		60.00	9.015	13.62	.1	2,554
	11.90	30.00	9.043	13.39	.1	2,923
115	12.50	22.50	18.492	13.14	149.0	-16,661
		45.00	16.318	13.18	116.9	-12,578
	12.25	45.00	10.216	13.10	23.0	81
	11.90	45.00	8.710	13.18	.1	3,191
120	12.50	30.00	21.061	13.20	198.5	-22,689
		60.00	19.232	13.22	171.7	-19,565
	12.05	60.00	10.824	12.90	38.8	-1,684
	11.90	60.00	8.404	13.00	.1	3,408

[a]From base year net welfare (consumers' surplus + producers' surplus - government expenditure) as reported in parentheses.

[b]Base year scenario.

Source: Appendices F-3, F-4, and F-6.

Impact of bST on the Aggregate Level of the Dairy Industry

If bST is introduced into the dairy industry and if the manufacturing milk support price and Class I milk price differentials are held at base year conditions, the total number of dairy cows rises under each of the four assumed increases in average milk yield. This rise varies with the average cost of bST, a lower average cost leading to a greater increase in the national herd.

A five percent yield increase raises the total number of cows from 11.0 million in the base year to 17.714 million. If the support price were $12.50 instead of $13.10, the same yield increase would lower total cows from 9.813 to 9.438 million.[2] This number would, however, rise to 10.117 million if the yield increase were changed from five to ten percent. If the support price were progressively decreased below $12.50, ever larger increases in average yield would be required to bring about a reversal in the response of total cows.

If, on the other hand, the five percent bST-induced yield increase were applied in the total absence of Class I price differentials (with support prices remaining unchanged), total cows would have declined, from 9.785 to 9.402 million.[3] In order to effect a reversal in this case, either a support price above base year conditions, or a substantial increase in average yield, or a combination of both would be necessary.

The interaction between yield increase and support price is shown in Figure 13. A given bST-induced yield increase may cause total cows to rise at one level of support price, e.g. $13.10, and to decline at another, e.g. $11.90. The figure shows that the three-dimensional surface is constituted by two distinct portions, of opposing slopes, separated by a clearly defined, trough-shaped boundary.

The response of the total number of cows to average yield increases and support price changes can be interpreted in terms of the typical elements of a U.S. raw milk market. Total demand is the aggregate of demands for fluid use and manufacturing use milk, the latter being determined by demands in several manufactured product markets. All final demands have quantity-related price functions of finite elasticities, except demands by the government for excess dairy products. Those have functions of an infinite negative

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[2]The number of cows is 9.813 million at no yield increase, base year price differentials, and a support price of $12.50.

[3]The number of cows is 9.785 million at no yield increase, at base year support price, and at Class I differentials equal to zero.

elasticity, at least in the short run.[4] The raw milk demand, which is the horizontal summation of these components, is then represented by a curve of several segments or portions of different slopes, such as shown in Figure 14. The curve, typically, is convex to the origin. The level of its horizontal lower portion is entirely dependent on the manufacturing milk support price. In a typical dairy product manufacturing region, raw milk market equilibrium lies on the flat part of the demand curve. Here, government purchases take place and the support price is said to be binding. In a typical fluid-milk-only region, equilibrium lies on the steepest portion and the support price is not binding.

The supply of raw milk, just as the supply of any other commodity, is primarily a function of technology and production factor costs. Technology determines the relative use of production factors. Their costs are a function of availability and of competition from other users. As the time horizon lengthens, the supply curve becomes increasingly elastic, due to the growing possibility of factor substitution.[5] In Figure 15, there are shown the events following the introduction of bST, for a dairy product manufacturing as well as for a fluid-milk-only region. In both cases, the amount of milk produced by the initial number of cows increases, due to the higher yield of milk per cow. At the same time, the marginal cost of milk decreases, due to bST-induced changes in the input-output relationships. The supply curve has, thus, been shifted to the right. The supply curves for the various time horizons (market period, short run, and long run) all pass through the new volume and marginal cost conditions. At these conditions, however, marginal cost does not equal price and, thus, equilibrium does not exist. Adjustment of marginal cost occurs instantly, along the market period supply curve. Subsequently, as the supply elasticity associated with the respective time horizon permits, price and volume adjust along the demand curve, towards long term equilibrium. After the initial surge in the volume of milk through bST, volume adjustment will only come through change in the number of cows.

For the typical dairy product manufacturing region, where raw milk equilibrium lies on the flat part of the demand curve, the equilibrium volume will be larger than the volume produced at the time of bST introduction and the number of cows will eventually increase. For a fluid-milk-only region, where raw milk equilibrium lies on the steep part of the demand curve, the final equilibrium volume, although larger than the initial one, is smaller than the volume produced immediately after the adoption of bST. There, the number of cows will eventually be reduced. At long-run equilibrium, the marginal product values of production factors in the dairy industry must be equal to those in other agricultural industries.

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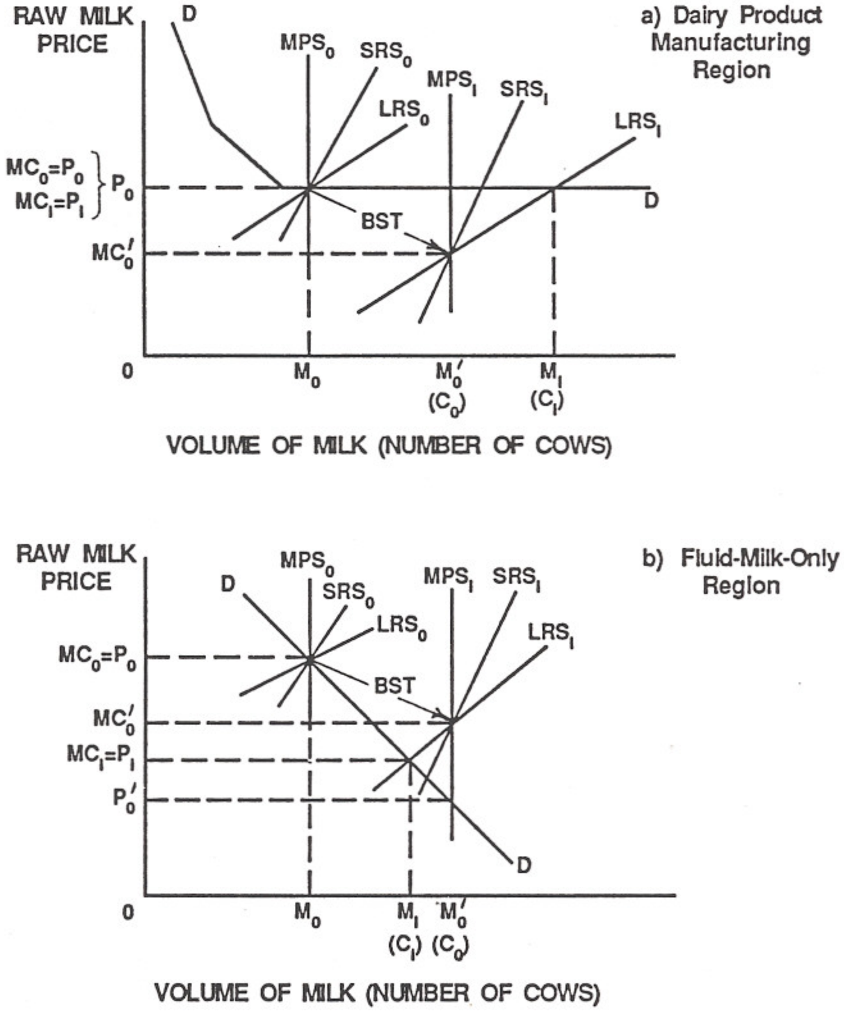
[4]The price elasticity of fluid milk demand is estimated at -.20. The elasticity of hard dairy products, for consumption as well as for export and storage, is estimated at -.45 (Cook et al.).

[5]The price elasticity of long term raw milk supply is estimated at 1.00 (Cook et al.).

FIGURE 15: EFFECT OF bST ON REGIONAL SUPPLY OF RAW MILK AND NUMBER OF COWS



1. VOLUME OF MILK FROM INITIAL NUMBER OF COWS C_0 INCREASES FROM M_0 TO M_0', DUE TO bST

2. MARGINAL COST OF MILK DECREASES FROM MC_0 TO MC_0' DUE TO IMPROVEMENT IN OUTPUT-INPUT RELATIONSHIPS

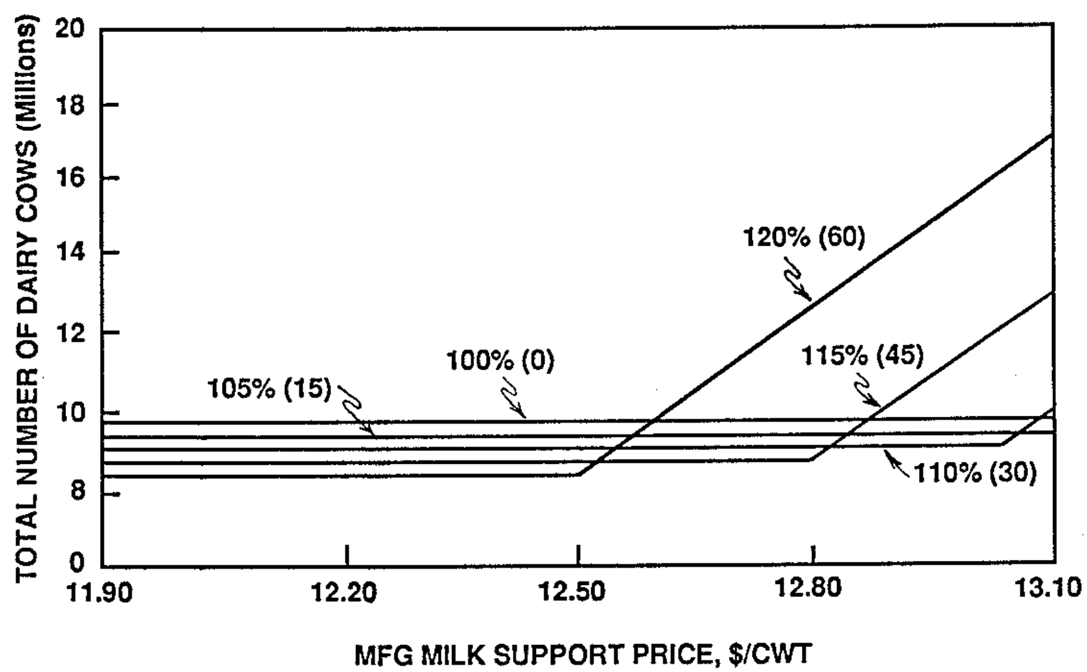
3. MARKET PERIOD, SHORT RUN, AND LONG RUN SUPPLY CURVES HAVE SHIFTED RIGHT, FROM MPS_0, SRS_0, AND LRS_0 TO MPS_I, SRS_I AND LRS_I, WHERE THEY PASS THROUGH (MC_0'', M_0')

4. AT M_0', $MC_0' \neq P_0'$

5. ADJUSTMENT STARTS IMMEDIATELY BY MC_0' GOING TO P_0' AND M_0' MOVING TOWARDS M_I, ALONG THE DEMAND CURVE

6. THE CHANGE IN THE VOLUME OF MILK FROM M_0' TO M_I OCCURS THROUGH AN ADJUSTMENT IN THE NUMBER OF COWS FROM C_0 TO C_I

FIGURE 16: TOTAL NUMBER OF DAIRY COWS VERSUS AVERAGE MILK YIELD AND PRICE SUPPORT
(Average bST Costs at Default Level, Class I Differentials Removed)[a]



[a] THE LINES LINK COW NR.-SUPPORT PRICE COMBINATIONS AT THE INDICATED CONSTANT AVERAGE MILK YIELDS (WITH AVERAGE bST COST, $/COW, IN PARENTHESES)
CLASS I MILK PRICE DIFFERENTIALS REMOVED
AVERAGE bST COSTS AT DEFAULT LEVELS

Source: Appendix F-7

Regional Impacts of bST and Regional Industry Characteristics

There are a number of factors that determine the regional impact of bST. The first is the structure of regional raw milk demand. As discussed previously, a substantial portion of the regional demand for raw milk is accounted for by the local consumption of fluid milk. This portion depends closely on the national population distribution, shown in Table 6.[9] The remainder is accounted for by the demand for manufacturing milk. Of the manufactured products, ice cream, much like fluid milk, is produced in all of the regions and, owing to its high transportation cost, is sold primarily in local markets. Due to tradition and to climatic conditions, the processing of milk into hard manufactured dairy products takes place mainly in the Lake States, Northeast, Pacific States, Corn Belt, Mountain States, and Northern Plains. The markets for these products are national, the various regional price levels being influenced by the respective interregional transportation costs. There is also a demand for exports and for privately operated stocks. The final component of manufactured product demand is the dairy price support program.

Appalachia, the Southeast, Delta States, and Southern Plains constitute the four fluid-milk-only regions. For them, the equilibrium portion of the raw milk demand curve shown in Figure 14 is determined by prices, quantities, and elasticities of fluid milk and ice cream. For the dairy product manufacturing regions, the raw milk demand curve also contains a portion exclusively determined by fluid milk and ice cream demand. The main portion, however, is determined by manufacturing and fluid milk demand jointly. At a lower price level, those demands will be boosted by the demand for manufactured products in other regions. And at a still lower level, it will be joined by the completely horizontal portion representing the unlimited government purchase of manufactured products. In the case of a manufacturing region, equilibrium may occur in any of these portions except, normally, the first one. Under classified pricing, the average price of raw milk will approach the support price level asymptotically as the quantity of raw milk produced increases.

In terms of dairy technology, the second determinant of bST's regional impact, regions may be grouped according to average base year milk yields and input usages.[10] Factor markets, the third of the regional determinants,

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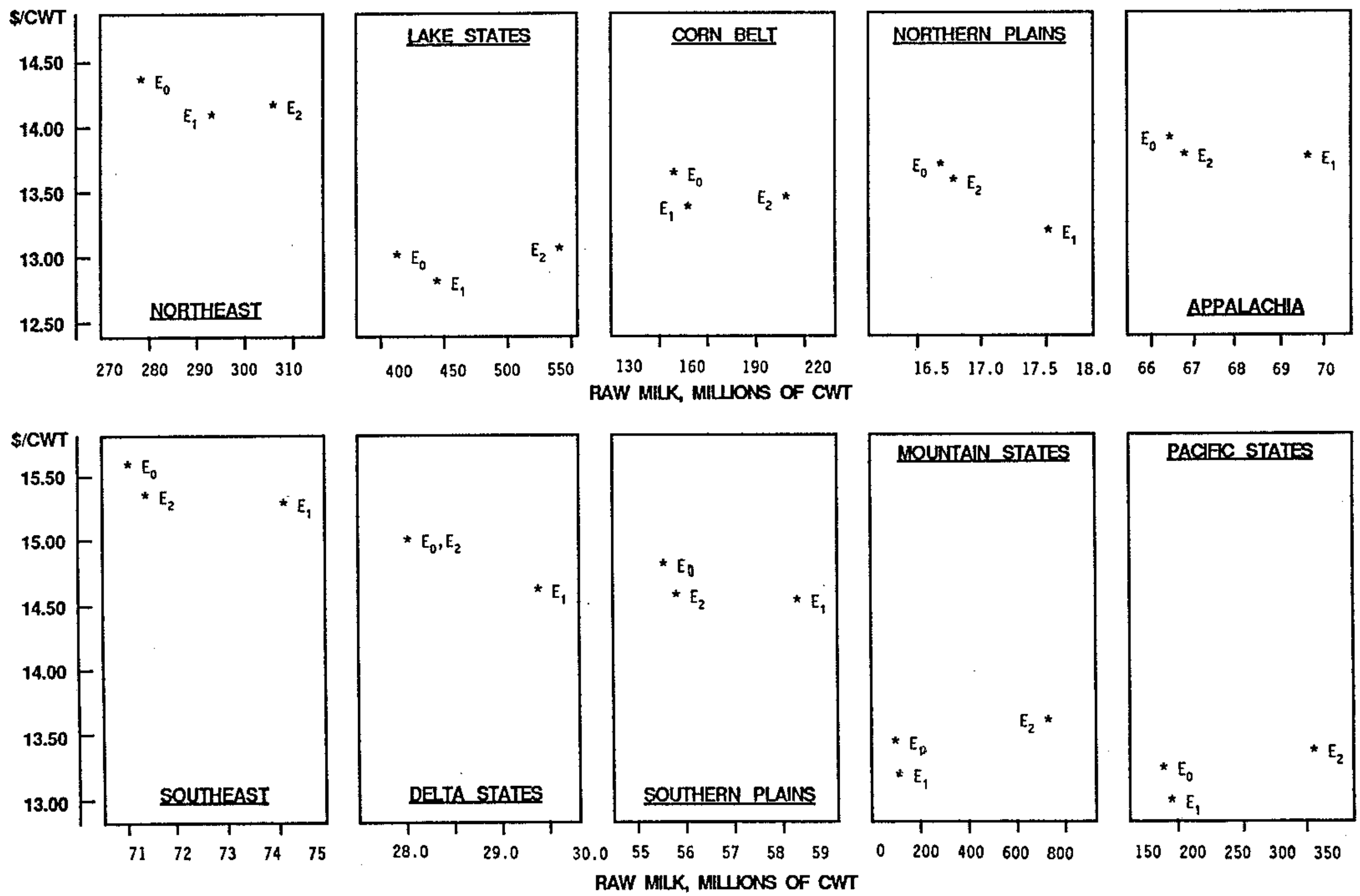
[9]The most heavily populated region is the Northeast, with the Corn Belt and Pacific States in the next category and the Southeast following closely behind. On the other extreme, the Northern Plains, Delta States, Southern Plains, and Mountain States combined have a smaller population than the Northeast alone.

[10]With respect to yields, the top regions are the Mountain States and Pacific States, at above 13,000 pounds per cow per year, while the Delta States are at the bottom, at below 10,000 pounds. With respect to protein supplement per cow, the lowest usages are recorded for the

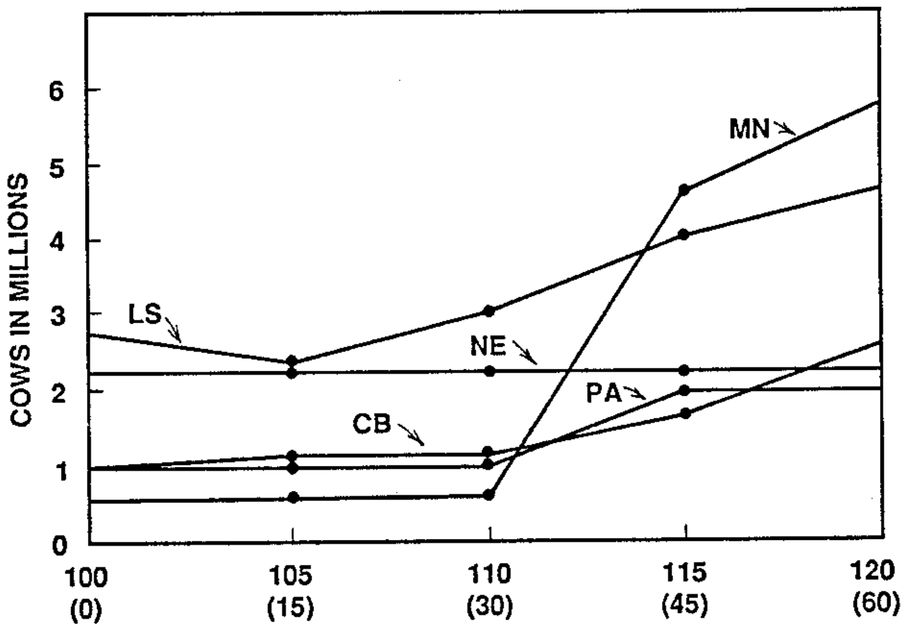
FIGURE 17: EFFECT OF A bST-INDUCED INCREASE IN AVERAGE MILK YIELD ON REGIONAL RAW MILK MARKETS
(Increase at 5%, Support Prices and Class I Differentials at Base Year Conditions, bST Cost at $15 per Cow)



E_0 = Base Year; E_1 = Short Run; E_2 = Long Run

Source: Appendix G-2

FIGURE 18: NUMBER OF DAIRY COWS IN VARIOUS REGIONS AT DIFFERENT LEVELS OF AVERAGE MILK YIELD [a]



AVERAGE MILK YIELD, % OF BASE YEAR
(AVERAGE bST COST, $/COW, IN PARENTHESES)

[a] THE LINES IDENTIFY THE MAIN DAIRY REGIONS
MFG MILKSUPPORT PRICE AT $12.50/CWT
CLASS I MILK PRICE DIFFERENTIALS IN EFFECT
AVERAGE bST COSTS AT DEFAULT LEVELS

Source: Appendix G-1.

binding support price, the same 20 percent increase would cause equilibrium to be established at 124.2 billion pounds and $13.00.[16] The response of the average raw milk price to bST-induced yield increases is presented in Figure 20. The pattern of responses would be similar if Class I differentials were removed, except that prices would be lower by about 70 cents.

A special comment is in order on the behavior of the price of raw milk vis-a-vis changing support price levels at no application of bST, as reported in the first two scenarios of Table 22. The lack of any decline in the raw milk price in response to a lowering of the support price which, at the same time, causes a sizeable reduction in the total number of cows, is due to the fact that the reported raw milk price is a weighted average of regional raw milk prices. As the regions affected by the lowering of the support price reduce their herds in response to lower prices, those prices also lose weight in the national average. On the other hand, for those regions unaffected by lower support prices, the share of national milk production increases. Therefore, the weight of the unchanged raw milk prices for those regions is also increased. These two effects cancel each other out, as may be seen in Appendix G-3.

Government purchases. With support price and Class I differentials at base year conditions, an average milk yield increase of ten percent raises government expenditure on manufactured dairy products tenfold, from $2.440 to $23.796 billion (see Appendix F-6).[17] Figure 21 presents a summary of the milk equivalents that would be purchased by the government at different yield and support price combinations while classified raw milk pricing is in effect. With the help of this summary, isoquants for the amount of government purchases can be visualized, as a conceptual aid in policy evaluation.

Markets of other commodities. At binding dairy support prices, prices of fed beef and slaughter hogs increase whenever the bST-induced production of excess raw milk causes feedstuff demand curves, especially that of feed grain,

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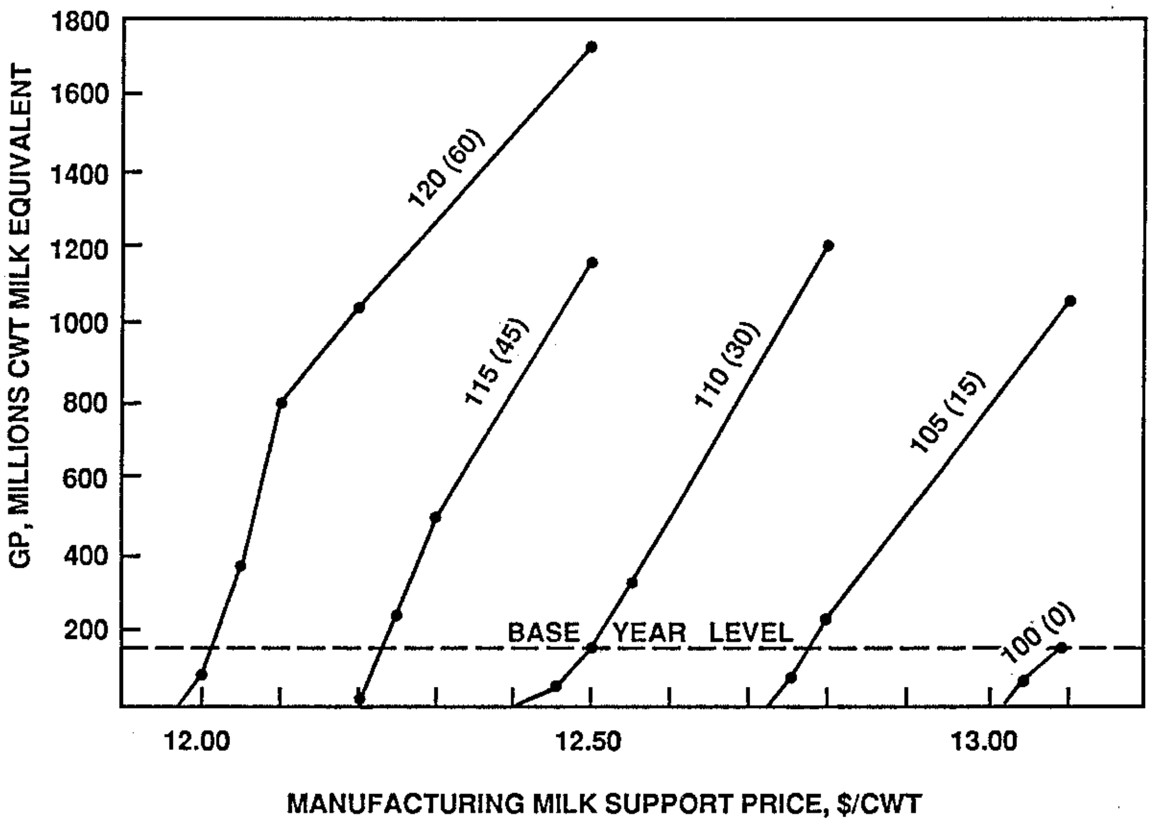
[16]There appears a residual quantity of NFDM purchased by the government even for scenarios without any excess production of raw milk. This quantity serves to balance model discrepancies between competitive demands for butter and NFDM on one side and the outputs of a fixed ratio processing activity on the other.

[17]This scenario also doubles raw milk production, bringing the total number of cows to 20.484 million. The combined 18 percent of the dairy industry held by the Mountain States and Pacific States regions in the base year rises to 40 percent.

FIGURE 21: GOVERNMENT PURCHASES OF DAIRY PRODUCTS AT DIFFERENT LEVELS OF AVERAGE MILK YIELD AND PRICE SUPPORT [a]



[a] THE LINES LINK GVT. PURCHASE-SUPPORT PRICE COMBINATIONS AT THE INDICATED CONSTANT AVERAGE MILK YIELDS (WITH AV. bST COSTS IN PARENTHESES)
CLASS I MILK PRICE DIFFERENTIALS IN EFFECT
AVERAGE bST COSTS AT DEFAULT LEVELS

Source: Appendix G-1

the Lake States. In the Northern Plains, Delta States, and Southern Plains, the share is less than ten percent. At non-binding support prices, the absolute decline of dairy cows in the Northeast and the Lake States causes a wage decline in excess of 30 and 20 cents per hour respectively, while in all remaining regions such declines lie between zero and ten cents.[22]

The relatively small changes in the prices of factors and other production inputs resulting from the application of bST are consistent with economic theory, as these input prices depend on the value of the corresponding marginal product in all industries.

Welfare measures. Social surplus or welfare is the sum of consumers' and producers' surplus.[23] It is measured in dollars and is used as the AGTEC objective function. Its maximum defines model equilibrium, at a point where the competing objectives of both groups of agents, producers and consumers of agricultural commodities, are reconciled. It also provides a measure of the overall well-being of society. Such a measure, however, is conditioned to several assumptions. They state that production is limited to the agricultural sector, consumption encompasses agricultural commodities only, and no links exist between the income of production factor owners and the consumption demand functions for commodities. For the AGTEC objective function, social surplus is computed across commodity demand and supply, the latter including all activities involving production, processing, transfer, and transportation. Social surplus may also be computed across factor owners and commodity consumers, thus allowing an analysis of welfare aspects by group of agents and by region.[24]

In this study, the designations gross social surplus (GSS) and net social surplus (NSS) are used. GSS equals the sum of producers' and consumers' surplus, while NSS, or net welfare, equals GSS minus government expenditure on the dairy price support program.[25] The largest increase in NSS, $3,689

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[22]The above comments apply specifically to scenarios in which base year Class I milk price differentials are in effect.

[23]It is represented geometrically by the difference between the areas under all linear demand and under all linear supply curves.

[24]In the AGTEC solutions, there is a discrepancy between social surplus as reported in the objective function and as computed by the sum of consumers' and producers' surplus. This discrepancy fluctuates around one third of one percent and is due to the fact that, in the first case, exogenous base year prices of intermediate commodities enter through the net activity cost calculation, while in the second case, endogenous solution prices are used throughout.

[25]This definition entails a considerable simplification. Equating the dead weight loss of the dairy price support program to the total expenditure on the program by the government implies the complete disappearance of all dairy products purchased by the CCC. Actually, most of

<u>Support price of manufacturing milk</u>. As opposed to the cost of bST, this parameter is completely independent of production technology. Therefore, its impact can be analyzed either alone or jointly with the impact of bST. The effects of a support price change in the absence of bST can be observed in a subset of the basic scenarios (Appendices F-3 through F-6). The solutions indicate that there is a level below which the support price is not binding. The effect of a support price change in the presence of bST has been discussed earlier in this section. In both cases, support-price-induced shifts in the distribution of the dairy industry are implemented through changes in the regional raw milk demand curves. Because of the different levels and slopes of regional raw milk supply curves, a given upward shift in the horizontal support price portion of all regional demand curves will imply different absolute dairy cow increases for different regions.

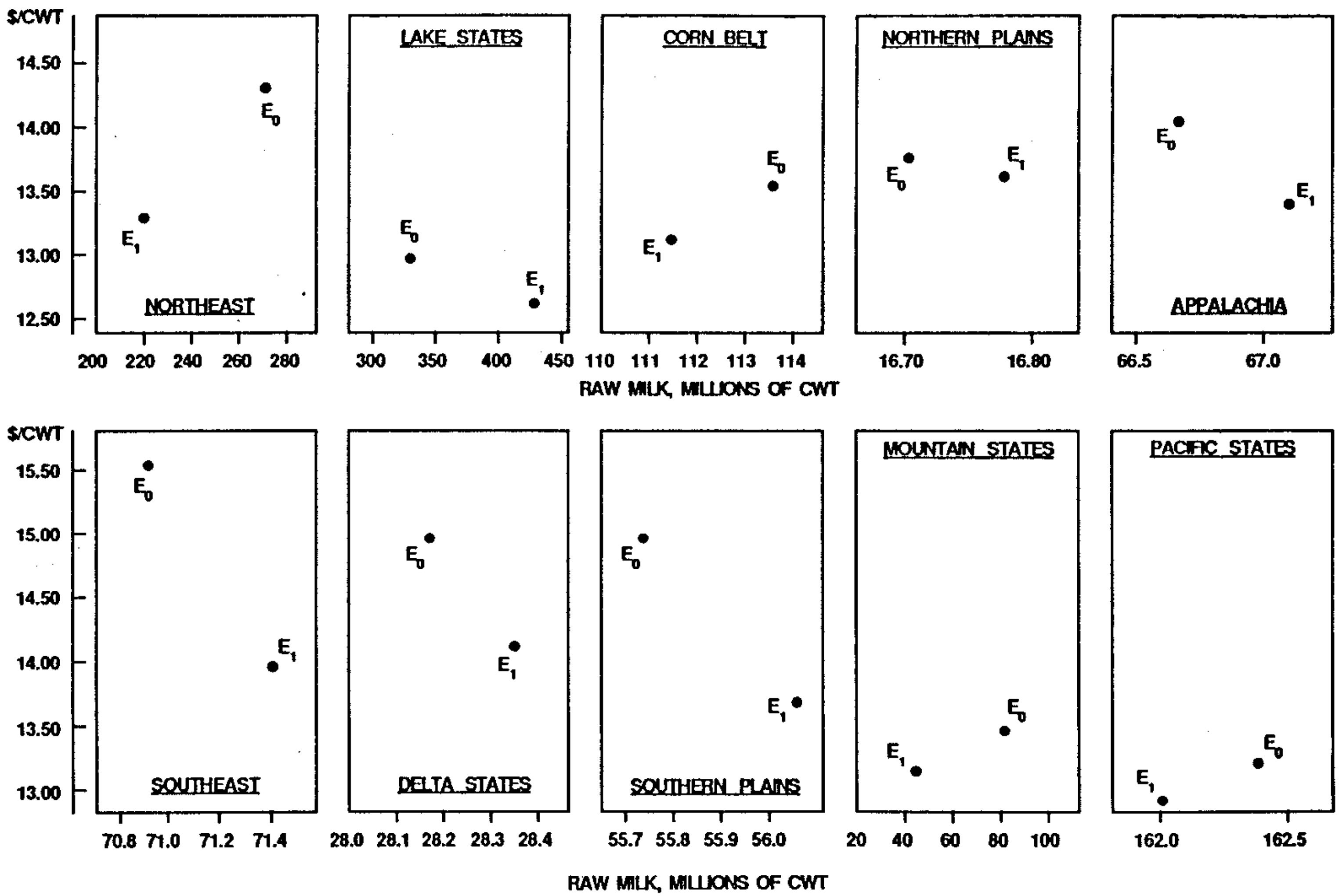
The impact of support price changes is limited to scenarios in which the support price is binding. There, such a change will affect the level of raw milk production, government purchases of manufactured dairy products, the markets of other livestock commodities, feeds, and production factors, and all measures of social surplus. The response of the average raw milk price to changes in the support price can again be seen in Figure 20.

<u>Class I milk price differentials</u>. In this investigation, there are two alternatives with respect to the mandatory Class I milk price differentials: They either are at their base year levels or at zero. As is the case with support prices, Class I differentials are independent of any yield increase, and therefore bear analysis in the presence as well as in the absence of bST. Results from runs with differentials at base year levels are listed in Appendices F-3 through F-6. Results from runs with differentials at zero can be found in Appendices F-7 through F-10. The mandatory Class I milk price differentials have both a subsidy and a spatial distribution effect.

The subsidy effect is demonstrated by the drop in overall raw milk production that occurs if Class I differentials are removed and other base year conditions remain the same. The current support price then becomes non-binding and no excess raw milk is produced. The spatial effect can be observed by comparing the resulting distribution with one that, at a similar total number of cows, and a non-binding support price has the base year Class I differentials in effect. The distribution without differentials shows an increase in the share of the industry in the Lake States region (from 28 to 35 percent) mainly at the expense of the Northeast and the Mountain States (Appendices F-7 and F-3).

The difference between the two distributions of dairy cows can be explained in terms of shifts in the regional raw milk demand curves, caused by the removal of the Class I differentials. Each demand curve shift is the net

FIGURE 22: EFFECT OF THE REMOVAL OF CLASS I DIFFERENTIALS ON REGIONAL RAW MILK MARKETS
(Av. Milk Yield at Base Year Levels, Support Price Not Binding)



E_0 = Diff. in Place, E_1 = Diff. Removed

Source: Appendix G-4

Table 24

MODEL RESULTS FOR LONG-RUN SPECIAL SCENARIOS

Analysis Parameters[a]			Key Solution Variables			
Class. Pricing In Eff.	Av. Milk Yield %	Support Price $/Cwt	Total Nr. of Cows Mill.	Av. Price Raw Milk $/Cwt	M.Equiv. to CCC Bill.Lbs.	Net Welf. Change[b] Mill. $
Regional Yield Increase as a Function of Herd Size Distribution						
Yes	RYH	12.50	12.477	13.34	56.3	-4,672
		12.45	10.743	13.34	31.4	-1,294
		11.90	8.785	13.34	.1	3,025
No	RYH	13.10	9.730	12.65	14.2	1,128
		12.50	8.763	12.63	.1	3,184
		11.90	8.737	12.63	.1	3,255
Commercial Use of Reverse Osmosis						
Yes	100	13.10	10.939	13.73	14.5	70
		12.50	9.772	13.74	.1	2,225
	105	12.80	11.023	13.50	22.7	-637
		12.50	9.397	13.53	.1	2,556
	110	12.55	11.175	13.28	31.8	-1,485
		11.90	8.985	13.36	.1	2,927
No	100	13.10	9.774	13.07	.1	2,424
	105	12.50	9.345	12.82	.1	2,804
	110	11.90	8.953	12.62	.1	3,183
Adoption of Porcine Somatotropin						
Yes	100	13.10	10.226	13.81	6.3	1,495
		12.50	9.770	13.82	.1	2,450
	105	12.80	10.045	13.59	9.8	-764
		12.50	9.403	13.60	.1	2,779
	110	12.55	11.276	13.35	33.8	-1,480
		11.90	9.027	13.39	.1	3,166
No	100	13.10	9.764	13.14	.1	2,670
	105	12.50	9.345	12.93	.1	3,070
	110	11.90	8.960	12.71	.1	3,455

[a]Default average bST cost is assumed for each av. milk yield: 0(100), 15.00(105), 30.00(110), RCH(RYH).

[b]From base year net welfare (Consumers' surplus + producers' surplus - government expenditure).

Source: Appendices F-11, F-12, F-13.

Results are similar at a five percent increase in average milk yield, as long as the support price is binding. If it were not, the total number of cows would be similar to that without pST. Dairy industry distribution, however, would still be characterized by a Lake States share that would be considerably lower than at base year conditions. The AGTEC solutions indicate that the changed technical coefficients for hog feeding have led to a partial displacement of dairy by hogs in the Lake States and to a redistribution of the displaced dairy cows in other regions. If Class I differentials were removed at the same time, the above shift of dairy, away from the Lake States, would be largely offset by a shift in the opposite direction, due to the advantages provided by such a removal to the dairy activity in the Lake States. Concerning the effect of pST on commodity markets, the market for slaughter hogs is at a lower price and a higher volume after the introduction of the hormone than before, just as it happens in the case of raw milk with respect to bST.

Not all of the impacts mentioned under special scenarios have been fully interpreted in terms of market functions. In part, they were dealt with earlier. In part, however, it was felt that some of the effects are too far removed from the main focus of this investigation which is, after all, the effect of bST on the spatial distribution of the dairy industry.

Table 25

IMPACT OF bST ON THE DISTRIBUTION OF THE U.S. DAIRY INDUSTRY[a]

Scenario	BST Yield Increase (%)	Class. Raw Milk Pricing	M. Milk Support Price ($)	Total Number of Cows (Mill.)	Relative Number of Cows (%)						Net Welfare Change[b] (Mill. $)
					North-east	Lake States	Corn Belt	Mount. States	Pacific States	All Others	
1	--	Yes	13.10	11.000	20.60	30.64	10.92	6.68	11.14	20.02	--
2	--	Yes	11.90	9.773	22.46	27.72	10.12	6.25	10.92	22.54	2,301
3	--	No	13.10[c]	9.785	18.09	34.93	9.92	3.53	10.88	22.65	2,418
4	--	No	13.10[c]	9.785	18.09	34.93	9.92	3.53	10.88	22.65	2,418
5	10	Yes	13.10	20.484	11.47	24.34	14.73	29.24	10.42	9.80	-20,345
6	10	Yes	11.90	9.043	24.87	22.94	12.88	6.23	10.83	22.26	2,923
7	10	No	13.10	10.020	18.46	36.97	10.42	4.18	9.75	20.22	1,082
8	10	No	11.90	8.968	19.08	34.07	9.88	3.53	10.85	22.60	3,181

[a]Average bST cost equals default value for the respective average yield increase.

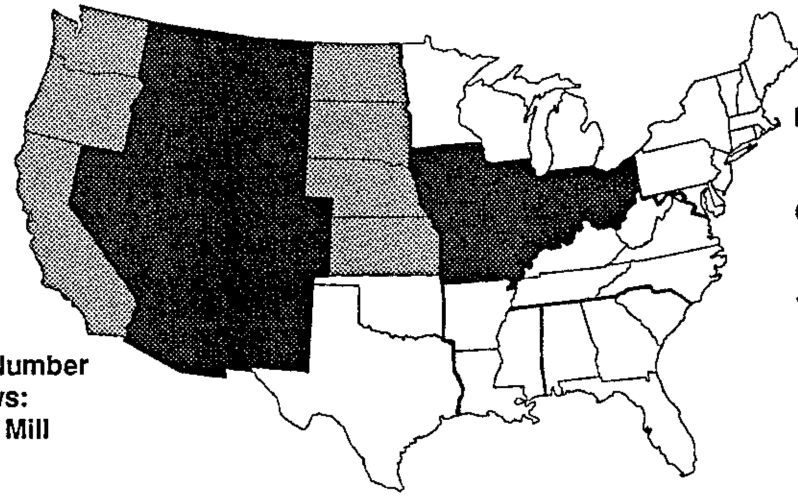
[b]From base year net welfare (consumers' surplus + producers' surplus - government expenditure).

[c]Support price is not binding.

Source: Appendices F-3, F-6, F-7, F-10.

FIGURE 23: RESPONSE OF THE RELATIVE REGIONAL NUMBER OF DAIRY COWS TO THE IMPACT OF bST UNDER VARIOUS POLICY CONDITIONS

(A)



Run # 356

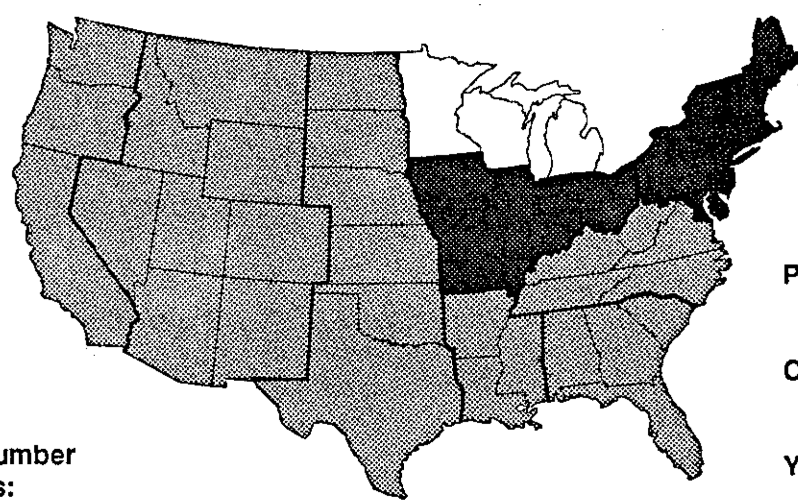
Price Support:
Base Year Cond.

Classified Pricing:
Base Year Cond.

Yield Increase (bST):
10%

Total Number
of Cows:
20.484 Mill

(B)



Run # 369

Price Support:
Not Binding

Classified Pricing:
Base Year Cond.

Yield Increase (bST):
10%

Total Number
of Cows:
9.043 Mill

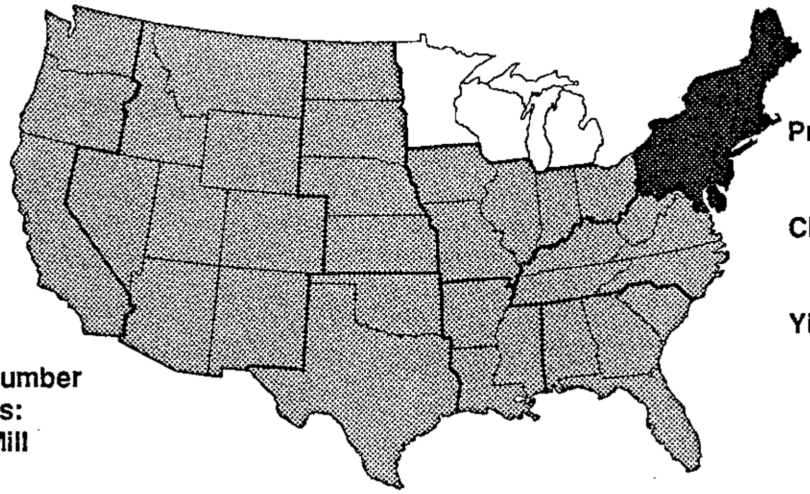
Increase greater than 1% of total number of cows

Change less than 1% of total number of cows either way

Decrease greater than 1% of total number of cows

FIGURE 24: RESPONSE OF THE RELATIVE REGIONAL NUMBERS OF DAIRY COWS TO CHANGES IN POLICY CONDITIONS WITHOUT bST

(A)



Run # 375

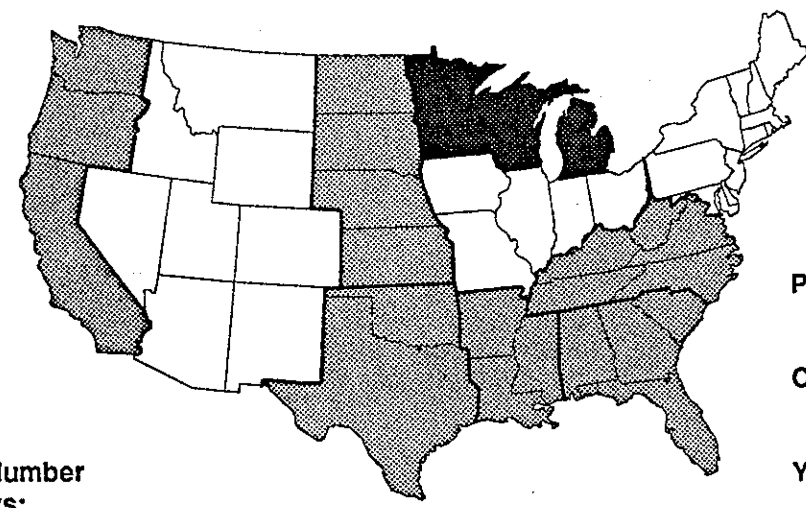
Price Support:
Not Binding

Classified Pricing:
Base Year Cond.

Yield Increase (bST):
—

Total Number
of Cows:
9,773 Mill

(B)



Run # 423

Price Support:
Not Binding

Classified Pricing:
Abolished

Yield Increase (bST):
—

Total Number
of Cows:
9,785 Mill

Increase greater than 1% of total number of cows

Change less than 1% of total number of cows either way

Decrease greater than 1% of total number of cows

To complement the foregoing comments on analysis results, some comments on the method of this investigation are in order. It appears that the general equilibrium approach to spatial effects of technical innovation is not only feasible but, indeed, worthwhile. This is apparent from a comparison of the scope of results presented here with that of the studies on the economic impact of bST quoted in Section IV. From the results involving special scenario conditions and dairy policy changes, it is evident that a general equilibrium sector model, once it has been properly developed, can be used to analyze other technical innovations in the industry originally examined, as well as in other industries, and that it will also serve to analyze other types of impact such as changes in policy.

Before using AGTEC beyond the reported level of detail and outside the specific area of dairy production, however, some of the limitations of the model should be addressed. Model parameters should definitely be updated, which would depend particularly on the availability of the appropriate technical coefficients. Introduction of a wider range of specified production activities, especially for livestock other than dairy cattle, would be equally desirable. It would make regional activity levels more than only roughly relevant. A major achievement would be the elimination of the AGTEC limitation to only two types of economic agents, a limitation which presently excludes from being modeled and analyzed the entire segment of intermediary profit maximizers of the sector. Ideally, an increase in modeled decision making agents would not occur at the expense of the number of regions and commodities.

In terms of a more detailed analysis of the bST impact, it would be desirable to substitute empirical data for the assumptions about increases in milk yield and feed usage, as well as those about the application rate and cost of bST. As FDA approval of bST appears to be possible in the near future, such data should start to become available within one or two years. Even if, at that time, observed dairy industry variables will have started to respond to bST, the adjustment process will be slow enough to make the long-run solution of an upgraded bST scenario relevant. As empirical data become available, it will also be increasingly interesting to solve such scenarios under short-run and, possibly, intermediate-run conditions.

Additional technical innovations in the agricultural sector for which the approach of this investigation might be used include the application of hormones in other livestock industries, as was attempted in this study with respect to pork. They may, however, also include innovations in crop production, such as changes in the relationship between crop yield and fertilizer usage due to nitrogen fixation or between crop yield and the usage of other inputs, due to herbicide resistance in plants or the use of biological pest control.

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Appendix A-1

LONG-TERM bST TRIAL RESULTS: DAILY INJECTION
(Monsanto)

Trial	Cows	Treatment			Milk Yield			Feed		Reference
		bST Dose, mg/Hd	Days Post-Partum	Days Duration	Raw Milk kg/D	Fat Corr. kg/D	Increase[a] %	Dry Mat. kg/D	Milk D.M. Ratio	
Cornell U.	6	0	84±10	188		27.9	--			J. of Dairy Science, 1985
	6	13.5	84±10	188		34.4	23.3			
	6	27.0	84±10	188		38.0	36.2			
	6	40.5	84±10	188		39.4	41.2			
	6	27.0[b]	84±10	188		32.5	16.5			
U. of Missouri, Texas A&M, U. of Maryl.[c]	6	0	86	189			--			P83, ADSA-1986
	6	13.5	86	189			12.6			
	6	27.0	86	189			2.2			
	6	40.5	86	189			4.4			
	6	27.0[b]	86	189			4.3			
Mississippi St. U.	6	0	84±10	188		26	--			P185, ADSA-1986
	6	13.5	84±10	188		34	30.7			
	6	27.0	84±10	188		33	26.9			
	6	40.5	84±10	188		31	19.2			
	6	27.0[b]	84±10	188		28	7.6			

[a]In 3.5% fat corrected milk.

[b]Pituitary bST.

[c]High ambient temperature, high humidity, low feed intake.

Appendix A-2 (Continued)

U. of Florida[e]	9	0	28-35	273	21.1		--			P52, ADSA-1987
	9	6.25	28-35	273	25.5		20.9			
	9	12.5	28-35	273	26.5		25.6			
	9	25.0	28-35	273	29.3		38.9			
U. of Guelph Canada[f]	9	0	28-35	266		26.7	--	19.5	1.38	P214, ADSA-1987
	10	12.5	28-35	266		30.5	14.2	19.6	1.53	
	10	25.0	28-35	266		31.5	18.0	20.5	1.50	
	9	50.0	28-35	266		30.8	15.4	19.8	1.55	
Animal and Grassland Res. Inst., U.K.[h]	80[g]	0	28	259	21.1		--			P213, ADSA-1987
		12.5	28	259	24.6		16.6			
		25.0	28	259	26.0		23.2			
		50.0	28	259	25.6		21.3			
Animal and Grassland Res. Inst., U.K.[i]		0	28	259	19.1		--			
		12.5	28	259	23.6		23.3			
		25.0	28	259	23.7		24.1			
		50.0	28	259	24.1		26.2			
Ohio St. U.	9	0	28	266	30.9		--	19.9	1.55	P261, ADSA-1988
	9	10.3	28	266	30.6		-1.0	19.5	1.57	
	9	20.6	28	266	32.6		5.5	20.8	1.57	
	9	41.2	28	266	35.7		15.5	21.4	1.67	

Appendix A-3
LONG-TERM bST TRIAL RESULTS: DAILY INJECTION
(Various Suppliers)

Trial	Cows	Treatment			Milk Yield			Feed		Reference
		bST Dose, mg/Hd	Days Post-Partum	Days Duration	Raw Milk kg/D	Fat Corr. kg/D	Increase[a] %	Dry Mat. kg/D	Milk D.M. Ratio	
Pennsylvania St. U.[c]	8	0	35	165		31.2[b]	--			P142, ADSA-1988
	8	0	70	130		32.3	--			
	8	25	35	165		36.2	16.0			
	8	25	70	130		35.9	11.1			
U. of Georgia (Upjohn)	8	0	75	230		22.5[d]	--		1.17	P272, ADSA-1988
	8	5	75	230		23.1	2.7		1.19	
	8	10	75	230		27.6	22.7		1.29	
	8	15	75	230		28.3	25.7		1.37	
	8	20	75	230		26.7	18.7		1.32	
South Dakota St.U. (Upjohn)	8	0	75	230	21.0	20.8[b]	--			P263, ADSA-1988
	8	5	75	230	24.3	23.1	11.1			
	8	10	75	230	22.1	21.0	1.0			
	8	15	75	230	24.3	23.1	11.1			
	8	20	75	230	25.4	25.0	20.2			

[a]In fat corrected milk if both raw and FC milk are reported.

[b]4% FCM.

[c]Post-treatment milk yield lower for treated than untreated cows .

[d]3.5% FCM.

Appendix A-4 (Continued)

U. of Arizona[h]	80	0	60	252	27.3		--	P264,
		500	60	252	29.6		8.4	ADSA-1988
Utah St. U.	36	0	60	252			--	P267,
	36	500	60	252			14.7	ADSA-1988
Monsanto	126	0	60	252		23.8	--	P271,
		500	60	252		29.0	21.8	ADSA-1988
Various[i]		0	60	252		25.7	--	P273,
		500	60	252		29.3	14.0	ADSA-1988

[a]Application at 14 day intervals.

[b]Intramuscular application in first treatment at each dose, subcutaneous in second.

[c]X = 500 mg.

[d] Cow numbers are totals for each group of four treatments.

[e]Second consecutive lactation with bST treatment.

[f]Crude protein in dry matter fed: 17%.

[g]Cyclical yield pattern parallel to injection cycle.

[h]105 days open and 85 percent conception in treated animals, 90 days and 81 percent in controls.

[i]Summarizes the four preceding trials.

Appendix A-6

SHORT-TERM bST TRIAL RESULTS: DAILY INJECTION (Various Suppliers)

Trial	Cows	Treatment			Milk Yield			Feed		Reference
		bST Dose, mg/Hd	Days Post-Partum	Days Duration	Raw Milk kg/D	Fat Corr. kg/D	Increase[a] %	Dry Mat. kg/D	Milk D.M. Ratio	
U. of Forida[b]	13[c]	0	81-110	28			--			P84, ADSA-1986
		0	81-110	28			--			
		25	81-110	28			2.7			
		25	81-110	28			8.6			
U. of Alberta[d]	12[c]	0	132	8	27.9		--	24.1		P186, ADSA-1986
		0	132	8	27.9		--	24.1		
		30	132	8	32.4		16.1	24.0		
		30	132	8	32.4		16.1	24.0		
PA St. U.	4	0	258	10	21.5	20.7	--			P187, ADSA-1986
	4	27.8	258	10	24.8	25.1	15.3			
U. of Florida	10[c]	0	211	10						P212, ADSA-1987
		27.8[e]	211	10			8.5			
U. of Pennsylvania[f]	4	0	28	70	36.0	33.8	--		1.49	P220, ADSA-1987
	4	0	28	70	35.7	33.5	--		1.52	
	4	50	28	70	37.6	36.9	4.4		1.73	
	4	50	28	70	40.3	40.3	12.9		1.95	

Appendix A-7
SHORT-TERM bST TRIAL RESULTS: SUSTAINED RELEASE
(Various Suppliers)

Trial	Cows	Treatment			Milk Yield			Feed		Reference
		bST Dose, mg/Hd	Days Interval	Days Duration	Raw Milk kg/D	Fat Corr. kg/D	Increase[a] %	Dry Mat. kg/D	Milk D.M. Ratio	
Monsanto[b]	8[c]	0	7	14		15.8	--			P147, ADSA-1988
		15,000	7	14		22.1	40.0			
Lilly	16[c]	0	1	14	22.9		--			P218, ADSA-1987
		25	1	14	26.3		14.8			
	14[c]	0	28	84	22.9	21.7[d]	--	20.2		
		960	28	84	27.0	25.0[d]	17.9	21.0		
Lilly	7[e]	0		84	26.4	23.6[d]	--	19.9	1.19	P219, ADSA-1987
	7	360	14	84	30.3[f]	26.8[d]	14.8	20.7	1.29	
	7	360	21	84						
	7	360	28	84						
	7	640	14	84	31.3[f]	27.6[d]	18.6	20.4	1.35	
	7	640	21	84						
	7	640	28	84						
	7	960	14	84	32.7[f]	28.6[d]	23.9	20.2	1.42	
	7	960	21	84						
	7	960	28	84						

[a]In raw milk.
[b]Subcutaneous application.
[c]Total for trial.
[d]13.5% solids corrected milk.
[e]Each group of 7 consisted of 3 cows in early lactation and 2 cows and 2 heifers in mid lactation.
[f]Average across intervals. No effect of interval length apparent.

Appendix B-1 (Continued)

CB	OH	E. OH-W.PA	(F)	53.175	2,019	1,074	1.85	1,986.90
	"	Ohio Valley	(F)	77.430	1,763	1,374	1.70	2,335.80
	IN	Ohio Valley	(F)		511	1,763		
	"	Louisv-Lex-Ev.	(F)	24.820	656	162	1.70	275.40
	"	Indiana	(F)	93.562	1,156	1,082	1.53	1,655.46
	IL	Chicago Region	(F)	65.777	2,868	1,886	1.26	2,376.36
	"	Iowa	(F)	10.142	764			
	"	Central Illinois	(F)	100.000	85	85	1.39	118.15
	"	South Illinois	(F)	100.000	548	548	1.53	838.44
	"	St.Louis-Ozarks	(F)	5.759	1,112			
	IA	Iowa	(F)	89.858	764	764	1.40	1,069.60
	"	Upper Midwest	(F)	1.701	1,467	25	1.12	28.00
	"	Eastern S.Dakota	(F)	3.119	105	3	1.40	4.20
	"	Nebr.-W.Iowa	(F)	22.419	593	133	1.60	212.80
	MO	Gr. Kansas City	(F)	52.043	446	232	1.74	403.68
	"	St. Louis-Ozarks	(F)	86.491	1,112	1,026	1.58	1,621.08
	"	Paducah	(F)	27.216	102	28	1.70	47.60
	"	SW Plains	(F)	1.375	837	11	1.98	21.78
						8,433	1.54	12,995.25
NP	ND	Upper Midwest	(F)	5.596	1,467	107	1.12	119.84
	SD	Upper Midwest	(F)	1.722	1,467			
	"	Eastern S.Dakota	(F)	84.196	105	88	1.40	123.20
	"	Black Hills	(F)	100.000	31	31	1.95	60.45

Appendix B-1 (Continued)

SE	GA	Georgia	(F)	100.000	1,404	1,404	2.30	3,229.20
	"	Tenn. Valley	(F)	8.705	956	83	2.10	174.30
	AL	Ala.-W. Florida	(F)		847	847	2.30	1,948.10
	FL	Ala.-W. Florida	(F)		847			
	"	Upper Florida	(F)	100.000	403	403	2.85	1,148.55
	"	Tampa Bay	(F)	100.000	1,001	1,001	2.95	2,952.95
	"	Se Florida	(F)	100.000	667	667	3.15	2,101.05
	SC	South Carolina	(S)	100.000	332	332	2.30	763.60
						4,737	2.60	12,317.75
DL	AR	St. Louis-Ozar.	(F)	7.750	1,112	86	1.58	135.88
	"	Central Ark.	(F)	100.000		414	1.95	807.30
	"	Fort Smith	(F)	100.000				
	"	Memphis	(F)	2.533	227	38	1.94	73.72
	MS	Memphis	(F)	14.358	227			
	"	N. Orl.-Miss.	(F)		715			
	LA	N. Orl.-Miss.	(F)		715	715	2.85	2,037.75
	"	Gr. Louisiana	(F)	100.000	420	420	2.47	1,037.40
						1,673	2.45	4,092.05
SP	OK	Southw.Plains	(F)	73.323	837	614	1.98	1,215.72
	TX	Texas Panhdle	(F)	100.000	85	85	2.25	191.25
	"	Lubb.-Plainv.	(F)	100.000	65	65	2.42	157.30
	"	Texas	(F)	100.000	2,958	2,958	2.32	6,862.56
	"	R. Grande V.	(F)	26.657	364	97	2.35	227.95
						3,819	2.27	8,654.78

Appendix B-1 (Continued)

PA	W A	Puget S.-Inl.	(F)	95.250	937	892	1.85	1,650.20
	"	Oregon-Wash.	(F)		822			
	OR	Oregon-Wash.	(F)		822	822	1.95	1,602.90
	"	SW ID-E.OR	(F)	15.138	106	16	1.50	24.00
	CA	California	(S)	100.000	6,308		1.60	10,092.80
						8,038	1.66	13,369.90

[a]Based on population.

[b]Received by handlers registered in MMOA.

[c]Differentials valid in 1982.

[d]F indicates Federal Order.

[e]S indicates State Order.

Source: Federal Milk Order Market Statistics 1984, Stat. Bull. 733, ERS, USDA.

Appendix C-2
NATIONAL PRODUCTION LEVELS AND AVERAGE PRODUCER PRICES

Commodity	Observed	SPATEQ	AGTEC	Observed	SPATEQ	AGTEC
	Million Units			$ per Unit		
101-COTTON	16	15	15	259.20	259.01	258.63
102-RICE	183	168	183	9.05	9.05	9.05
103-SOYBNS	1,989	2,086	1,778	6.04	6.08	6.04
104-WHEAT	2,799	2,963	2,738	3.65	3.66	3.65
105-SORGHM	876	418	642	2.39	2.40	2.39
106-CORN	8,119	8,038	8,128	2.50	2.54	2.50
107-BARLEY	474	294	346	2.45	2.51	2.45
108-OATS	510	382	452	1.89	1.93	1.89
109-SILAGE				23.09	23.40	23.05
110 HAY	143	109	124	67.10	68.28	63.47
141-RAWMLK	1,361	1,322	1,362	13.60	12.48	13.75
145-CL1MLK	555		581	14.63		14.62
146-CL2MLK	806		780	12.49		12.43
151-CDRCAL				44.85	44.61	39.63
151-CDRCOW				462.00	471.96	473.63
161-LBFCAL				68.16	68.94	67.60
162-BFYRLG				61.50	61.72	62.34
163-CBFCOW				38.50	38.43	39.08
164-FBFSLA	291		294	64.22	64.88	64.81
165-CALSLA				59.80	57.83	51.85
166-NBFSLA				38.50	38.27	39.04
171-FDRPIG				110.00	104.35	107.58
172-CULSOW				46.50	44.35	46.36
173-HOGSLA	194		188	53.20	50.64	53.05
201-SBMEAL	493	471	425	13.73	9.30	13.55
202-SBOIL	110	110	99	19.00	19.41	20.40
211-PRSUPD				7.95	8.14	7.96
221-LOPRCT				10.52	10.02	10.50
222-HIPRCT				12.00	9.18	11.95
223-CORNCT				2.50	2.57	2.50
232-HIPRSW				13.98	11.85	13.83
233-CORNSW				2.50	2.57	2.50
241-FLUMLK	555	552	549	26.10	25.02	26.22
251-ICECRM	38		43	101.00		101.31
252-SOFTCP	18		18	186.00		186.02
255-HARDCP	28		28	139.50		140.38
256-BUTTER	13		13	149.00		151.52
257-NFDMLK				94.00		94.11
261-FBEEF	123	141	122	240.50	242.09	241.92
262-VEAL	3	3	4	314.60	310.08	296.36
263-NBEEF	37	44	37	197.86	197.23	199.36
271-PORK	115	139	115	173.40	169.04	173.13
281-PLTPUM	21		21	243.00	247.58	245.58

Appendix C-4

MODEL VALIDATION RESULTS: DISTRIBUTION OF PRIMARY CROP COMMODITIES BY PRODUCTION REGION

Region	Obs.	SPATEQ	AGTEC	Obs.	SPATEQ	AGETC
	Soybeans, Million Bu.			Wheat, Million Bu.		
NE01	26	--	34	26	27	36
LS02	181	570	641	191	198	68
CB03	1,085	972	515	375	439	300
NP04	153	133	151	830	1,086	1,202
AP05	172	87	74	100	8	83
SE06	128	73	67	85	2	4
DL07	239	170	285	103	88	273
SP08	17	80	12	356	379	270
MN09	--	--	--	403	652	386
PA10	--	--	--	353	102	116
	1,989	2,086	1,778	2,790	2,963	2,738
	Sorghum, Million Bu.			Corn, Million Bu.		
NE01	--	--	--	309	698	393
LS02	--	--	--	1,396	1,147	617
CB03	83	22	332	4,440	3,343	4,298
NP04	423	29	114	1,161	801	625
AP05	11	--	--	407	637	466
SE06	7	--	--	154	494	500
DL07	23	136	22	12	--	--
SP08	295	20	76	131	230	457
MN09	27	169	55	136	163	263
PA10	9	42	41	53	525	508
	876	418	642	8,119	8,038	8,128
	Barley, Million Bu.			Oats, Million Bu.		
NE01	11	46	14	54	55	55
LS02	61	81	63	164	29	161
CB03	--	--	--	100	119	102
NP04	128	80	52	139	124	101
AP05	12	--	--	7	--	--
SE06	1	--	--	9	--	--
DL07	--	--	--	2	--	--
SP08	4	--	--	22	--	--
MN09	116	6	183	12	54	33
PA10	96	80	34	10	--	--
	474	294	346	510	382	452

Appendix C-6

MODEL VALIDATION RESULTS: DISTRIBUTION OF SECONDARY DAIRY COMMODITIES BY PRODUCTION REGION

Region	Observed	AGTEC	Observed	AGTEC	Observed	AGTEC
	Fluid Milk,Mill.Cwt		Ice Cream,Mill.Cwt		Soft Cheese,Mill.Cwt	
NE01		123.539	12.967	9.613	4.019	5.614
LS02		44.618	4.025	3.493	6.131	5.684
CB03		87.245	4.391	6.803	3.669	1.879
NP04		13.130	.874	1.022	.894	--
AP05		52.466	2.756	4.064	.352	--
SE06		55.666	2.877	4.360	--	--
DL07		22.120	.836	1.724	.260	--
SP08		43.763	2.689	3.442	--	--
MN09		29.139	1.524	2.282	.553	2.329
PA10		76.876	5.404	6.037	2.016	2.466
	554.990	548.562	38.343	42.820	17.894	17.970

Region	Hard Cheese (Mill. Cwt)		Butter (Mill. Cwt)		NFDM (Mill. Cwt)	
NE01	3.483	4.133	2.543	2.188		3.971
LS02	16.346	17.848	5.229	6.707		12.174
CB03	2.264	--	1.081	.691		1.254
NP04	1.628	--	.280	--		--
AP05	.622	--	.273	--		--
SE06	--	--	--	--		--
DL07	.109	--	--	--		--
SP08	--	--	.117	--		--
MN09	1.739	2.696	.282	.913		1.658
PA10	1.332	2.840	2.765	2.022		3.669
	27.523	27.516	12.570	12.521		22.726

Appendix D-2

NUTRIENTS SUPPLIED BY PASTURE LAND AND HAY: DATA FOR STATE-BASED CALCULATIONS[a]

	Pasture Land		Hay			
Dairy State	Dry Land Hay Yield Tons/Acre (1)	Hay Equiv. of Pasture Lbs./Unit (2)	Total Hay Harvest 1982 Million Tons (3)	Alfalfa Hay Harvest 1982 Million Tons (4)	Alfalfa Hay Fraction (5)	Other Hay Fraction (6)
30-NY	2.23[b]	2230[c]	5.056[d]	2.365[d]	.4460	.5340
36-PA	2.29	2290	4.230	2.173	.5137	.4863
21-MN	2.77	2770	6.624	5.118	.7726	.2274
47-WI	3.13	3130	11.847	8.301	.7007	.2993
13-IA	3.44	3440	6.202	5.091	.8209	.1791
33-OH	2.57	2570	2.931	1.642	.5602	.4398
39-SD	1.65	91.67[e]	6.595	4.152	.6296	.3704
15-KY	1.96	1960	2.787	.615	.2207	.7793
40-TN	1.57	1570	1.924	.266	.1383	.8617
08-FL	2.19	2190	.721	.020	.0277	.9723
09-GA	2.19	2190	1.091	.059	.0541	.9459
16-LA	2.19	2190	.743	.032	.0432	.9568
41-TX	Not Applicable		5.690	.619	.1088	.8912
10-ID	Not Applicable		3.846	3.359	.8926	.1274
04-CA	Not Applicable		6.485	5.046	.7781	.2219

[a]To calculate units of nutrient per unit of ingredient using Appendices D-1 and D-2:
Pasture Land: Content (Code 110) x (2);
Hay:[Content (Code 110) x (5) + Content (Code 130) x (6)] x 2000.

[b]From FEDS 1982 Budgets.

[c](2.23t x .5)/Acre x 2000 lb /t.

[d]From U.S. Census of Agriculture, 1982.

[e](.65t x .33)/12 AUM x 2000 lb./t (see Appendix D-4).

Appendix D-4

NUTRIENT CONTENT OF DAIRY FEED INGREDIENTS IN AGTEC, ASSUMPTIONS

The nutrient content of dairy feed ingredients as used in AGTEC is based on data from Least Cost Balanced Dairy Rations (LCBDR) by Milligan et al., summarized in Appendix D-1. In order to assign specific nutrient contents to pasture, silage, hay, and protein supplement and to calculate total base year nutrient intakes, several specific assumptions are needed.

Pasture usages in AGTEC are not expressed in weight of feed but in area of pasture land. As data on pasture land yields are not readily available it is assumed that in states for which pasture land is reported in acres, one acre produces, in Grass Hay (Code 140) or its equivalent, 0.5 of the FEDS hay yield per acre of unirrigated cropland. In states for which pasture land is given in animal-unit- months (AUM), it is assumed that 12 AUM produce, in Grass Hay (Code 140) or its equivalent, 0.33 of the FEDS hay yield per acre of unirrigated cropland. Appendix D-2 shows the amounts of grass hay per unit of pasture land produced under these assumptions.

AGTEC silage is assumed to have a set of nationally uniform nutrient contents, namely, that specified for Corn Silage (Code 151).

The nutrient contents of hay in AGTEC are assumed to range from the specification of Legume Hay (Code 110) to that of Mixed Mostly Grass Hay (Code 130), in accordance with the proportions of Alfalfa Hay and All Other Hay produced in each state (Census of Agriculture of 1982). These data are also shown in Appendix D-2.

Conditions assumed for the AGTEC model provide for the mixing of dairy protein supplement from corn, wheat, sorghum, barley, oats, and soybean meal in six different ways. Applying to the respective ingredient proportions the LCBDR nutrient contents, it can be seen that the overall nutrient contents of the six mixtures are sufficiently similar to justify the assumption of a nationally uniform dairy supplement specification. The calculations and the resulting values appear in Appendix D-3.

Appendix E-1 (Continued)

2. Dairy Activity Unit Requirements per Year:

Dry Matter, lbs:

Per cow, Dry:	60 x 2.00 x 12 =	6,771	
Per cow, Lact.:	305 x 1.85 x 12 =	1,440	
			8,211
Per cwt milk:	.305 x 100 =		30.5
Per calf:	90 x 2.00 x .75 =		135
Per heifer:	730 x 2.00 x 8 =		11,680

Adjusted Crude Protein, lbs:

Per cow, Dry :	60 x 1.05(.56 + .11 x 12) =	118.4	
Per cow, Lact.:	305 x 1.05(.32 + .06 x 12) =	335.1	
			453.5
Per cwt milk:	.087 x 100 =		8.7
Per calf:	90 x 1.20(.56 + .11 x .75) =		86.74
Per heifer:	730 x 1.50(.56 + .11 x 8) =		1,261

Net Energy, Mcal:

Per cow, Dry :	60 x 1.05(2.77 + .74 x 12) =	734	
Per cow, Lact.:	305 x 1.05(2.10 + .58 x 12) =	2,901	
			3,635
Per cwt milk:	.34 x 100 =		34
Per calf:	90 x 1.20(2.77 + .74 x.75) =		448.9
Per heifer:	730 x 1.50(2.77 + .74 x 8) =		7,612

Appendix E-1 (Continued)

4. Partitioning of Base Year Requirements:

	Dry Matter lbs	Adjusted Protein lbs	Net Energy Mcal	Dry Matter Fraction	Adjusted Protein Fraction	Net Energy Fraction
Output	(B_1) DAU Requirem. for Milk					
Milk, Cwt	30.5	8.7	34			
Calf, Hd	0	0	0			
Heifer, Hd	0	0	0			
Region	(D) B.Y. Requirem. for Milk[a]			(E) B.Y. Fraction for Milk[b]		
NE01	3,792	1,082	4,228	.2655	.5938	.4429
LS02	3,787	1,080	4,221	.2560	.5782	.4289
CB03	3,506	1,000	3,908	.2464	.5691	.4184
NP04	3,305	943	3,684	.2312	.5467	.3971
AP05	3,366	960	3,752	.2428	.5660	.4145
SE06	3,327	949	3,709	.2381	.5589	.4080
DL07	2,890	824	3,221	.2135	.5238	.3744
SP08	3,421	976	3,813	.2455	.5688	.4173
MN09	4,095	1,168	4,565	.2737	.6008	.4517
PA10	4,643	1,324	5,175	.2965	.6263	.4791

[a]Matrix Calculations: $\mathbf{D = AB_1}$

[b]Matrix Calculations: $\mathbf{E = (e_{i,m}) = d_{i,m}/c_{i,m}}$

where i = NE01 .... PA10;

m = DM, AP, EN;

Appendix E-3

RATIO OF RAW MILK PRODUCED TO DRY MATTER FED, bST TRIAL RESULTS

Trial	Yield Inc. (Per Lact.) (%)	Milk/Dry Matter (Treatm.) (lb/Lb)	Milk/Dry Matter (Year) (llb/Lb)
U. of KY	0	1.21[a]	1/21
	13.98[a]	1.36	1.32
	11.51	1.35	1.31
	17.99	1.34	1.30
U. of PA	0	1.41	1.41
	16.03	1.67	1.60
	19.27	1.69	1.62
	26.94	1.70	1.62
U. of MN	0	1.31	1.31
	8.66	1.45	1.41
	25.90	1.55	1.48
	20.30	1.50	1.45
U. of MN	0	1.24	1.24
	5.11	1.34	1.31
	20.03	1.29	1.28
	30.60	1.53	1.45
U. of Guelph	0	1.38	1.38
	12.10	1.53	1.49
	15.34	1.50	1.47
	13.13	1.55	1.50
OH St. U.	0	1.55	1.55
	-.87	1.57	1.56
	4.80	1.57	1.56
	13.52	1.67	1.64
U. of GA	0	1.17	1.17
	2.04	1.19	1.18
	17.12	1.29	1.25
	19.38	1.37	1.30
	14.10	1.32	1.26
Clemson U.	0	1.21	1.21
	10.32	1.51	1.36
	8.41	1.37	1.29
	9.25	1.49	1.35

[a]From Appendices A-1 through A-5.

Appendix F-1

INTERREGIONAL FLOW OF MILK: SHORT-RUN BASIC SOLUTIONS

Class. R.M Pricing	Av. Milk Yield	Mfg.Mlk Support Price	Av. bST Cost	Milk Flow into (+) and out of (-) Regions, Mill. Cwt.								Total Class I	Total Class II
				NE	LS	CB	NP	AP	SE	DL	SP		
Yes[a]	100	13.10	--	--	--	--	--	--	--	--	--	--	--
		12.50	--	-.007	--	.007	-	--	--	--	--	.007	
	105	13.10	7.50	1.214	--	3.039	1.483	-2.419	-1.214	-.620	-1.483	--	5.736
			15.00	1.214	--	3.039	1.483	-2.419	-1.214	-.620	-1.483	--	5.736
			30.00	1.214	--	3.039	1.483	-2.419	-1.214	-.620	-1.483	--	5.736
		12.50	7.50	.634	--	2.435	1.064	-2.022	-.634	-.413	-1.064	--	4.133
			15.00	.623	--	2.435	1.064	-2.022	-.634	-.413	-1.064	-	4.133
			30.00	.623	--	2.435	1.064	-2.022	-.634	-.413	-1.064	--	4.133

[a]Base year scenario.

Appendix F-3

DAIRY INDUSTRY DISTRIBUTION: LONG-RUN BASIC SOLUTIONS WITH CLASSIFIED PRICING

Av. Milk Yield	Milk Support Price	Av. bST Cost	Dairy Cows, Millions										
			NE	LS	CB	NP	AP	SE	DL	SP	MN	PA	Total
100[a]	13.10	0.00	2.265	3.370	1.201	.154	.604	.650	.297	.497	.735	1.227	11.000
	12.50	0.00	2.197	2.743	.989	.154	.604	.650	.297	.497	.613	1.069	9.813
	11.90	0.00	2.195	2.709	.989	.154	.604	.650	.297	.497	.611	1.067	9.773
105	13.10	15.00	2.347	4.227	1.814	.147	.576	.621	.283	.474	5.186	2.040	17.714
	12.80	15.00	2.280	3.344	1.212	.147	.577	.621	.284	.474	.703	1.428	11.070
	12.50	7.50	2.210	2.382	1.143	.147	.577	.622	.284	.475	.589	1.024	9.453
		15.00	2.210	2.371	1.142	.147	.577	.621	.284	.474	.588	1.023	9.438
		30.00	2.211	2.348	1.140	.147	.576	.620	.283	.474	.587	1.022	9.408
110	13.10	30.00	2.350	4.986	3.018	.140	.550	.593	.270	.452	5.990	2.135	20.484
	12.55	30.00	2.254	3.414	1.179	.141	.552	.595	.271	.454	.742	1.614	11.215
	12.50	15.00	2.259	3.585	1.344	.141	.552	.596	.272	.455	3.411	1.692	14.305
		30.00	2.254	3.016	1.179	.141	.551	.595	.271	.454	.675	.981	10.117
		60.00	2.244	1.990	1.124	.140	.550	.593	.270	.453	.671	.978	9.015
	11.90	30.00	2.249	2.074	1.164	.141	.552	.595	.271	.454	.563	.979	9.043
115	12.50	22.50	2.237	4.494	2.153	.135	.529	.571	.260	.436	5.700	1.978	18.492
		45.00	2.171	4.022	1.677	.135	.528	.570	.260	.435	4.606	1.915	16.318
	12.25	45.00	2.169	2.969	1.132	.135	.528	.571	.260	.436	.648	1.367	10.216
	11.90	45.00	2.167	1.937	1.131	.135	.529	.571	.260	.436	.604	.941	8.710
120	12.50	30.00	2.440	5.087	3.687	.129	.506	.548	.249	.416	5.967	2.033	21.061
		60.00	2.323	4.663	2.681	.129	.506	.547	.249	.416	5.743	1.975	19.232
	12.05	60.00	2.091	3.374	1.239	.129	.507	.549	.250	.417	.678	1.589	10.824
	11.90	60.00	2.090	1.898	1.089	.129	.507	.549	.250	.417	.569	.905	8.404

Appendix F-4

COMMODITY MARKETS: LONG-RUN BASIC SOLUTIONS WITH CLASSIFIED PRICING

Av. Milk Yield	Mfg.Mlk Support Price	Av. bST Cost	Milk, M.Cwt Total	Milk, M.Cwt Govt.	Raw Milk $/Cwt	Fed Beef $/Cwt	Sl. Hogs $/Cwt	Silage, M. t Total	Silage, M. t Dairy	Hay, M. t. Total	Hay, M. t. Dairy	Corn Fed, M. Bu Total	Corn Fed, M. Bu Dairy
100[a]	13.10	0.00	1,362	150	13.75	64.81	53.05	88.4	41.7	123.7	38.9	4,445	888
	12.50	0.00	1,211	1	13.76	64.69	52.84	67.5	34.4	118.3	35.6	4,490	798
	11.90	0.00	1,205	1	13.76	64.67	52.82	65.7	34.1	118.3	35.5	4,499	795
105	13.10	15.00	2,372	1,164	13.64	65.86	53.57	96.3	47.0	147.4	68.1	4,622	1,237
	12.80	15.00	1,446	227	13.52	64.85	53.17	79.9	35.3	124.8	39.5	4,556	988
	12.50	7.50	1,223	1	13.51	64.68	52.80	58.1	26.6	118.1	34.4	4,587	858
		15.00	1,221	1	13.56	64.68	52.80	58.0	26.6	118.0	34.3	4,587	857
		30.00	1,217	1	13.68	64.68	52.79	57.9	26.5	117.7	34.3	4,586	854
110	13.10	30.00	2,865	1,658	13.64	66.79	54.42	102.1	48.9	151.0	75.5	4,832	1,567
	12.55	30.00	1,543	318	13.30	64.88	53.20	73.4	28.8	126.4	40.5	4,676	1,106
	12.50	15.00	1,995	771	13.19	65.24	53.31	78.6	29.0	138.1	55.2	4,606	1,170
		30.00	1,373	146	13.34	64.78	53.09	61.5	26.7	122.0	35.8	4,659	998
		60.00	1,223	1	13.62	64.66	52.70	50.0	17.5	118.4	33.8	4,631	893
	11.90	30.00	1,225	1	13.39	64.66	52.74	50.7	19.3	117.7	33.2	4,650	905
115	12.50	22.50	2,712	1,490	13.14	66.46	54.12	81.5	32.5	147.7	69.5	4,846	1,512
		45.00	2,392	1,169	13.18	65.77	53.69	75.1	27.4	142.4	62.0	4,762	1,383
	12.25	45.00	1,463	230	13.10	64.78	53.09	49.3	23.4	122.7	35.9	4,814	1,098
	11.90	45.00	1,234	1	13.18	64.66	52.72	43.8	11.5	118.8	32.9	4,694	943
120	12.50	30.00	3,202	1,985	13.20	67.80	55.26	94.2	41.4	146.3	71.8	5,199	1,953
		60.00	2,937	1,717	13.22	66.87	54.61	80.0	26.7	147.0	70.3	5,014	1,737
	12.05	60.00	1,625	388	12.90	64.88	53.19	55.9	13.8	126.2	39.7	4,882	1,272
	11.90	60.00	1,242	1	13.00	64.66	52.72	37.7	4.6	120.1	32.2	4,755	992

[a]Base year scenario.

Appendix F-5 (Continued)

Av. Milk Yield	Mfg.Mlk Support Price	Av. bST Cost	Cropland, Million Acres	Pasture Land Prices, $/Acre-Year						Past.L. Million Acres	Western Pasture Land	
				NE	LS	CB	AP	SE	DL		$/AUY[b]	M. AUY
100[a]	13.10	0.00	353.5	11.88	22.69	33.40	19.09	13.17	15.95	77.8	12.00	33.7
	12.50	0.00	353.6	11.88	24.64	33.21	18.95	13.05	15.87	78.1	12.00	36.2
	11.90	0.00	353.6	11.88	24.76	33.20	18.94	13.04	15.78	78.1	12.00	36.3
105	13.10	15.00	353.9	11.88	22.34	33.77	19.69	14.23	15.27	78.5	12.00	27.8
	12.80	15.00	353.6	11.88	22.69	33.29	19.12	13.25	15.87	77.9	12.00	33.2
	12.50	7.50	353.7	11.88	25.62	33.28	19.03	13.16	16.01	78.5	12.00	36.0
		15.00	353.7	11.88	25.62	33.29	19.04	13.17	16.02	78.6	12.00	36.0
		30.00	353.7	11.88	25.62	33.28	19.03	13.17	16.01	78.5	12.00	36.1
110	13.10	30.00	356.7	11.88	21.45	32.51	18.81	14.47	14.71	77.3	12.00	26.4
	12.55	30.00	353.6	11.88	22.69	33.31	19.15	13.37	15.90	78.0	12.00	32.6
	12.50	15.00	353.3	11.88	22.69	33.66	19.43	13.76	15.69	78.4	12.00	30.1
		30.00	353.7	11.88	23.82	33.07	18.95	13.25	15.68	77.9	12.00	33.6
		60.00	353.8	11.88	25.63	33.28	19.03	13.24	16.06	78.6	12.00	35.7
	11.90	30.00	353.7	11.88	25.63	33.30	19.06	13.26	16.07	78.6	12.00	35.8
115	12.50	22.50	355.4	11.88	22.33	33.84	19.77	14.74	15.51	79.0	12.00	26.9
		45.00	353.7	11.88	22.34	33.88	19.73	14.14	15.40	78.6	12.00	29.0
	12.25	45.00	353.8	11.88	24.03	33.13	19.00	13.36	15.75	78.1	12.00	33.2
	11.90	45.00	353.8	11.88	25.74	33.24	19.02	13.35	16.00	78.6	12.00	35.1
120	12.50	30.00	359.3	11.88	21.84	31.71	17.63	13.68	14.48	75.9	12.00	26.4
		60.00	356.9	11.88	22.33	33.13	19.36	14.57	15.27	78.3	12.00	26.8
	12.05	60.00	353.8	11.88	22.71	33.33	19.20	13.54	15.89	78.1	12.00	32.7
	11.90	60.00	354.0	11.88	15.85	33.29	19.05	13.42	16.07	78.8	12.00	34.0

Appendix F-6

WELFARE MEASURES: LONG-RUN BASIC SOLUTIONS WITH CLASSIFIED PRICING

Av. Milk Yield	Mfg.Mlk Support Price	Av. bST Cost	Gvt Expend.,M.$		Welf. ChangeM.$[a]		Breakdown of Gross Welf.Change M.$[a]			
			Total	Change	Gross	Net	Consmrs	Exprtrs	Stk Ops	Producrs
100[b]	13.10	0.00	2,440	--	462,030	459,590	390,325	31,856	9,369	30,480
	12.50	0.00	257	-2,183	37	2,219	37	11	30	-42
	11.90	0.00	175	-2,264	36	2,301	22	21	52	-59
105	13.10	15.00	16,792	14,352	451	-13,901	-382	-130	-63	1,026
	12.80	15.00	3,468	1,028	378	-650	316	1	77	-16
	12.50	7.50	309	-2,131	495	2,626	429	24	105	-62
		15.00	302	-2,137	413	2,551	356	22	93	-57
		30.00	289	-2,151	253	2,404	220	19	70	-56
110	13.10	30.00	23,796	21,346	1,000	-20,345	-696	-363	-165	2,225
	12.55	30.00	4,644	2,204	714	-1,490	561	13	135	5
	12.50	15.00	10,766	8,326	834	-7,492	466	-4	133	239
		30.00	2,299	-141	720	861	617	16	145	-58
		60.00	318	-2,122	432	2,554	389	26	105	-77
	11.90	30.00	257	-2,183	740	2,923	608	36	168	-72
115	12.50	22.50	20,512	18,073	1,411	-16,661	98	-218	43	1,488
		45.00	16,164	13,724	1.146	-12,578	392	-78	114	718
	12.25	45.00	3,382	942	1,024	81	889	25	202	-92
	11.90	45.00	295	-2,144	1,047	3,191	901	44	221	-119
120	12.50	30.00	27,211	24,771	2,082	-22,689	-269	-527	-85	2,963
		60.00	23,588	21,148	1,583	-19,565	-113	-334	4	2,026
	12.05	60.00	5,404	2,964	1,279	-1,684	1,057	30	246	-54
	11.90	60.00	331	-2,109	1,299	3,408	1,152	49	268	-171

Appendix F-7

DAIRY INDUSTRY DISTRIBUTION: LONG-RUN BASIC SOLUTIONS WITHOUT CLASSIFIED PRICING

			Dairy Cows, Millions										
Av. Milk Yield	Milk Support Price	Av. bST Cost	NE	LS	CB	NP	AP	SE	DL	SP	MN	PA	Total
100[a]	13.10	0.00	2.265	3.370	1.201	.154	.604	.670	.297	.497	.735	1.227	11.000
100	13.10	0.00	1.770	3.418	.970	.155	.608	.654	.299	.500	.346	1.064	9.785
105	13.10	15.00	1.707	3.301	.926	.148	.580	.626	.286	.478	.330	1.019	9.402
	12.50	15.00	1.706	3.267	.926	.148	.580	.626	.286	.478	.330	1.097	9.363
110	13.10	30.00	1.850	3.704	1.044	.141	.555	.599	.273	.457	.419	.977	10.020
	12.50	30.00	1.714	3.087	.886	.141	.555	.599	.273	.457	.316	.975	9.005
	11.90	30.00	1.711	3.055	.886	.141	.555	.599	.273	.457	.317	.973	8.968
115	13.10	45.00	2.055	4.889	1.581	.135	.531	.575	.262	.439	.561	1.787	12.815
	12.50	45.00	1.722	2.920	.850	.135	.532	.575	.262	.439	.303	.937	8.674
	11.90	45.00	1.720	2.888	.850	.135	.532	.575	.262	.439	.303	.935	8.638
120	13.10	60.00	2.069	5.598	2.379	.130	.509	.551	.251	.419	3.280	1.907	17.095
	12.50	60.00	1.779	3.137	.835	.130	.510	.552	.251	.420	.291	.901	8.806
	11.90	60.00	1.745	2.693	.835	.130	.510	.552	.251	.420	.291	.899	8.328
100[b]	13.10	0.00	1.857	3.100	1.193	.154	.604	.652	.298	.497	.460	1.071	9.886

Appendix F-8

COMMODITY MARKETS: LONG-RUN BASIC SOLUTIONS WITHOUT CLASSIFIEDC PRICING

Av. Milk Yield	Mfg.Mlk Support Price	Av. bST Cost	Milk, M.Cwt Total	Milk, M.Cwt Govt.	Raw Milk $/Cwt	Fed Beef $/Cwt	Sl. Hogs $/Cwt	Silage, M. t Total	Silage, M. t Dairy	Hay, M. t. Total	Hay, M. t. Dairy	Corn Fed, M. Bu Total	Corn Fed, M. Bu Dairy
100[a]	13.10	0.00	1,362	150	13.75	64.81	53.05	88.4	41.7	123.7	38.9	4,445	888
100	13.10	0.00	1,204	1	13.07	64.79	52.97	78.4	36.7	118.5	34.6	4,413	814
105	13.10	15.00	1,215	1	12.83	64.70	52.99	61.0	28.2	119.8	33.9	4,542	871
	12.50	15.00	1,210	1	12.83	64.77	53.98	60.3	27.8	119.7	33.8	4,544	868
110	13.10	30.00	1,357	139	12.70	64.83	53.20	62.2	25.7	122.6	35.8	4,631	994
	12.50	30.00	1,219	1	12.63	64.71	53.80	51.4	20.3	119.4	33.0	4,620	920
	11.90	39.00	1,214	1	12.63	64.69	52.98	51.2	20.0	119.3	33.0	4,619	916
115	13.10	45.00	1,842	624	12.61	64.98	53.47	78.1	34.5	128.1	43.4	4,884	1,402
	12.50	45.00	1,228	1	12.45	66.69	53.00	44.7	13.3	119.5	32.4	4,667	965
	11.90	45.00	1,223	1	12.45	64.69	52.99	44.5	13.1	119.5	32.3	4,664	962
120	13.10	60.00	2,589	1,375	12.59	65.81	54.20	78.1	29.0	140.5	60.5	5,191	1,741
	12.50	60.00	1,301	69	12.30	64.74	53.10	40.3	14.3	119.7	31.1	4,767	1,048
	11.90	60.00	1,230	1	12.30	64.72	52.98	38.3	7.1	119.0	31.4	4,664	1,010
100[b]	13.10	0.00	1,678	469	13.73	64.96	53.33	101.0	54.9	128.2	45.7	4,611	1,078
	12.50	0.00	1,216	1	13.55	64.74	52.94	82.3	36.1	118.2	35.0	4,403	817

[a]Base year scenario.

[b]Single marketing order differential in effect.

Appendix F-9 (Continued)

Av. Milk Yield	Mfg.Mlk Support Price	Av. bST Cost	Cropland, Million Acres	Pasture Land Prices, $/Acre-Year						Past.L. Million Acres	Western Pasture Land	
				NE	LS	CB	AP	SE	DL		$/AUY[b]	M. AUY
100[a]	13.10	0.00	353.5	11.88	22.69	33.40	19.09	13.17	15.95	77.8	12.00	33.7
100	13.10	0.00	353.6	11.88	22.69	33.63	19.30	13.36	16.17	78.3	12.00	35.6
105	13.10	15.00	353.8	11.88	22.86	33.57	19.25	13.35	16.13	78.3	12.00	34.7
	12.50	15.00	353.8	11.88	22.97	33.63	19.22	13.33	16.11	78.2	12.00	34.7
110	13.10	30.00	353.7	11.88	22.40	33.47	19.21	13.40	16.01	78.0	12.00	33.6
	12.50	30.00	353.9	11.88	23.57	33.37	19.12	13.31	16.09	78.2	12.00	34.8
	11.90	30.50	354.0	11.88	23.67	33.37	19.12	13.29	16.10	78.2	12.00	34.8
115	13.10	45.00	353.4	11.88	21.85	32.86	19.02	13.40	15.14	77.2	12.00	31.7
	12.50	45.00	354.0	11.88	24.08	33.30	19.09	13.38	16.03	78.3	12.00	34.7
	11.90	45.00	354.0	11.88	24.20	33.32	19.10	13.38	16.06	78.4	12.00	34.7
120	13.10	60.00	354.3	11.88	21.18	32.96	19.13	13.74	14.67	77.1	12.00	29.0
	12.50	60.00	354.0	11.88	23.52	33.34	19.15	13.50	16.04	78.3	12.00	33.8
	11.90	60.00	354.0	11.88	25.03	33.36	19.15	13.49	16.09	78.7	12.00	34.6
120[b]	13.10	0.00	353.3	11.88	22.34	32.90	18.78	13.08	15.07	77.0	12.00	32.4
	12.50	0.00	353.6	11.88	23.52	33.40	19.13	13.18	15.90	78.1	12.00	35.9

Appendix F-10

WELFARE MEASURES: LONG-RUN BASIC SOLUTIONS WITHOUT CLASSIFIED PRICING

Av. Milk Yield	Mfg.Mlk Support Price	Av. bST Cost	Gvt Expend.,M.$		Welf. ChangeM.$[a]		Breakdown of Gross Welf.Change M.$[a]			
			Total	Change	Gross	Net	Consmrs	Exprtrs	Stk Ops	Producrs
100[b]	13.10	0.00	2,440	--	462,030	459,590	390,325	31,856	9,369	30,480
100	13.10	0.00	263	-2,177	241	2,418	429	-4	-91	-92
105	13.10	15.00	312	-2,128	583	2,711	748	2	29	-138
	12.50	15.00	225	-2,215	578	2,793	727	6	-10	-144
110	13.10	30.00	2,284	-155	927	1,082	986	-2	9	-61
	12.50	30.00	266	-2,173	930	3,104	1,056	9	50	-184
	11.90	30.00	185	-2,255	926	3,181	1,037	13	69	-193
115	13.10	45.00	9,152	6,712	1,363	-5,349	1,220	-28	17	254
	12.50	45.00	305	-2,135	1,245	3,380	1,329	17	105	-206
	19.90	45.00	221	-2,219	1,239	3,458	1,305	19	123	-208
120	13.10	60.00	17,329	17,329	1,781	-15,548	895	-178	-27	1,090
	12.50	60.00	1,247	-1,192	1,492	2,684	1,514	19	148	-188
	11.90	60.00	253	12,187	1,505	3,689	1,505	26	170	-198
100[c]	13.10	0.00	6,946	4,506	158	-4,348	-109	-21	4	284
	12.50	0.00	285	-2,155	78	-2,233	80	28	79	-109

Appendix F-11

DAIRY INDUSTRY DISTRIBUTION: LONG-RUN SPECIAL SOLUTIONS

Av. Milk Yield	Milk Support Price	Av. bST Cost	Dairy Cows, Millions NE	LS	CB	NP	AP	SE	DL	SP	MN	PA	Total
RYH[a,d]	12.50	RCH[a]	2.271	1.900	1.008	.143	.556	.566	.269	.443	2.997	2.323	12.477
	12.45	RCH	2.241	1.598	.898	.143	.556	.566	.269	.443	1.483	2.544	10.743
	11.90	RCH	2.168	1.414	.898	.143	.557	.567	.269	.443	.584	1.743	8.785
RYH[e]	13.10	RCH	1.752	2.659	.902	.144	.560	.570	.271	.446	.412	2.014	9.730
	12.50	RCH	1.727	2.042	.902	.144	.560	.570	.271	.446	.412	1.689	8.763
	11.90	RCH	1.726	2.047	.902	.144	.560	.570	.271	.446	.411	1.668	8.737
100[b,d]	13.10	0.00	2.265	3.367	1.472	.154	.604	.650	.050	.497	.735	1.146	10.939
	12.50	0.00	2.195	2.726	1.213	.154	.604	.650	.051	.497	.613	1.069	9.772
105[b,d]	12.80	15.00	2.218	3.343	1.407	.147	.577	.621	.047	.474	.703	1.423	11.023
	12.50	15.00	2.205	2.376	1.337	.137	.577	.621	.047	.474	.588	1.023	9.397
110[b,d]	12.55	30.00	2.254	3.411	1.366	.141	.551	.595	.045	.454	.743	1.614	11.175
	11.90	30.00	2.249	2.133	1.351	.024	.552	.595	.045	.454	.603	.979	8.985
100[b,e]	13.10	0.00	1.773	3.462	.970	.097	.608	.654	.299	.500	.346	1.064	9.774
105[b,e]	12.50	15.00	1.717	3.361	.926	.024	.580	.626	.286	.478	.330	1.017	9.345
110[b,e]	11.90	30.00	1.712	3.157	.886	.023	.555	.599	.273	.457	.317	.973	8.953
100[c,d]	13.10	0.00	2.284	2.121	1.269	.154	.604	.650	.297	.497	.735	1.615	10.226
	12.50	0.00	2.265	2.035	1.272	.154	.604	.650	.297	.497	.733	1.264	9.770
105[c,d]	12.80	15.00	2.303	2.091	1.232	.147	.577	.621	.284	.475	.704	1.612	10.045
	12.50	15.00	2.272	1.957	1.230	.147	.577	.621	.284	.475	.703	1.137	9.403
110[c,d]	12.55	30.00	2.255	2.201	1.342	.141	.551	.595	.271	.454	1.818	1.647	11.276
	11.90	30.00	2.250	1.905	1.178	.141	.552	.595	.272	.454	.673	1.008	9.027
100[c,e]	13.10	0.00	1.834	3.049	1.144	.155	.607	.654	.299	.500	.457	1.065	9.764
105[c,e]	12.50	15.00	1.853	2.746	1.177	.148	.580	.625	.286	.478	.436	1.017	9.345
110[c,e]	11.90	30.00	1.831	2.615	1.127	.141	.554	.599	.273	.457	.389	.974	8.960

[a]RYH and RCH vary by region according to herd size distribution.

[b]Assumes commercial use of reverse osmosis.

[c]Assumes adoption of porcine somatotropin.

[d]Classified raw milk pricing in effect.

[e]Classified raw milk pricing abolished.

Appendix F-13
WELFARE MEASURES: LONG-RUN SPECIAL SOLUTIONS

Av. Milk Yield	Mfg.Mlk Support Price	Av. bST Cost	Gvt Expend.,M.$		Welf. ChangeM.$		Breakdown of Gross Welf.Change M.$			
			Total	Change	Gross	Net	Consmrs	Exprtrs	Stk Ops	Producrs
RYH[a,d]	12.50	RCH[a]	7,937	5,497	826	-4,672	455	11	142	217
	12.45	RCH	4,550	2,110	817	-1,294	568	14	156	79
	11.90	RCH	278	-2,162	863	3,025	721	41	195	-99
RYH[e]	13.10	RCH	2,333	-107	1,021	1,128	1,031	-9	11	-13
	12.50	RCH	265	-2,175	1,009	3,184	1,092	12	12	-136
	11.90	RCH	185	-2,255	1,000	3,255	1,075	16	62	-135
100[b,d]	13.10	0.00	2,368	-69	1	70	11	--	1	-11
	12.50	0.00	257	-2,183	43	2,225	52	14	32	-55
105[b,d]	12.80	15.00	3,465	1,016	380	-637	321	3	78	-22
	12.50	15.00	303	-2,137	419	2,556	380	22	95	-78
110[b,d]	12.55	30.00	4,663	2,204	718	-1,485	567	12	135	5
	11.90	30.00	257	-2,183	744	2,927	613	35	168	-72
100[b,e]	13.10	0.00	260	2,180	244	2,424	413	-3	-94	-89
105[b,e]	12.50	15.00	224	-2,216	588	2,804	745	10	-9	-158
110[b,e]	11.90	30.00	184	-2,256	928	3,183	1,045	14	69	-200
100[c,d]	13.10	0.00	1,217	1,223	272	1,495	239	39	-18	12
	12.50	0.00	251	-2,189	261	2,450	245	42	--	-26
105[c,d]	12.80	15.00	1,676	-764	661	-764	565	41	56	-1
	12.50	15.00	298	-2,142	637	2,779	564	53	65	-45
110[c,d]	12.55	30.00	2,471	2,471	991	-1,480	774	33	118	66
	11.90	30.00	255	-2,185	981	3,166	846	61	144	-69
100[c,e]	13.10	0.00	248	-2,192	478	2,670	604	15	-133	-9
105[c,e]	12.50	15.00	210	-2,230	839	3,070	892	26	-51	-28
110[c,e]	11.90	30.00	174	-2,266	1,188	3,455	1,188	34	36	-70

Appendix G-1

VALUES FOR SELECTED VARIABLES: LONG-RUN BASIC SOLUTIONS[a]

Av. Milk Yield	Mfg.Mlk Support Price	Av. bST Cost	Dairy Cows, Millions NE	LS	CB	MN	PA	Total	Av. R.M. Price	Milk Eq. to Govt.
100	13.20	0.00	2.324	3.594	1.267	3.183	1.731	14.300	13.76	603
	13.10	0.00	2.265	3.370	1.201	.735	1.227	11.000	13.75	150
	13.05	0.00	2.220	2.993	1.078	.615	1.071	10.179	13.76	42
	13.00	0.00	2.199	2.764	.996	.615	1.071	9.847	13.76	1
	12.50	0.00	2.197	2.743	.989	.613	1.069	9.813	13.76	1
	11.90	0.00	2.195	2.709	.989	.611	1.067	9.773	13.76	1
105	13.10	15	2.347	4.227	1.814	5.186	2.040	17.714	13.64	1,164
	12.80	15	2.280	3.344	1.212	.703	1.428	11.070	13.52	227
	12.75	15	2.236	2.920	1.176	.703	1.024	10.162	13.54	96
	12.70	15	2.211	2.381	1.143	.589	1.024	9.451	13.56	1
	12.50	7.5	2.210	2.382	1.143	.589	1.024	9.453	13.51	1
	12.50	15	2.210	2.371	1.142	.588	1.023	9.438	13.56	1
	12.50	30	2.211	2.348	1.140	.587	1.022	9.408	13.68	1
110	13.10	30	2.350	4.986	3.018	5.990	2.135	20.484	13.64	1,658
	13.10	60	2.248	4.419	1.984	5.758	2.051	18.463	13.69	1,397
	12.80	30	2.256	4.186	1.827	4.960	1.987	17.226	13.41	1,200
	12.55	30	2.254	3.414	1.179	.742	1.614	11.215	13.30	318
	12.50	15	2.259	3.585	1.334	3.411	1.692	14.305	13.19	771
	12.50	30	2.254	3.016	1.179	.675	.981	10.117	13.34	146
	12.50	60	2.244	1.990	1.124	.671	.978	9.015	13.62	1
	12.45	30	2.254	2.102	1.162	.628	.981	9.139	13.39	10
	12.40	15	2.258	3.126	1.181	.676	.983	10.239	13.22	160
	12.40	30	2.253	2.085	1.162	.575	.981	9.072	13.39	1
	12.40	60	2.243	1.985	1.124	.671	.978	9.008	13.62	1
	11.90	30	2.249	2.074	1.164	.563	.979	9.043	13.39	1

Appendix G-2

IMPACT OF bST ON REGIONAL RAW MILK MARKETS

Region	Base Year Solution		105% Yield Short Term Solution[a]				105% Long Term Solution[a]	
	Q	P_o	Q	P'	Change	P_1	Q	P_2
NE	281.650	14.395	295.395	14.461	.314	14.146	306.432	14.239
LS	418.453	13.003	439.340	13.100	.295	12.805	551.045	13.102
CB	138.031	13.627	144.945	13.657	.259	13.398	218.930	13.487
NP	16.701	13.696	17.522	13.297	.234	13.531	16.705	13.679
AP	66.689	14.122	69.984	12.860	1.077	13.937	66.777	13.996
SE	70.886	15.577	74.454	13.141	2.171	15.312	71.104	15.351
DL	28.144	14.947	29.545	12.782	1.991	14.773	28.144	14.946
SP	55.714	14.825	58.531	12.932	1.683	14.615	55.785	14.724
MN	98.616	13.553	103.607	13.614	.267	13.347	731.037	13.613
CA	186.746	13.303	196.113	13.402	.306	13.096	325.979	13.402

[a]Support price at $13.10; classified raw milk pricing in effect; bST cost at $15,.00.

Appendix G-4

IMPACT OF CLASS I PRICE DIFFERENTIAL REMOVAL ON REGIONAL RAW MILK MARKETS

Region	Class I Differentials Abolished[a]		Class I Differentials in Effect[b]	
	Q	P	Q	P
NE	220.093	13.250	272.864	14.315
LS	424.404	12.655	336.312	12.923
CB	111.542	13.175	113.719	13.617
NP	16.780	13.615	16.706	13.671
AP	67.099	13.430	66.695	14.115
SE	71.392	13.952	70.894	15.569
DL	28.349	14.077	28.145	14.945
SP	56.060	13.706	55.719	14.817
MN	46.406	13.083	82.009	13.539
CA	162.028	12.846	162.411	13.300

[a]Total of 9.785 million cows; milk yield at base year level; price support not binding at $13.10.

[b]Total of 9.773 million cows; milk yield at base year level; price support not binding at $11.90.

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