Analysis of Economic Incentives for Additional Dairy Processing Capacity in Pennsylvania[1]

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Executive Summary

Motivated by concerns about the adequacy of dairy processing capacity in Pennsylvania (and the Northeast more generally), we evaluated the benefits and costs of investments in additional processing capacity in Pennsylvania based on milk supplies and product demands for March and September 2016 using a detailed spatial economic model of the US dairy sector.

Our key findings are:

- Substantial incentives appear to exist for additional processing capacity in Pennsylvania –especially for other" cheese (non-American types, including Italian and specialty cheese) plants—based on their potential to reduce overall supply chain costs given 2016 milk production and dairy product demands;
- Significant economic benefits would accrue to the state because additional processing capacity would markedly increase processing of milk in Pennsylvania that is now shipped out-of-state;
- Investment in two "other" cheese (non-American types, including Italian and specialty cheese) plants processing volumes of 4 million lbs of milk per day in the State College and Reading locations would result in the largest reduction in supply chain costs, and thus indicate the strongest incentives for new processing capacity;
- Investment in these two plants could enhance the marginal value of milk for Pennsylvania dairy producers by about $28.8 million per year compared to *Baseline* scenario model outcomes, at least in the short-term. These plants would also reduce hauling costs for Pennsylvania dairy producers by an estimated $5.9 million per year compared to *Baseline* scenario outcomes;
- The combined estimated value of hauling cost savings and increased marginal milk values of $34.7 million per year compared to the *Baseline* scenario would support investment of about $433 million in new plant capacity, which is approximately equal to the amount required for construction of the two plants;

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[1] The analyses described in this document are one component of the Study to Support Growth and Competitiveness of the Pennsylvania Dairy Industry, which has been funded by the Pennsylvania Department of Agriculture and the Center for Dairy Excellence. The report can be downloaded at http://DairyMarkets.org/PA/Plant_Capacity.pdf

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- Additional benefits in terms of enhanced milk values are estimated for dairy producers in Maryland and Virginia, which may provide an incentive for their involvement as investment partners;
- In addition to the potential direct benefits to Pennsylvania dairy producers, investment in the two plants would generate additional economic activity estimated at $1.5 billion and about 1,100 full-time jobs. These multiplier effects may provide a basis for discussion of concessions with local and state government that may lower the investment and operating costs.

Background and Study Objectives

The balance between milk production and dairy processing capacity and in the Northeast has long been a topic of discussion and analysis. Particularly with the events of the last few years, when a considerable amount of farm milk has been dumped and cooperatives have been much more restrained about supporting increases in milk production on member farms, the degree to which processing capacity is adequate for current milk supplies is a key question. Although other analyses will review the historical performance of dairy processing in Pennsylvania, it is also useful to assess the degree to which spatial economic considerations suggest the potential for (or need for) modifications to dairy processing capacity in the region. Thus, the overarching objective of this study is to assess the potential for new processing capacity in Pennsylvania to reduce dairy supply chain costs, enhance farm milk values and generate a broader range of economic activity. The specific objectives include:

- Assessment of the plant types and locations that would minimize overall dairy supply chain costs if additional processing capacity were possible in Pennsylvania, and a more specific analysis of a smaller number of plants;
- Assessment of the changes in farm milk values and milk assembly costs associated with least-cost dairy supply chain configurations;
- Assessment of dairy product manufacturing volumes, dairy product value and milk uses associated with least-cost dairy supply chain configurations;
- Estimation of the economic multiplier effects of increased dairy processing in the state in terms of economic activity and employment creation.

Overview of the Analysis

For supply chains more generally, decisions about the amounts and locations of capacity are part of what is termed "distribution network design" and often are made on the basis of whether overall costs can be lowered. We apply this basic approach to assess what types and locations of dairy processing facilities in Pennsylvania are consistent with the lowest supply chain costs. To implement this analysis, we use a large-scale spatial economic model of the US dairy supply chain (the United States Dairy Sector Simulator, USDSS) that has a long history of use to address spatial economics research questions[3]. A more detailed description of the USDSS is provided in the appendix, but the basic description is that the model begins with assumptions about the locations and amounts of farm milk supplies, locations of potential processing facilities and the locations and amounts of dairy product demand (including for exports) for a given month[4] for the entire US. The model also uses information on the transportation costs for milk assembly between all possible points of farm milk supplies and (potential) dairy processing locations, dairy product processing costs and distribution costs for all possible movements of

[3] The USDSS has a twenty-year history of development, and has been used in the assessment of spatial pricing surfaces for Class I milk, impacts of dairy plant closures, assessment of the potential for and impacts of localization of dairy supply chains, and the optimal locations for new processing capacity.
[4] The model assumes fixed milk supplies (and components) and dairy product demands during the given month, which are reasonable assumptions for that time scale. The model does not include any dynamic response of production or dairy product demand over time, so it indicates incentives for supply chain re-configuration for a given point in time.

dairy products from all potential dairy processing facilities to demand locations. The USDSS uses an optimization approach to determine which supply chain configuration (milk assembly movements, processing locations and volumes, and distribution movements) minimizes the overall supply chain costs—milk assembly, product processing and product distribution from the large number of possible configurations. (This is consistent with the "Network Optimization" approach that is commonly used in supply-chain-related analyses of distribution networks.)

The USDSS can be used to assess the potential of additional plant capacity in Pennsylvania to reduce supply chain costs by comparing scenarios that limit processing to existing plant locations and capacity with the results from scenarios that allow additional plant locations. If the least-cost supply chain configuration when additional (potential) processing locations are possible includes many new plant locations processing increased volumes of farm milk, this suggests that the spatial economics supports investments in new plant capacity. That is, if new plant capacity has the potential to markedly reduce supply chain costs, this is an initial measure of whether investment in additional capacity would be financially feasible. The USDSS also indicates when reductions in the volume of production for dairy products might be appropriate based on supply chain costs.

The specific implementation of this analysis uses data for March and September 2016, for which nine milk supply points in Pennsylvania are defined (Table 1) and existing processing capacity is represented at 21 points for 13 different product types (Table 2). Demand for dairy products is specified at 13 locations in Pennsylvania, which, as for farm milk, represent the aggregation of quantities for multi-county areas. Note that although the focus in the tables and discussion is on Pennsylvania, the model includes similar data for all of the 48 continental US states, with a total of 240 farm milk supply locations, 628 potential processing locations and 334 demand locations, as well as import and export volumes and locations.

Table 1. USDSS Milk Supply Locations[a] and Production Values for Pennsylvania, March and September 2016

Milk Supply Location	March (mil lbs/mo)	September (mil lbs/mo)
Chambersburg	155.4	169.0
Greenburg	71.3	77.5
Lancaster	242.9	264.1
Lewiston	157.5	171.3
Meadville	57.7	62.7
Reading	74.1	80.6
Towanda	46.6	50.6
Tunkhannock	17.9	19.4
Wellsboro	43.8	47.6
Total	867.0	943.0

[a] Supply locations are the city used to represent multi-county supply areas. See Appendix describing the US Dairy Sector Simulator (USDSS).

Table 2. USDSS Allowable Processing Locations in Pennsylvania, Baseline Scenario*

Potential Plant Location	Fluid	Yog	GRK Yog S	Grk Yog T	NDM	ICM MIX	ICM	BUT	COT	CHE	OCH	Dry Whey	Other ECD
Allentown										X	X	X	
Altoona								X					
Carlisle		X		X	X	X	X	X	X				X
Chambersburg	X	X		X			X		X				
Erie	X												
Greenburg	X									X	X	X	
Harrisburg	X	X		X	X		X		X	X	X	X	
Johnstown	X				X	X		X		X	X	X	X
Lancaster	X	X		X	X	X	X	X	X	X	X	X	X
Lansdale	X	X		X			X		X	X	X	X	
Meadville													
New Wilmington	X	X		X			X		X	X	X	X	
Philadelphia	X	X		X			X		X	X	X	X	
Pittsburgh	X	X								X	X	X	
Reading	X	X		X	X	X	X	X	X				X
Scranton										X	X	X	
Sharon	X	X		X									
State College								X					
Towanda													
Wellsboro		X		X	X		X	X	X	X	X	X	
Williamsport	X									X	X	X	

* Actual plants and estimates of milk intakes occur at 24 Pennsylvania locations. However, those locations, volumes and product mix are assigned to the nearest city location in the model table. Products not shown because no processing is allowed in the baseline include WPC products, lactose, casein, caseinates, MPC products, ultra-filtered milk products.

We use the above information to determine the least-cost supply chain configuration for a *Baseline* scenario that uses information on existing plant locations, product types and capacities. We then examine the changes in key outcomes if <u>any</u> of 17 products[5] can be processed at <u>any</u> of the 21 possible plant locations in Pennsylvania, referred to as the *All Pennsylvania Locations* scenario. Under this scenario, any new capacity that lowers overall supply chain costs is assumed to be available without (investment) cost. The results of this analysis suggest the product types and locations that incur the largest changes in processing volumes, which were used to develop an additional scenario (*Two New Plants*) that limited additional capacity to two locations (State College and Reading) where "other" (non-American types) cheese and WPC products would be processed, assuming utilization of 4 million lbs of farm milk per day. This latter is more consistent with assessment of the potential for making actual investments in a limited number of new processing facilities in the state.

We examine the impact that additional processing capacity has on milk assembly costs, and regional milk location values (which can be thought of as location-related or market premiums), on total milk processed and product volumes in Pennsylvania, and on the value of dairy products based on prices in March and September 2016. The change in overall values is then used to estimate economic multiplier effects on overall economic activity and employment. The estimated benefits to dairy producers from reduced milk hauling costs and higher milk values can be calculated on an annualized basis and under the assumption that this value accrues to them in future years, can be used with an assumed discount rate to estimate the total value of investment in capacity that would be supported by this stream of future values—assuming that the actual processing operation breaks even (has no profits from operating sales and processing costs which is a conservative assumption).

Results

The results of our analysis suggest that there are substantial spatial economic incentives for additional dairy processing capacity in Pennsylvania based on milk production values in 2016, and that additional processing capacity would generate significant benefits to dairy producers and the state economy.

Additional processing capacity would provide economic incentives for a substantive increase in milk processed within Pennsylvania rather than shipped to other states for processing (Table 3). On an annualized basis, the increases in milk processed in Pennsylvania amount to more than 20% of the state's 2016 milk supply of 10.9 billion lbs. Milk shipped to neighboring states (especially New York and New Jersey) would be decreased in both months under both scenarios analyzed.

The additional milk processed in the state would be accompanied by changes in product volumes (Tables 4 and 5). The volume of "other" cheese (all non-American cheese types, including Italian and specialty cheeses) showed the largest increase and accounted for more than three-quarters of the overall increase of $921 million per year in value of dairy products processed in Pennsylvania for the *All Pennsylvania Locations* scenario. Other products for which additional processing capacity increased production included ice cream, whey protein

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[5] In addition to the products shown for the Baseline scenario in Table 2, this scenario allows the processing of WPC34, WPC80, lactose, and casein.

Table 3. Estimate of Change in Farm Milk Shipment Volumes from Pennsylvania Milk Supply Locations to Processing Location Destination States, March and September 2016

Scenario, Destination State for Farm Milk	March (mil lbs/mo)	September (mil lbs/mo)	Average (mil lbs/mo)	Annual (mil lbs/yr)[a]
All PA Locations				
Delaware	-8	-11	-9	-112
Florida	0	0	0	0
Maryland	-5	-7	-6	-72
New Jersey	-106	-41	-73	-882
New York	-102	-88	-95	-1,137
Pennsylvania	**242**	**169**	**205**	**2,465**
Virginia	-19	-20	-20	-238
West Virginia	-2	-2	-2	-25
Two New Plants				
Delaware	-8	-11	-9	-114
Florida	0	5	3	30
Maryland	-7	-18	-12	-145
New Jersey	-109	-51	-80	-960
New York	-74	-61	-67	-807
Pennsylvania	**218**	**161**	**190**	**2,274**
Virginia	-19	-25	-22	-266
West Virginia	-2	0	-1	-12

[a] Calculated as the average of March and September values times 12.

concentrates, lactose, and Greek yogurt. The analyses of both scenarios suggest that fluid milk processing in the state would be decreased under the optimal supply chain configuration if new processing capacity were available. Together, the results of the *All Pennsylvania Locations* scenario suggest that the incentives for increased processing capacity are strongest for “other” cheese types, perhaps in association with a facility processing whey into WPC products. The USDSS also indicates the specific plant locations that minimize supply chain costs, and the largest “other” cheese plants were indicated for the State College and Reading locations, respectively. These locations were chosen for the Two New Plants scenario with a total processing capacity equal to the overall increase in “other” cheese production indicated by the *All Pennsylvania Locations* scenario.

The overall utilization of farm milk produced in Pennsylvania would also be different under the scenarios with additional processing capacity (Table 6). Although the total farm milk used is the same by definition, there would be increases in milk used in cheese and yogurt, and reductions in milk used in fluid.

Table 4. Changes in Dairy Product Manufacturing Volumes and Values in Pennsylvania With *All PA Locations* Scenario, March and September 2016.

Product	Change in Volume					Change in Value		
	March, mil lbs/mo	September, mil lbs/mo	Average, mil lbs/mo	Annual[a], mil lbs/yr		March $/mo	September, $/mo	Annual[a], $/yr
Butter	0.8	2.2	1.5	18.4		1,627,215	4,476,581	36,622,773
American cheese	0.0	0.0	0.0	0.0		0	0	0
Cottage cheese	-4.2	-4.0	-4.1	-49.7		[b]	[b]	[b]
Dried buttermilk	0.1	0.3	0.2	2.2		64,101	232,220	1,777,929
Dry whey	-4.6	-4.8	-4.7	-56.3		-1,166,054	-1,556,000	-16,332,324
Lactose	9.0	6.1	7.5	90.4		2,040,782	1,963,360	24,024,855
Other ECD	2.7	0.7	1.7	20.2		3,465,012	907,066	26,232,464
Fluid	-16.8	-13.3	-15.1	-180.6		-2,773,054	-2,650,011	-32,538,389
Greek yogurt, strained	3.1	4.4	3.7	44.5		3,924,434	6,652,260	63,460,169
Greek yogurt, thickened	0.3	0.3	0.3	3.6		33,879	59,522	560,404
Ice Cream	14.1	10.7	12.4	148.6		3,981,653	2,908,198	41,339,102
NDM	-2.8	-2.1	-2.5	-29.5		-2,185,151	-1,941,890	-24,762,246
Other Cheese	31.7	23.4	27.6	331.1		67,684,437	54,145,575	730,980,068
WPC34	0.7	2.9	1.8	21.3		381,433	2,120,934	15,014,202
WPC80	6.7	0.0	3.3	40.0		9,176,762	0	55,060,573
Yogurt (non-Greek)	0.0	0.0	0.0	0.0		0	0	0
Total						86,255,449	67,317,815	921,439,581

Note: Values based on product prices for March and September from various sources.

[a] Calculated as the average of March and September values times 12.

[b] Value for cottage cheese not calculated

Table 5. Changes in Dairy Product Manufacturing Volumes and Values in Pennsylvania With *Two New Plants* Scenario, March and September 2016.

Product	Change in Volume					Change in Value		
	March, mil lbs/mo	September, mil lbs/mo	Average, mil lbs/mo	Annual[a], mil lbs/yr		March $/mo	September, $/mo	Annual[a], $/yr
Butter	-3.5	-2.4	-3.0	-35.7		-6,880,571	-4,853,835	-70,406,435
American cheese	0.6	0.0	0.3	3.6		865,116	0	5,190,697
Cottage cheese	-4.2	-3.4	-3.8	-45.8		[b]	[b]	[b]
Dried buttermilk	0.0	0.0	0.0	0.0		0	0	0
Dry whey	-1.4	-1.7	-1.5	-18.3		-352,461	-536,087	-5,331,285
Lactose	0.0	0.0	0.0	0.0		0	0	0
Other ECD	2.2	0.1	1.1	13.7		2,872,394	74,374	17,680,606
Fluid	-18.6	-12.6	-15.6	-187.7		-3,083,633	-2,511,264	-33,569,386
Greek yogurt, strained	0.0	0.0	0.0	0.0		0	0	0
Greek yogurt, thickened	-0.2	-0.1	-0.1	-1.4		11,496	2,547	84,263
Ice Cream	5.3	3.6	4.5	53.5		1,492,136	988,489	14,883,749
NDM	-0.6	-1.9	-1.3	-15.2		-488,536	-1,753,136	-13,450,031
Other Cheese	27.5	21.6	24.6	294.6		58,708,280	49,845,728	651,324,046
WPC34	0.1	1.3	0.7	8.3		57,057	937,962	5,970,114
WPC80	3.3	0.0	1.7	19.9		4,568,966	0	27,413,797
Yogurt (non-Greek)	0.0	0.0	0.0	0.0		0	0	0
Total						57,770,245	42,194,778	599,790,136

Note: Values based on product prices for March and September from various sources.

[a] Calculated as the average of March and September values times 12.

[b] Value for cottage cheese not calculated

Table 6. Estimated Change in Product Uses of Pennsylvania Milk for *All Pennsylvania Locations* and *Two New Plants Scenarios*, March and September 2016

Scenario, Product for Which Milk Used	March (mil lbs/mo)	September (mil lbs/mo)		March (% of Base)	September (% of Base)
All PA Locations					
American cheese	0.0	0.0		0.0%	0.0%
Cottage cheese	-26.7	-25.6		-100.0%	-100.0%
Fluid	-191.0	-130.0		-33.6%	-23.7%
Greek yogurt, strained	9.1	12.8		[a]	[a]
Greek yogurt, thickened	-0.4	0.3		-17.1%	9.8%
NDM	-6.8	0.0		-5.1%	0.0%
Other Cheese	200.9	142.6		130.6%	111.1%
Yogurt	15.0	0.0		91.6%	0.0%
Two New Plants					
American cheese	6.1	0.0		12.9%	0.0%
Cottage cheese	-26.7	-21.5		-100.0%	-83.9%
Fluid	-168.4	-120.4		-29.6%	-21.9%
Greek yogurt, strained	0.0	0.0		[a]	[a]
Greek yogurt, thickened	-0.7	-0.1		-32.0%	-2.6%
NDM	-6.8	-3.9		-5.1%	-2.9%
Other Cheese	180.9	141.6		117.6%	110.3%
Yogurt	15.7	4.2		95.6%	13.4%

[a] Percentage change from Baseline not calculated because use is 0 in that scenario.

Economic Benefits of Additional Processing Capacity

From the perspective of dairy producers in Pennsylvania, the benefits of additional processing capacity include reductions in hauling costs and increases in milk location values (market premiums). These benefits can be assessed by location (Table 7), but are positive for all Pennsylvania supply locations and total $35 million per year for the *Two New Plants* scenario and $48 million per year for the *All Pennsylvania Locations*. Hauling costs would be reduced by an average of $0.05/cwt for all Pennsylvania milk for the *Two New Plants* scenario and milk location values increased a statewide average of $0.26/cwt to $0.29/cwt—with some variation by location. As noted previously, the total benefits per year—if assumed to continue into the future—can be used to develop a rough estimate of the total investment that this stream of benefits would support, assuming an annual percentage return. Assuming an 8% rate of return and breakeven (no profits accruing from production and sale of products), annualized benefits of $35 million and $48 million would support investments of $433 million and $598 million, respectively, which compare favorably to plant construction costs under the *Two New Plants* scenario. This initial assessment of financial feasibility suggests that further consideration of specific investment scenarios is merited based on the benefits accruing to Pennsylvania dairy farms.

Table 7. Estimate of Net Benefits of Additional Processing Capacity, All Pennsylvania Locations and Two New Plant Scenarios, 2016

Scenario, Location	Change in Milk Value, $/cwt		Change in Milk Value, $/month		Change in Milk Value, $/year
	March	September	March	September	Annual[a]
All PA Locations					
Chambersburg	0.44	0.34	675,860	534,013	7,259,233
Greenburg	0.44	0.33	315,726	238,435	3,324,968
Lancaster	0.43	0.35	1,034,541	854,441	11,333,891
Lewiston	0.47	0.37	746,692	591,095	8,026,722
Meadville	0.36	0.26	209,306	150,687	2,159,956
Reading	0.37	0.29	273,540	218,605	2,952,868
Towanda	0.36	0.30	166,219	139,670	1,835,334
Tunkhannock	0.34	0.26	61,438	47,583	654,128
Wellsboro	0.30	0.25	130,902	110,406	1,447,851
Total			3,614,224	2,884,934	38,994,950
Assembly Cost Reduction			-791,488	-682,026	-8,841,088
Total Benefit			4,405,712	3,566,961	47,836,038
Two New Plants					
Chambersburg	0.37	0.34	570,208	538,752	6,653,762
Greenburg	0.17	0.05	117,596	34,062	909,946
Lancaster	0.36	0.34	883,974	849,502	10,400,855
Lewiston	0.41	0.38	637,997	602,308	7,441,827
Meadville	0.05	0.00	29,983	1,173	186,935
Reading	0.27	0.23	202,375	171,869	2,245,461
Towanda	0.07	0.07	30,730	33,615	386,070
Tunkhannock	0.12	0.10	21,789	17,435	235,345
Wellsboro	0.09	0.03	41,591	12,910	327,009
Total			2,536,242	2,261,627	28,787,210
Assembly Cost Reduction			-564,661	-413,129	-5,866,739
Total Benefit			3,100,903	2,674,755	34,653,949

[a] Calculated as the average of March and September values times 12.

However, farms in a broader area of the mid-Atlantic states (especially in Maryland and Virginia) would be predicted to experience substantive increases in milk premiums if additional processing capacity were available in Pennsylvania (Figures 1 and 2) under the *Two New Plants* scenario. Producers in these two states would also benefit from reductions in hauling costs (particularly producers in Virginia) although the overall savings are smaller than those in Pennsylvania. These results suggest that investments in additional processing capacity in Pennsylvania would provide benefits to producers outside that state that may provide an additional motivation for investment by entities whose operations encompass a wider geographical area.

In addition to the benefits accruing to dairy producers from additional processing capacity, it is possible to estimate the impacts on economic activity and employment from increases in dairy processing in Pennsylvania. The estimated change in the value of dairy products produced in the state with additional processing capacity was $599 million for the *Two New Plants* scenario and $921 million for the *All Pennsylvania Locations* scenario. Using an approximate (but conservative) multiplier of 2.5 dollars of additional economic activity for each additional dollar generated by dairy processing[6], this suggests that overall economic activity generated by dairy processing would be $1.5 billion and $2.3 billion for the two scenarios, respectively. Previous studies have estimated that every additional $1 million in processing activity can generate 1.8 full-time equivalent positions (in dairy processing and other industries), which in this case suggests that between about 1,100 and 1,700 new jobs would be created under the increased processing volumes for the *Two New Plants* and *All Pennsylvania Locations* scenarios.

Implications and Limitations

Although the foregoing analyses suggest that substantive benefits can accrue to dairy farmers, the overall dairy supply chain and the state's economy if additional processing capacity were available in the state, there are a number of important considerations and limitations that merit mention.

First, of the two scenarios described, the *All Pennsylvania Locations* is overly optimistic in the sense of allowing a wide range of processing capacity investments to occur with no cost. It does, however, provide a useful indicator of what products and location would most reduce supply chain costs—thus providing the basis for the *Two New Plants* scenario—and suggests a benchmark for the largest possible benefits from supply chain reconfiguration of a single state. However, the results of the *Two New Plants* scenario should be considered suggestive, rather than definitive. The results of our analysis suggest sufficiently large benefits to merit further, more detailed evaluation the construction of new dairy plants in Pennsylvania. In addition to more specific detail based on the actual hauling costs for Pennsylvania dairy producers, next steps would include: 1) further assessment of the specific plant locations, 2) examination of the sales potential of the proposed products from "other" cheese and WPC plants, 3) greater refinement of the costs of constructing these plants, 4) exploration of potential investors in and

[6] A more specific analysis of the multipliers for dairy farming and dairy processing activity in Pennsylvania are currently in progress, and will provide more accurate assessments of the multiplier effects discussed here.

concessions for building the plants, 5) ownership structure of the facilities and 6) plant management.

Second, our analyses report supply chain configurations that minimize relevant costs, which captures a large component of the incentives for location of dairy processing facilities relative to milk supplies and dairy product demands. However, other institutional factors, such as ongoing supply relationships between dairy cooperatives and milk buyers, incentives due to service charges to serve fluid markets and pooling under milk marketing orders, can have a notable influence on the incentives for milk movements and new processing capacity.

Third, our analyses suggest that additional processing capacity in Pennsylvania is most likely to reduce supply chain costs if it focuses on "other" cheese. This would imply that more milk would be used in Class III, but much of that milk would have been used in fluid processing under the *Baseline* scenario. Although most Pennsylvania milk would continue to be pooled under the Northeast Federal Milk Marketing Order and the overall utilization in the Northeast similar under the different scenarios, our analyses do not include effects on service payments, other over-order premiums from fluid use, or potential effects on regional blend prices.

Fourth, our analyses focus on the effects of larger-scale dairy processing investments in commodity products with large economies of scale under the *Two New Plants* scenario, but the *All Pennsylvania Locations* analysis also suggests that there may be a role for smaller-scale investments in a broader range of products, especially "other" cheese (specialty cheese), ice cream and Greek yogurt, that might be branded products.

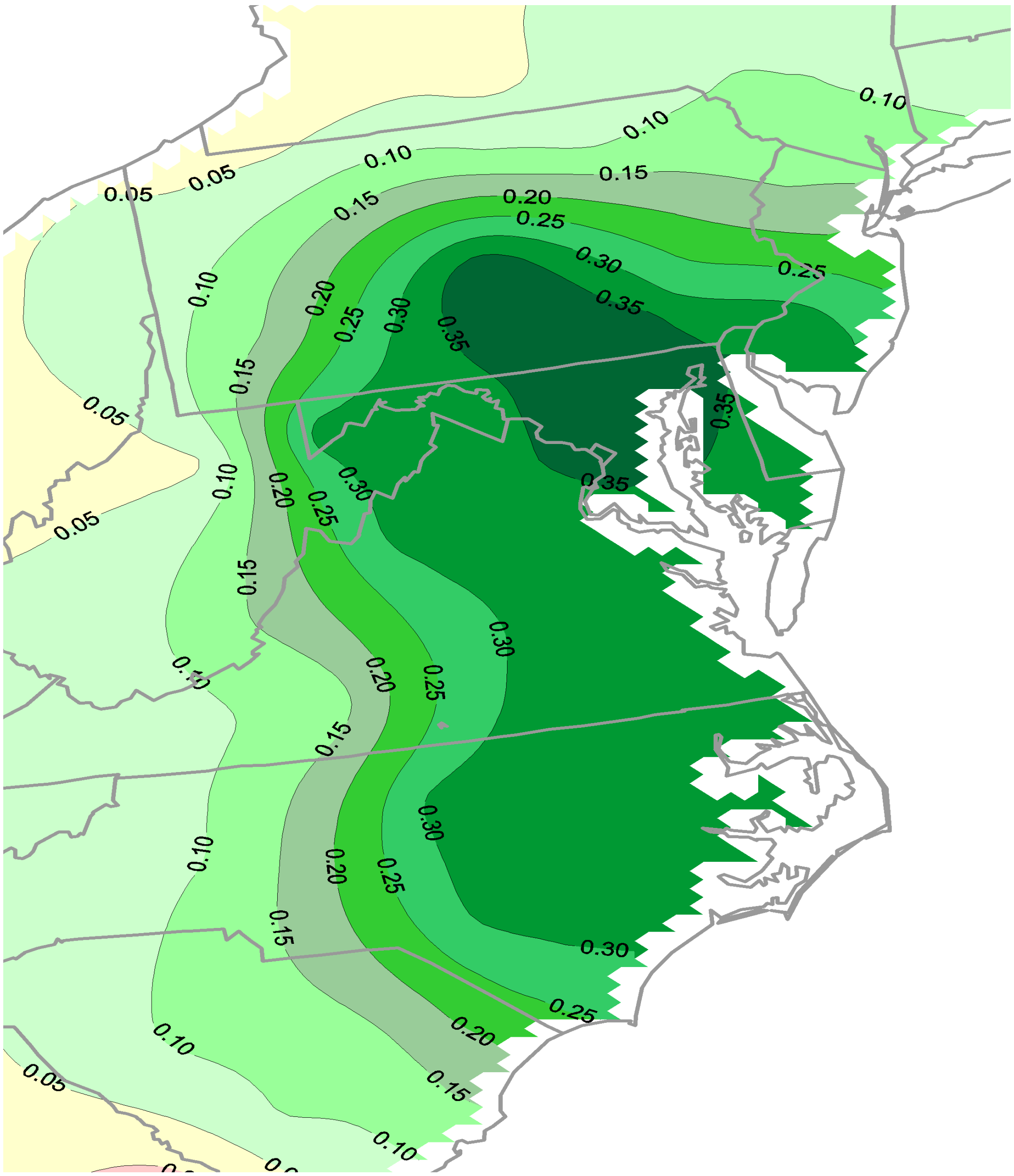

Figure 1. Impact of Two New Plants Scenario on Milk Values at Supply Locations in the Mid-Atlantic Region of *Two New Plants* Scenario, March 2016

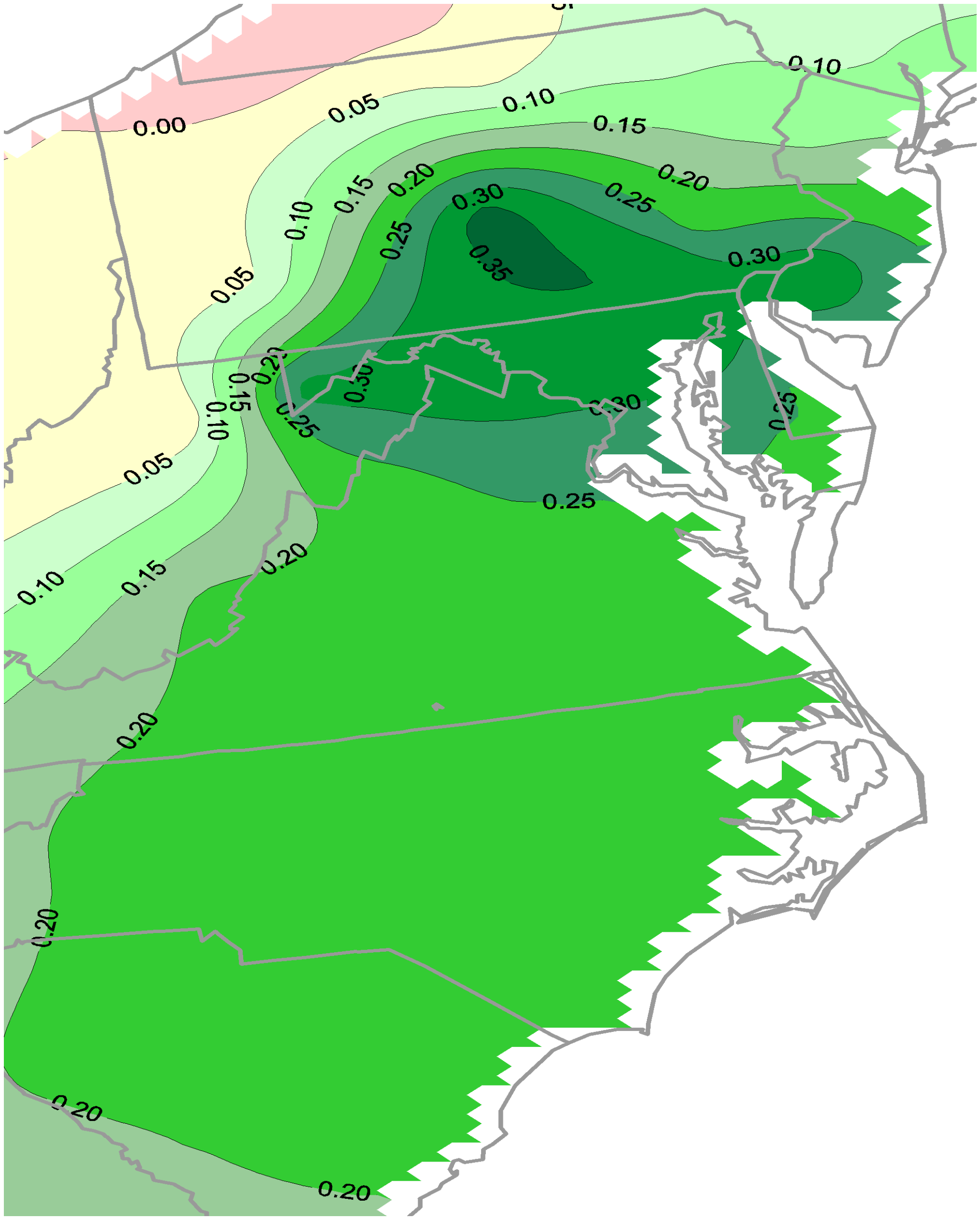

Figure 2. Impact of Two New Plants Scenario on Milk Values at Supply Locations in the Mid-Atlantic Region of *Two New Plants* Scenario, September 2016

APPENDIX: Description of the U.S. Dairy Sector Simulator (USDSS)

The USDSS is a highly detailed mathematical spatial optimization model, but at its core solves a fairly practical problem: how to get milk from dairy farms to plants to be processed into various dairy products and distribute those products to consumers in the most efficient way (lowest cost) possible. The model takes the total milk supply, plant locations and product mix, and product demand as it existed for an individual month. It indicates how to move that farm milk to plants via the existing road network, process milk into final and intermediate products and distribute the finished products to consumers also according to the road network.

The Milk Supply Data

Data needs for the USDSS are significant. These data include the amounts and composition of farm milk and dairy products consumed, disaggregated by regions in the U.S. and also accounting for imports and exports. To represent the U.S. milk supply, where possible we use county estimates of milk production and composition. California and Wisconsin are states where those values are available. Where those data are not available, we use state values and estimate county-level milk production from Agricultural Census and Federal Milk Marketing Order (FMMO) data. We aggregate the data from the 3108 counties in the contiguous 48 states into 231 milk supply regions (Figure A1) to reduce the computational intensity of solving such a spatially disaggregated model.

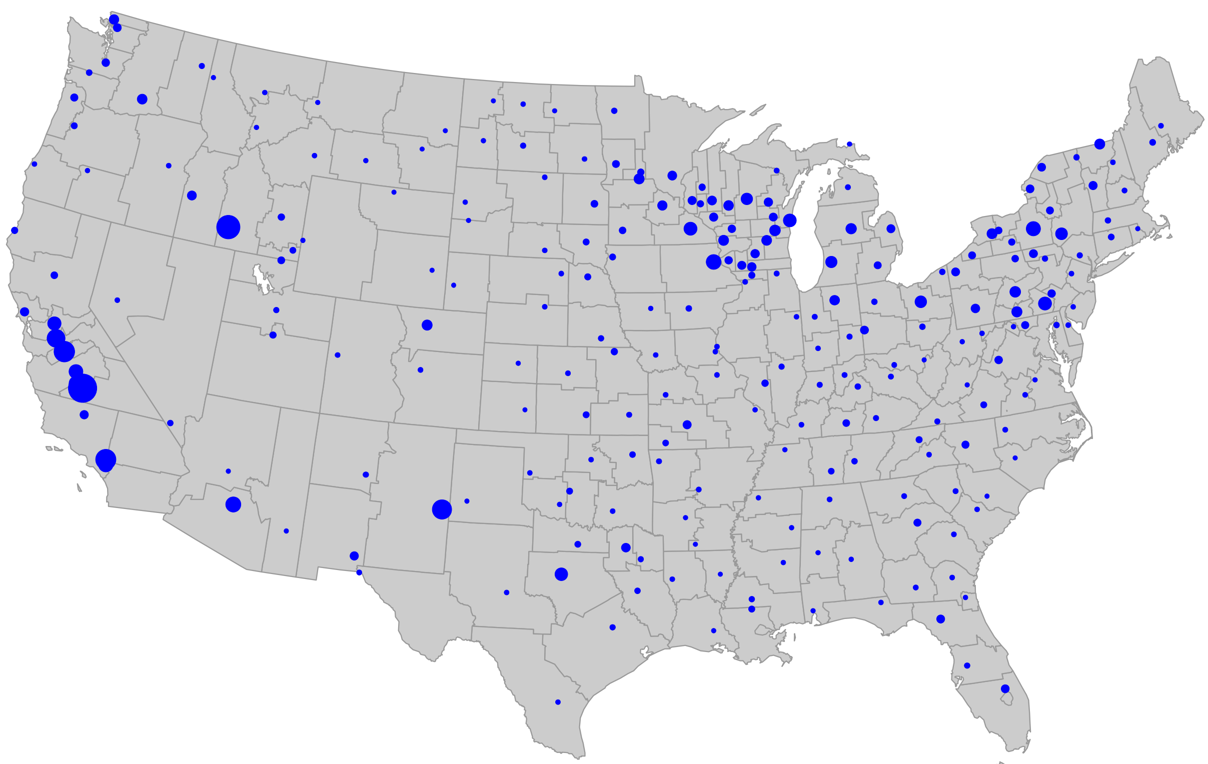

Figure A1. 240 U.S. Milk Supply Locations in the USDSS.

Dairy Product Demand Data

The USDSS model is comprehensive: it includes all sources and uses of milk and dairy components in the U.S. The current structure includes 19 final and 18 intermediate product categories. Intermediate products are those like cream, condensed skim milk, nonfat dry milk, etc., which can be used in the further manufacture of other dairy products such as cheese or ice cream. The final products are products such as fluid milk, yogurt, cheese, etc., which satisfy domestic consumption (by individuals, food service and other food manufacturers) or export sales. All dairy products have different component requirements and some product component values differ by region. For instance, California's lower fat fluid milk is fortified with skim milk solids as per the state regulation.

A variety of data sources are used to determine per capita demand for dairy products. For example, the Economic Research Service (ERS) reports calculations for some dairy product demands[7] and other values are determined from route dispositions of FMMOs. County-level demands are then calculated based on per capita demand and population and then aggregated to 424 demand locations (Figure A2).

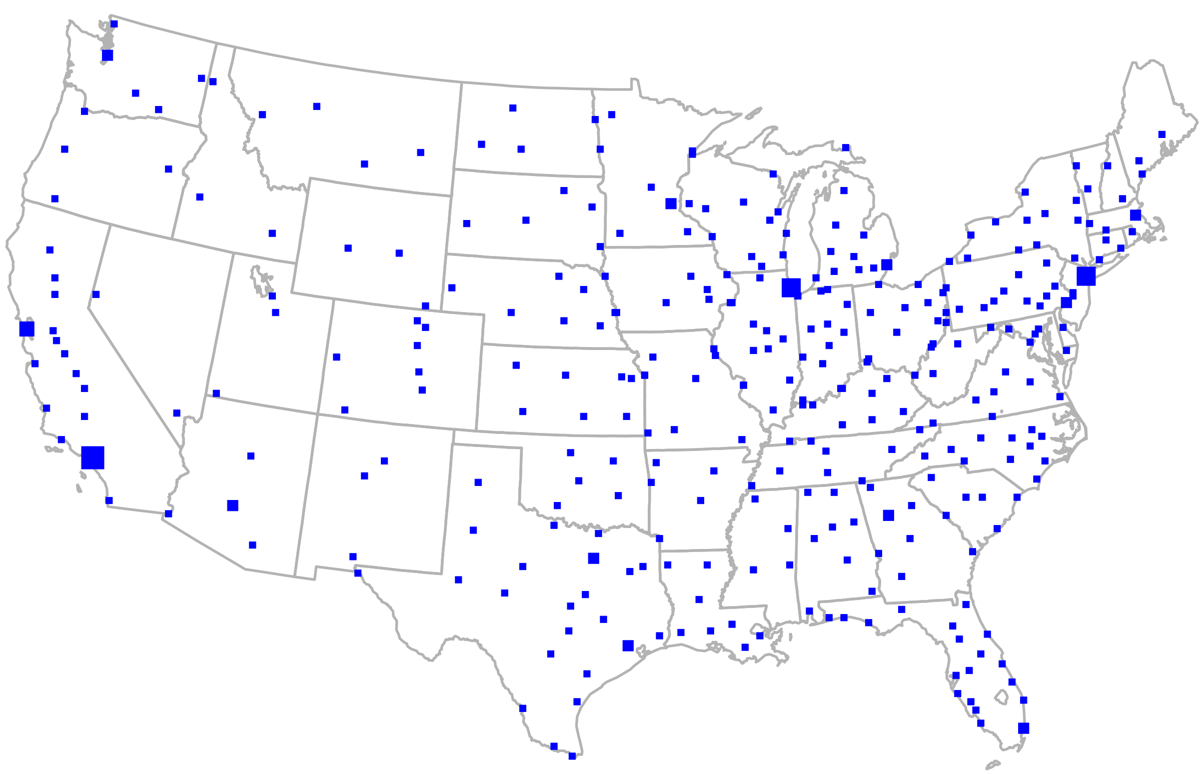

Figure A2. 424 U.S. Milk Demand Locations in the USDSS.

[7] https://www.ers.usda.gov/webdocs/DataFiles/48685/CmDsProd.xlsx?v=42866

Dairy Plants Data

We maintain a fairly extensive database that includes 1167 dairy plant locations and products processed in the U.S. Of these plants, we have estimates of processing volume for more than 500 of the most significant plants, which account for more than 95% of the US milk supply. As with the aggregation of milk supply and demand locations, dairy plants could be represented at up to 628 possible locations (Figure A3) but actually are represented at 281 locations in the USDSS. Although there are more plants than this in the U.S., we use a single location to represent a multiple processing entities if they are not actually geographically distant from one another (most USDSS plant locations are within 30 miles of the actual plants). Plants are constrained to process only the products that are produced at any location (i.e., a fluid milk plant location cannot process cheese).

The USDSS tracks and accounts for multiple components in products. For example, a fluid milk plant that has excess butterfat can send cream to a churn, ice cream plant or other manufacturing facility with need of the cream. Of course, sending cream from a fluid plant also sends nonfat solids to the receiving plant requiring somewhat more raw milk than is necessary to meet only fluid needs.

Figure A3. 628 Possible U.S. Dairy Plant Locations in the USDSS.

Imports, Exports and Stocks

USDSS uses thirty-four locations to represent export demand, based on US port district designations. Imports and exported products exactly match those reported in the months modeled. Some dairy products are storable and accounted for in the model as stocks, which can be increased or drawn upon as observed in the months modeled.

Products

The model includes 19 final and 18 intermediate product categories (Table A1). Note that some products, such as NDM, are in both categories. In our terminology, "intermediate" products refer to those dairy products that are used in the manufacture of other dairy products, such as NDM in cheese making. "Final products" are those that are sold by the dairy manufacturers to uses other than further dairy processing, regardless of whether sales are directly to consumers or to other food manufacturers or wholesalers. This is different than the terminology more typically used by economists, but is useful as a means of tracking and modeling component sources and uses in the U.S. dairy industry. Although many products are allowed as intermediate products, some combinations have been excluded to limit model size and facilitate model solution in a reasonable time. We include unit costs of processing at average plant milk processing volume based on previous data collection efforts and other secondary sources.

Coponents

For most products, component composition can be adequately modeled using three components: fat, protein and other solids. For ultra-filtered products (whey protein concentrates, ultra-filtered milk, milk protein concentrates), this disaggregation is inadequate, because product yields and compositions depend on retention of components that differs for the other solids components. Thus, for these products, six components are specified: fat, casein, whey protein, non-protein nitrogen, lactose and ash. When needed for calculations and reporting purposes, these six components are aggregated back to the three components used for most of the products incorporated into the model. The composition of products are determined by the components supplied in raw milk or intermediate products received at a particular processing plant, based on iterative solutions of the model given exogenously-specified product compositions based on the product composition determined by the previous model solution.

Transportation Costs

A road network of actual road mileage connects all of the supply, demand, plant and trade locations in the model. There are about 200,000 possible road routes connecting the 628 locations in the USDSS. States also have differing Gross Vehicle Weight (GVW) limits, which restrict the size of loads shipping raw milk or finished products that can be transferred between some states. These limits are also represented within the model. Most states have an 80,000 GVW but some states have GVWs up to 164,000. The most limiting state along a route becomes the GVW restriction in the USDSS. Being able to haul greater GVWs does reduce the cost of transporting raw milk and products.

Table A1. Product Categories Included in the USDSS Model

Product	Description	Final Product	Inter-mediate Product	IP Allowed to Make This Product	This Product Allowed as IP in	Imports or Exports
Fluid milk	Fluid milk, cream	X		Cream, skim milk		
Yogurt		X		Cream, skim milk, dry whey, WPC34, WPC80		X
Ice cream				Mix		X
Nonfat dry milk		X	X	Skim milk	Fluid[a], yogurt, American cheese, other cheese, casein, ice cream mix	X
Butter		X		Cream, whey cream		X
Dried buttermilk		X		Cream, whey cream		
Cottage cheese		X		Cream, skim milk		
American cheese		X		NDM, cream, skim milk, condensed skim, UFS42, UF56, MPC42, MPC56, MPC70, MPC80		X
Other cheese		X		NDM, cream, condensed skim, UFS42, UF56, MPC42, MPC56, MPC70, MPC80		X
Dry whey		X	X	Separated whey	Yogurt, ice cream mix	X
WPC34		X	X	Separated whey	Yogurt, ice cream mix	X
Dried whey permeate (lactose)		X	X	Separated whey	Yogurt, ice cream mix	X
WPC80		X	X	Separated whey	Yogurt, ice cream mix	X

Table A1. Product Categories Included in the USDSS Model

Product	Description	Final Product	Inter-mediate Product	IP Allowed to Make This Product	This Product Allowed as IP in	Imports or Exports
Casein		X	X	NDM	Caseinates	X
Caseinates		X		Casein		X
MPC42		X	X	UF skim milk	American cheese, other cheese	X
MPC56		X	X	UF skim milk	American cheese, other cheese	X
MPC70		X	X	UF skim milk	American cheese, other cheese	X
MPC80		X	X	UF skim milk	American cheese, other cheese	X
Other evaporated condensed and dried		X		Cream, skim milk		X
Cream			X	Raw milk	Most products	
Skim milk			X	Raw milk	Most products	
Ice cream mix			X	Cream, NDM, WPC34, WPC80, dry whey	Ice cream	
Fluid whey			X		Separated whey, whey cream	
Separated whey			X	Fluid whey		
Whey cream			X	Fluid whey		
Condensed skim milk			X	Skim milk	Ice cream mix, American cheese, other cheese	
UF skim for MPC42			X	Skim milk	American cheese, other cheese, MPC42	

Table A1. Product Categories Included in the USDSS Model

Product	Description	Final Product	Inter-mediate Product	IP Allowed to Make This Product	This Product Allowed as IP in	Imports or Exports
UF skim for MPC56			X	Skim milk	American cheese, other cheese, MPC56	
UF skim for MPC70			X	Skim milk	MPC70	
UF skim for MPC80			X	Skim milk	MPC80	

All of the 200,000 possible road routes have transportation costs calculated for raw milk assembly, inter-plant movements of bulk products (cream, skim milk, condensed skim milk, etc.), and final products, both refrigerated and non-refrigerated distribution. These transportation costs are updated to reflect changes in equipment, fuel and labor costs for 2016. There are also regional variations in fuel and labor costs reflected in the USDSS depending on the point of origin for a transportation movement. Transportation costs are an important driver of model outcomes and as for other information, are calculated for each month for which the model is used.

The Primal Solution

The model's purpose is to find the least-cost combination of assembling milk from farms to plants, processing all different final and intermediate dairy products and distributing them to meet domestic and export demand while respecting a large number of constraints imposed (Figure A4). There are about 1.6 million possible activities (milk assembly routes, processing volumes, interplant movements, and final distribution routes) that the USDSS model must evaluate to determine the least-cost solution. Constraints include such things as cheese or any other dairy product can't be made without ingredients that ultimately come from milk supplied by the farms represented in the model. Another constraint is that finished dairy products must contain the milk components and be provided in the amounts that customers in the region demand. Finally, shipments can't exceed the road weight limits of any state. There are about a half million constraints in the USDSS model.

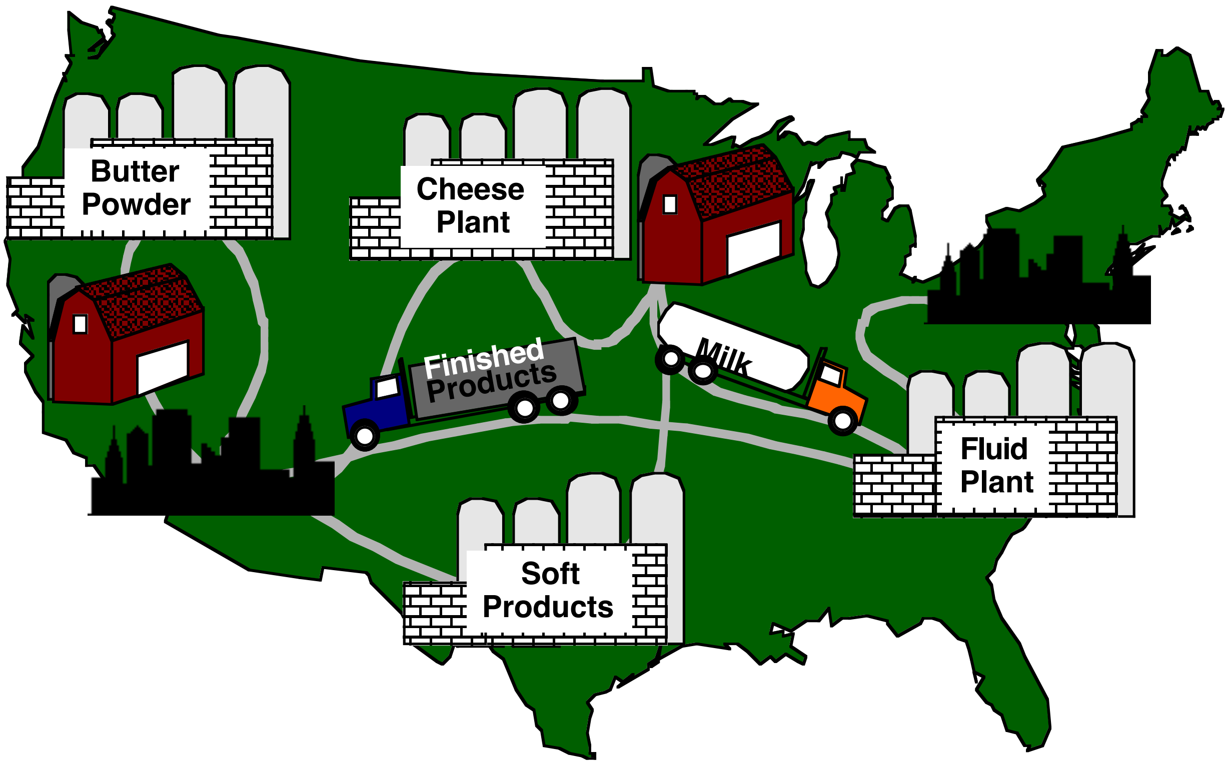

Figure A4. Conceptualized Primal Solution of the USDSS Model.

There are two types of output that come from such a model: a “primal solution” and a “dual solution”. The primal solution describes the physical flows of product through the dairy supply chain network. The dual solution represents the relative monetary values of milk and dairy products at each model location.

We have assembled data and determined solutions for the USDSS model for March and September 2016 (representative of flush and short months). An example of the primal output is shown in Figure A5. In this figure, the green lines represent milk assembly flows from farms to plants, which are represented by triangles. A triangle with no obvious green line simply represents a local milk supply. Orange squares represent demand locations and orange lines represent distribution of finished products from plants to demand locations. The yellow lines are cream shipments from fluid plants. The size of triangles, squares and the thickness of lines gives an indication of relative volume shipped or processed—larger triangles, squares and thicker lines indicate larger quantities transported or processed.

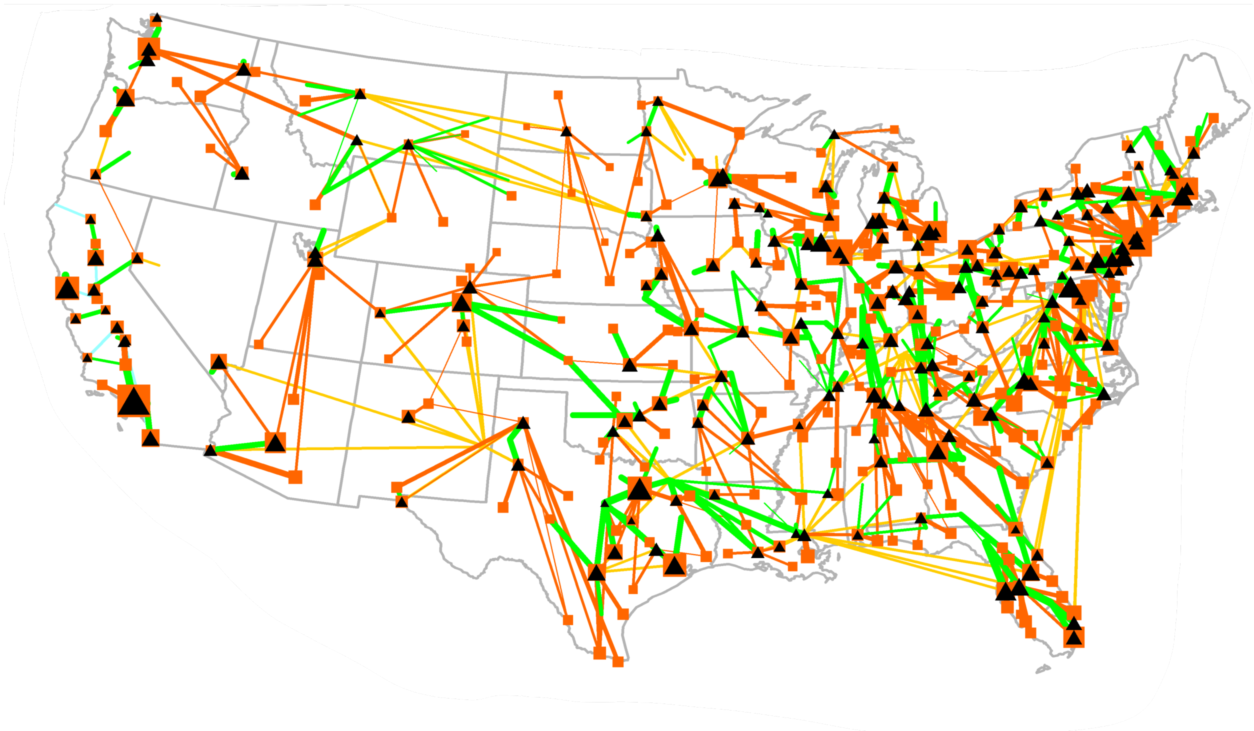

Figure A5. Milk Assembly and Packaged Milk Flows (USDSS Primal Solution), March 2016.

Figure A6 shows the primal solution of cheese plants for March 2016. Cost-minimizing solutions favor a more local milk supply and more distant distribution of finished products than is the case for fluid milk plants (Figure A5). This is an outcome that was expected from a supply chain in this type of market characterized by surplus and deficit regions of the country.

Criticism of the optimization modeling approach is that it does not exactly replicate what is seen in reality. It should be noted that by definition, modeling is a simplification of reality but it can reveal underlying insights as to what "should" happen. There will always be some institutional rigidity in a supply chain that causes milk from one cooperative to be sent to a particular bottler that the model would say is not the most efficient movement. Some of these less-than-optimal arrangements can be made at the margin, but it is like swimming in an economic current—much easier to go with the flow than against it.

Although it is difficult to fully evaluate the degree to which the USDSS model matches actual outcomes with available data, we can compare the model-generated volume of five dairy products to those produced in regions of the US based on the monthly *Dairy Products* report from the National Agricultural Statistics Service. The correlation between the model-generated regional production quantities and observed values is greater than 0.88 for all products evaluated in both months and as high at 0.99 for many products such as cheese. Previous results have been assessed by analysts familiar with milk movements in various US regions, and they indicated that spatial milk values reasonably closely matched those generated by the model. Moreover, the model results are not sensitive to changes of plus or minus 5% in demand values or estimated transportation costs. All of these suggest a high degree of confidence in the basic sensibility of the model outcomes.

Figure A6. Milk Assembly and Cheese Flows (USDSS Primal Solution), September 2016.

Primal solution information for other products during March and September 2016 is less directly relevant to understand how the USDSS model works, but they are provided in the Appendix for the interested reader.

The Dual Solution

The dual solution shows the marginal value of milk at a processing location—such as for fluid plants—or at a supply location as for raw milk. Conceptually, this can be thought of as follows. If you would ask fluid plant owners how much more they would be willing to pay for another hundredweight of milk, they would have to consider all of their options for other milk supplies and the cost of transporting that milk to their plant. And, they would have to consider the additional sales opportunities for the finished product and the cost of distribution to those locations. This value would never be more than the cost of transportation from the closest supply region and it will be minimal in some locations where there is plenty of milk or little nearby demand. These three factors: supply, demand and transportation costs become the important determinants for the relative spatial values of milk.

Dual values are calculated by the USDSS at all fluid milk plant locations across the country. A mapping software is then used to develop a continuous "price surface" by interpolating the values between the points.

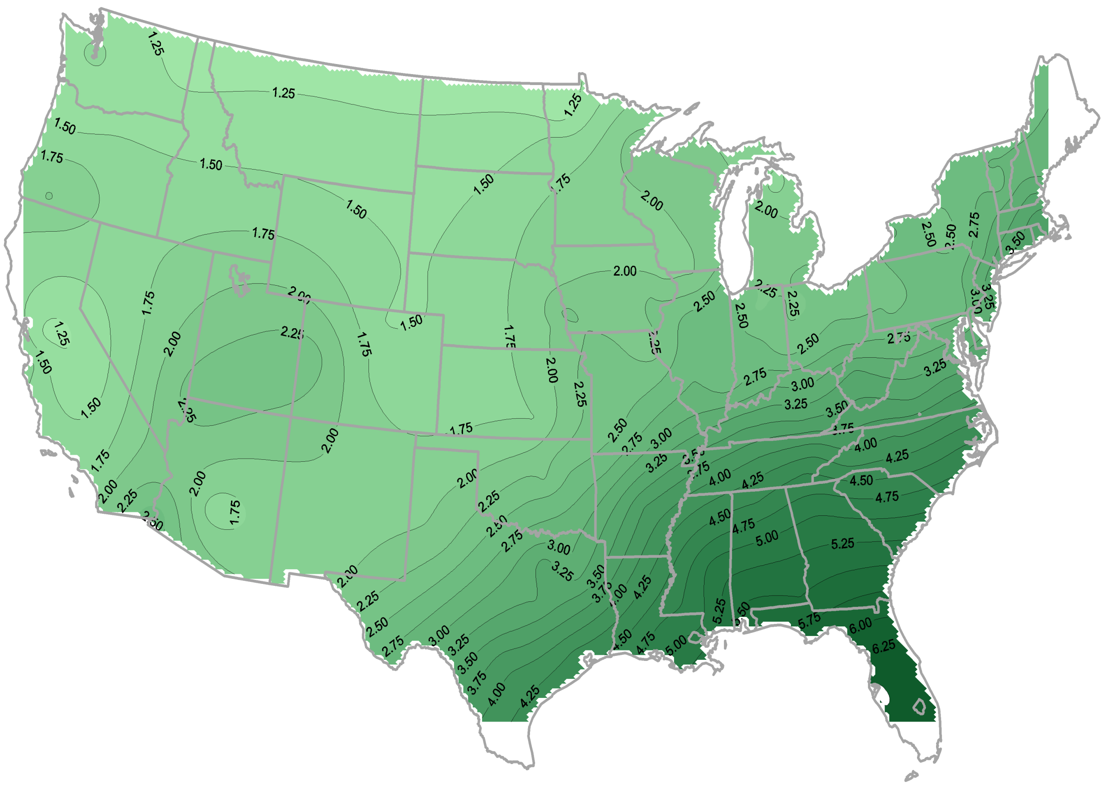

Figure A7. Marginal Value of Milk at Fluid Plants (USDSS Dual Solution), March 2011.

The values indicated in Figures A7 should not be interpreted as class I differentials. Rather, they should be thought of as "price relatives", the relative difference in values across space. For instance, the March value in most of Wisconsin is about $2.00 whereas in southern Florida the value is about $6.25, which would suggest a $4.25 price difference in class I values between these regions. In fact, a decision was made to increase the Southeast class I differentials in 2008 from a maximum of $4.30 to $6.00. The current class I differential in Wisconsin is about $1.75 which would make a $4.25 relative price difference. In this case, the model results are consistent with the federal order price difference between southern Florida and the Upper Midwest. The Agricultural Marketing Service (AMS) of the USDA has used this model in many Federal Order hearings as evidence of the need to change Class I differentials.

The dual solution for the value of raw milk is also important in our analyses. We will calculate this value to see what the impact marginal milk values of allowing an additional plant or plants in the Southeast would be.

<u>The Analytical Approach</u>

For the dairy industry as a whole, the USDSS calculates something called the "objective function". Quite literally, this is the model's estimate of the entire cost of the dairy industry as described by the model. Because we take milk supplies as a given, it does not include the cost of milk production. But, it does include the relevant costs between the farm gate and the retail store, food service buyer or food manufacturer. The model's job is to minimize this total cost without violating any of the physical constraints that we have imposed upon the system.

For dairy producers, there are two potentially important sources of benefit for the consideration of new plants in Pennsylvania. One is the reduction of milk assembly costs (getting milk from farms to a plant) and the raw milk dual value (this can be thought of as a change in the premiums paid above the Federal Order minimum prices). The final analyses considers both the cost savings and the revenue enhancement.

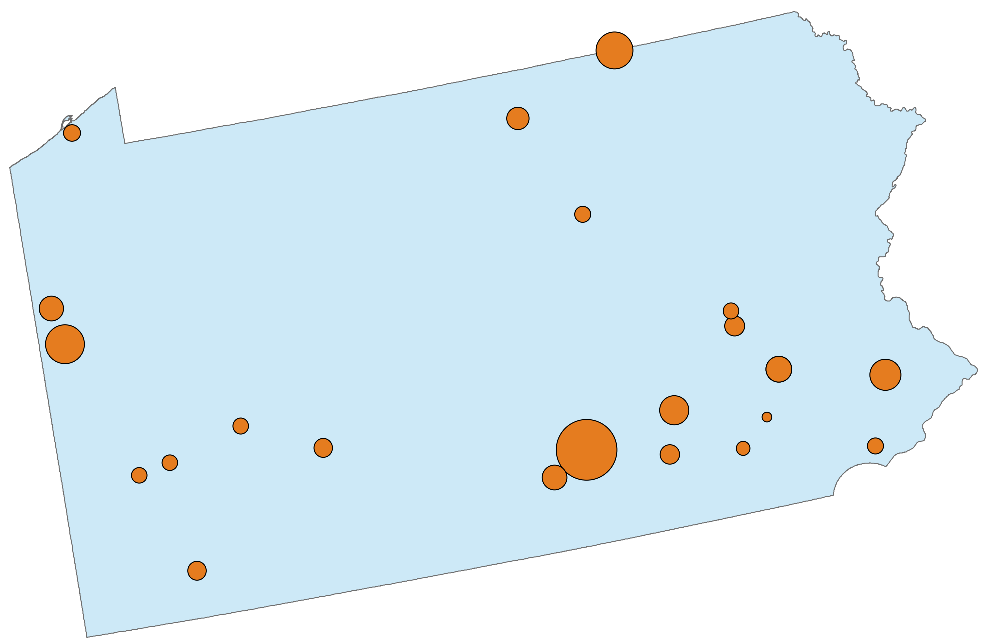

Figure A8. Location and Estimated Milk Intake of Actual PA Plants, 2016.

(Not model generated results)