Agricultural and Applied Economics
UNIVERSITY OF WISCONSIN–MADISON

Written Prepared Statement of Testimony on Spatial Values of Milk Used in Fluid Processing

presented at the

Hearing on Proposed Amendments to Marketing Agreements and Orders

Carmel, Indiana

Submitted September 15, 2023

by

Charles F. Nicholson

Associate Professor of Agricultural & Applied Economics
University of Wisconsin-Madison

Written Prepared Statement of Testimony on Spatial Values of Milk Used in Fluid Processing

Charles F. Nicholson
Departments of Animal and Dairy Science and Agricultural and Applied Economics
University of Wisconsin—Madison

1 Introduction

This statement provides a summary of the methods and findings of a recent research project that analyzed differences in the spatial values of milk in the contiguous United States, in particular the spatial differences in values at fluid milk processing plants. This is a summary of research performed in collaboration with Dr. Mark Stephenson, who recently retired as the Director of Dairy Policy Analysis at the University of Wisconsin—Madison. It does not represent an official statement of the University of Wisconsin—Madison or the Dairy Innovation Hub.

The analyses reported herein are based on spatial economic models of the U.S. dairy industry that have a long history of development beginning in the 1980s at Cornell University[1]. Earlier versions of these models have provided evidence about spatial milk values for previous Federal Milk Marketing Order hearings, notably in 1998. These models have been further refined and expanded during the past 20 years to account for changes in the product mix of the U.S. dairy industry and the location of dairy production, processing and demand. Analyses based on these models have appeared in refereed academic journal articles[2] [3] and book chapters[4]and have been used by state government and industry groups to support investment decisions[5].

Summary of Key Results

1) The economic modeling results indicate the location-specific values for a <u>competitive benchmark</u> consistent with the lowest possible systemwide costs, which also indicates the economic pressures for processing particular products at particular locations.

---

[1] Novakovic, Andrew and James Pratt. *Geographic Price Relationships Under Federal Milk Marketing Orders*. Agricultural Economics Research Bulletin 91-8, Cornell University September 1991.
[2] Nicholson, C. F., M. I. Gómez and Oliver H. Gao. 2011. The Costs of Increased Localization for a Multiple-Product Food Supply Chain: Dairy in the United States. *Food Policy*, 36:300-310.
[3] Nicholson, C. F., X. He, M. I. Gómez, H. O. Gao and E. Hill. 2015. Environmental and Economic Analysis of Regionalizing Fluid Milk Supply Chains in the Northeastern U.S. *Environmental Science and Technology*, 49:12005–12014. DOI: 10.1021/acs.est.5b02892
[4] Nicholson, C. F. and M. I. Gómez. 2022. "Market and Supply Chain Models for Analysis of Food Systems", in C. Peters and D. Thilmany (eds.), *Food Systems Modeling: Tools for Assessing Sustainability in Food and Agriculture*. Elsevier / Academic Press.
[5] Nicholson, C. F. 2023. Assessment of Milk Price Impacts and Transportation Cost Savings for an Extended Shelf Life Fluid Milk Plant in Janesville, Wisconsin. Reported submitted to the Wisconsin Department of Agriculture Trade and Consumer Protection, April 2023.

2) The analyses suggest that there are considerable differences between the values of milk at fluid plants derived from spatial economic modeling and the current values of Class I differentials, differences as large as $3.00/cwt.

3) These differences between current spatial economic values at fluid milk plants and current Class I differentials arise due to substantive changes over time in the locations of milk production, the composition of dairy product demand, changes in the locations of demand for dairy products given regional population shifts, and the costs of transporting farm milk to plants, transporting dairy products between plant locations and distributing products to final demand locations.

4) Review and adjustment of spatial values from the model for the purposes of revising Class I differentials are appropriate to account for local circumstances and institutional factors not included in the model analysis. Any quantitative model is, by definition, a simplification of reality, and the USDSS does not directly represent existing commercial relationships that can be important determinants of the locations and volumes processed in existing operations.

2 Description of the U.S. Dairy Sector Simulator

Spatial milk values are calculated using the US Dairy Sector Simulator (USDSS). The USDSS is a highly detailed mathematical spatial optimization model, but at its core solves a practical problem: how to get milk from dairy farms to plants to be processed into various dairy products and distribute those products to consumers with the lowest cost possible. The model takes the total milk supply, plant locations and product mix, and consumer demand as observed for an individual month. It indicates how to move that farm milk to plants via the existing road network and distributes the finished products to consumers also according to the road network. For the US dairy industry as a whole, the USDSS minimizes the systemwide cost of assembling milk at plants, making final and intermediate dairy products and transporting them to other plants and locations of final demand. Because the model assumes milk supplies are fixed in a given month, the model does not include the cost of milk production. However, it does include all of the principal costs between the farm gate and the retail locations for the consumer. The model minimizes this total cost subject to the physical constraints (mass balance and required product composition) that we have imposed upon the system. A highly simplified graphical representation of the model shows the key model components (Figure 1).

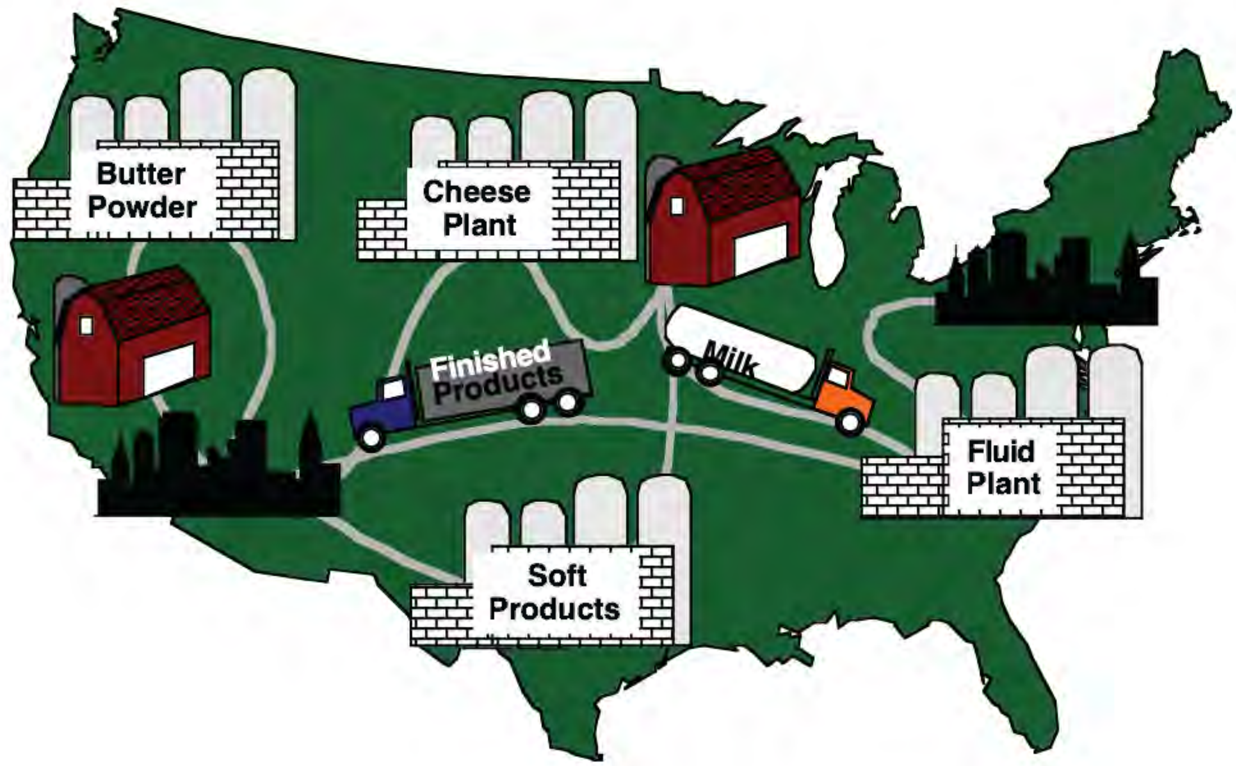

Figure 1. Simplified Conceptional Diagram of the U.S. Dairy Sector Simulator

The most recent spatial milk values derive from two versions of the USDSS model: a large version with data disaggregated at the county level (3108 counties), and a smaller version with a few hundred multi-county regions. The smaller version is useful because it is mathematically more tractable and solves in several minutes rather nearly an hour. The smaller model also allows more direct comparison with prior analyses and facilitates the representation of product flows on maps. Both the large and small models yield similar quantitative values and patterns of spatial milk prices.

2.1 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. 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. When those data are not available, we use National Agricultural Statistics Service state values and estimate county-level milk production from Agricultural Census for dairy cows by county and Federal Milk Marketing Order (FMMO) data. Data include county-level milk production as a density (estimated milk production per square mile, Figure 2). These data are used directly in the larger model version with 3108 counties but are aggregated into 231 multi-county milk supply regions for the smaller version of USDSS.

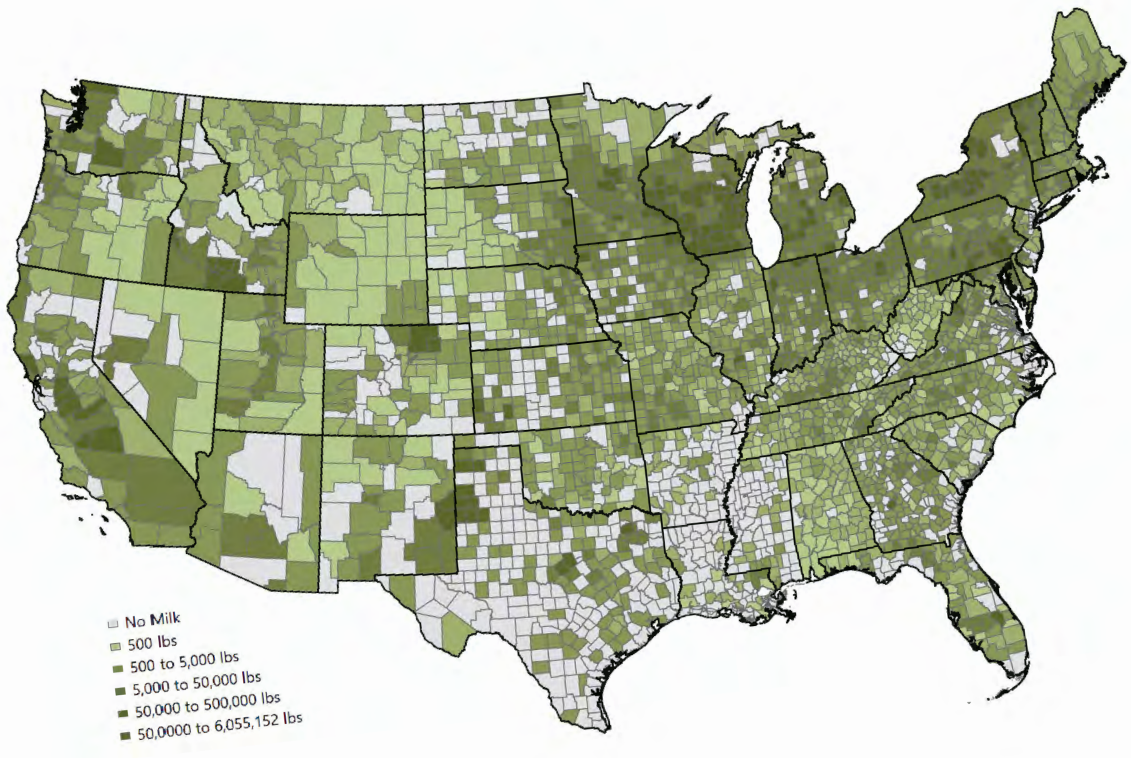

Figure 2. Estimated U.S. Milk Production per Square Mile per Month, 2021

2.2 Dairy Product Demand Data

The USDSS model is comprehensive: it includes all sources and uses of milk and dairy components in the contiguous U.S. The current structure includes 20 final and 11 intermediate-only product categories. Intermediate products are those like cream, condensed skim milk, nonfat dry milk, etc., that are 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., that satisfy domestic consumption or export sales. All dairy products have different component composition 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 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 some calculations of dairy product demand and other values are determined from route dispositions of FMMOs. County-level demands are then calculated based on per capita demand and population for each of the 3108 counties (Figure 3) or aggregated to 424 demand locations for the small USDSS model.

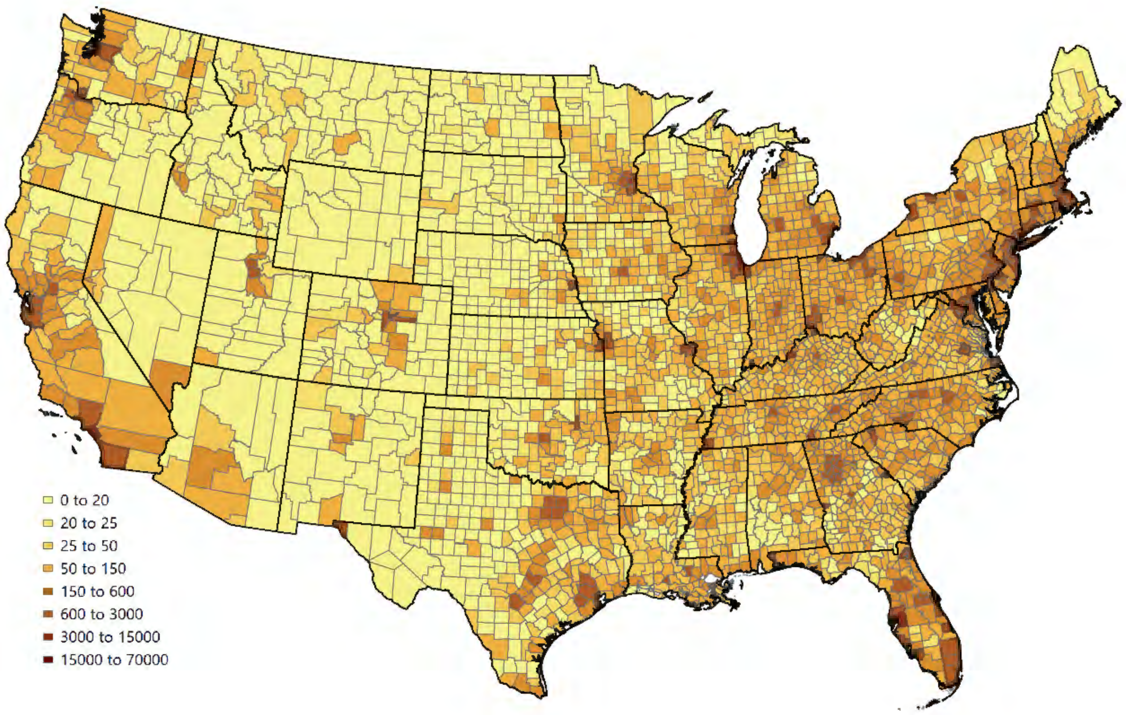

Figure 3. U.S. Population per Square Mile, 2021

2.4 Dairy Plant Data

The USDSS represents in considerable detail the locations, products and capacities of US dairy plants. Our research team has developed and maintain an 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 650 of the most significant plants. The plants are modeled within the county they are located in the large version of the model, a total of 663 locations (Figure 4). Although there are more plants than this in the U.S., we use a single location to represent multiple-processing entities within a given county. Plants are constrained to process only the products that are produced at any location (i.e., a fluid milk plant location cannot process cheese) and up to capacities expressed in terms of milk volumes per month.

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 some nonfat solids to the receiving plant requiring somewhat more raw milk than is necessary to meet only fluid needs.

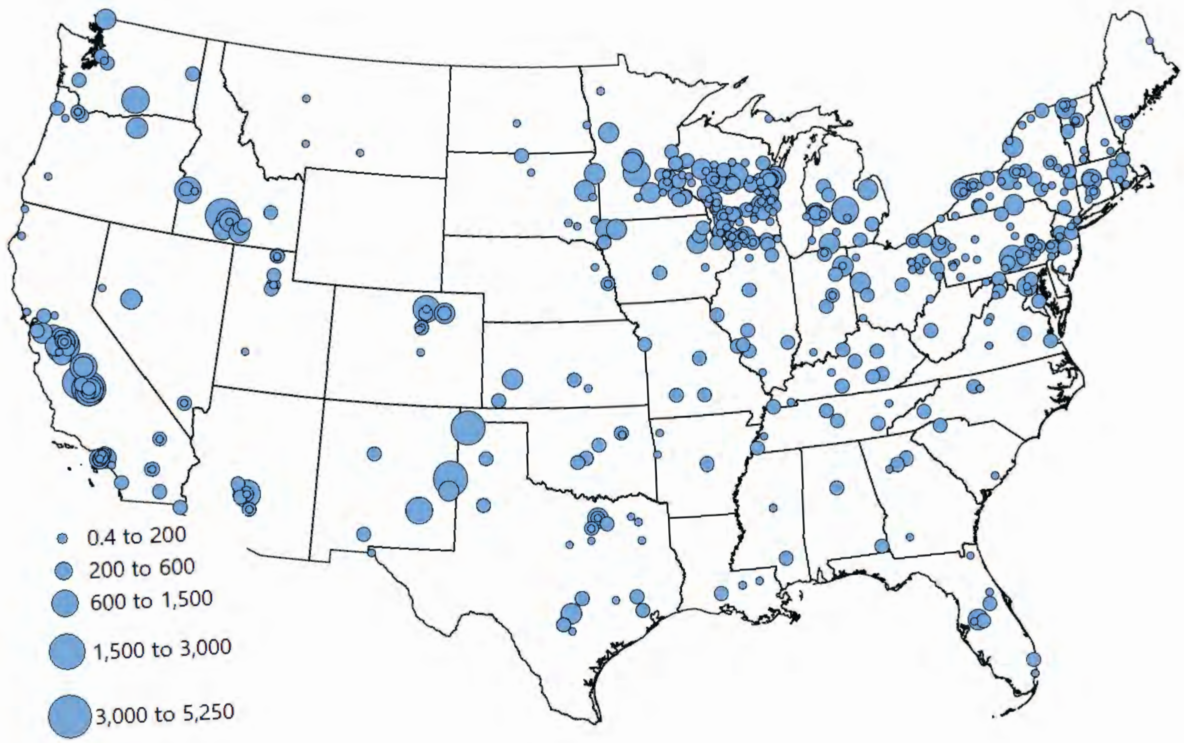

Figure 4. 663 Possible U.S. Dairy Plant Locations in the County-Level USDSS Model and Estimated Milk Processing Volumes

2.5 Imports, Exports and Stocks

USDSS uses three locations for imports, the port cities in New York, Los Angeles/Long Beach and Houston. These imports can then be transported through the U.S. road network to reach plants or consumption points. Exports of dairy products occur at 35 cities associated with Census Bureau port districts. Exported products require transportation through the U.S. road network to reach the port district cities and the quantity of exports from each port location is equal to those reported for those port districts in the months modeled. Some dairy products are storable and accounted for in the model as stocks that can be increased or drawn upon as observed in the months modeled.

2.6 Products

The USDSS includes 22 final and 21 intermediate-only product categories (Table 1). Note that some products, such as NDM, are in both categories. For USDSS analyses, “intermediate products” refer to 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 dairy manufacturers, regardless of whether sales are directly to consumers or to other food manufacturers or wholesalers.

Table 1. Product Categories Included in the USDSS Model.

Product	Final Product	Inter-mediate Product	IP Allowed to Make This Product	This Product Allowed as IP in	Imports or Exports
Fluid milk	X		Cream, skim milk		X
Yogurt	X		Cream, skim milk, dry whey, WPC34, WPC80		X
Greek Yogurt (Thickened and Strained)	X		NDM, Ultrafiltered milk, Condensed skim		
Ice cream	X		Ice cream mix		X
Nonfat dry milk	X	X	Skim milk	Fluid, 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		X
American cheese	X		NDM, cream, skim milk, condensed skim, UFS42, UF56, MPC42, MPC56, MPC70, MPC80		X

Product	Final Product	Inter-mediate Product	IP Allowed to Make This Product	This Product Allowed as IP in	Imports or Exports
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
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	X		Cream, skim milk		X

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

2.7 Components

The USDSS accounts for the mass balance of dairy components. 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 is endogenous, that is, it is determined by the components supplied in raw milk or intermediate products received at a particular processing plant.

2.8 Processing and Transportation Costs

The costs for processing both final and intermediate products are modeled as per unit product (e.g., $/lb of cheese or NDM). These per-unit costs are based on previous cost of processing studies updated to reflect 2021 cost structures.

A road network using the shortest actual road mileage connects all of the supply, demand, plant and export locations in the model. For the larger version of the USDSS, there are about 6.5 million road routes connecting all 3108 county seats. There are about 200,000 possible road routes connecting the 628 locations in the small version of 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 GWV along a route determines the cost of the route in the USDSS. Being able to haul greater GVWs reduces the cost of transporting raw milk and products.

All of the 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 based on simulated costs of product movements for farm milk, refrigerated and non-refrigerated dairy products generate by a stand-alone transportation cost simulation program, updated to reflect changes in equipment, fuel and labor costs for 2021. Regional variations in fuel and labor costs are reflected in the USDSS based on the point of origin for a transportation movement, i.e., transportation from states like California have significantly higher transportation costs than states like Texas. Transportation and processing costs are key drivers of differences in spatial milk and product values and as for other information, are calculated for each month for which the model is used.

3 USDSS Model Outputs

3.1 The Primal Solution

The objective of the USDSS is to find the least-cost combination of assembling milk from farms to plants, processing all different dairy products and distributing them to meet domestic consumer and export demand while respecting a large number of constraints imposed. There are about 6.1 million possible activities that can be chosen in the larger USDSS model. 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 consumers in the region demand. There are about 80,000 constraint equations in the larger USDSS model.

There are two types of results provided by the USDSS: 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 optimal (least-cost) solutions for the USDSS model for May and October 2021 (representative of flush and short months). An example of the primal output from the smaller USDSS model (Figure 5) shows milk assembly flows, processing locations and distribution flows to final demand locations[6]. Green lines represent milk assembly flows from farms to plants whereas orange lines represent the distribution of finished products from plants to demand locations. Plants are shown as black triangles. The size of assembly and distribution flows are represented by the relative thickness of the lines. The size of plant-location triangles indicates the relative volume of product processed at each plant.

[6] It is difficult to visualize the larger model because there are far more individual transportation lines, so the smaller model results are used to illustrate the basic idea.

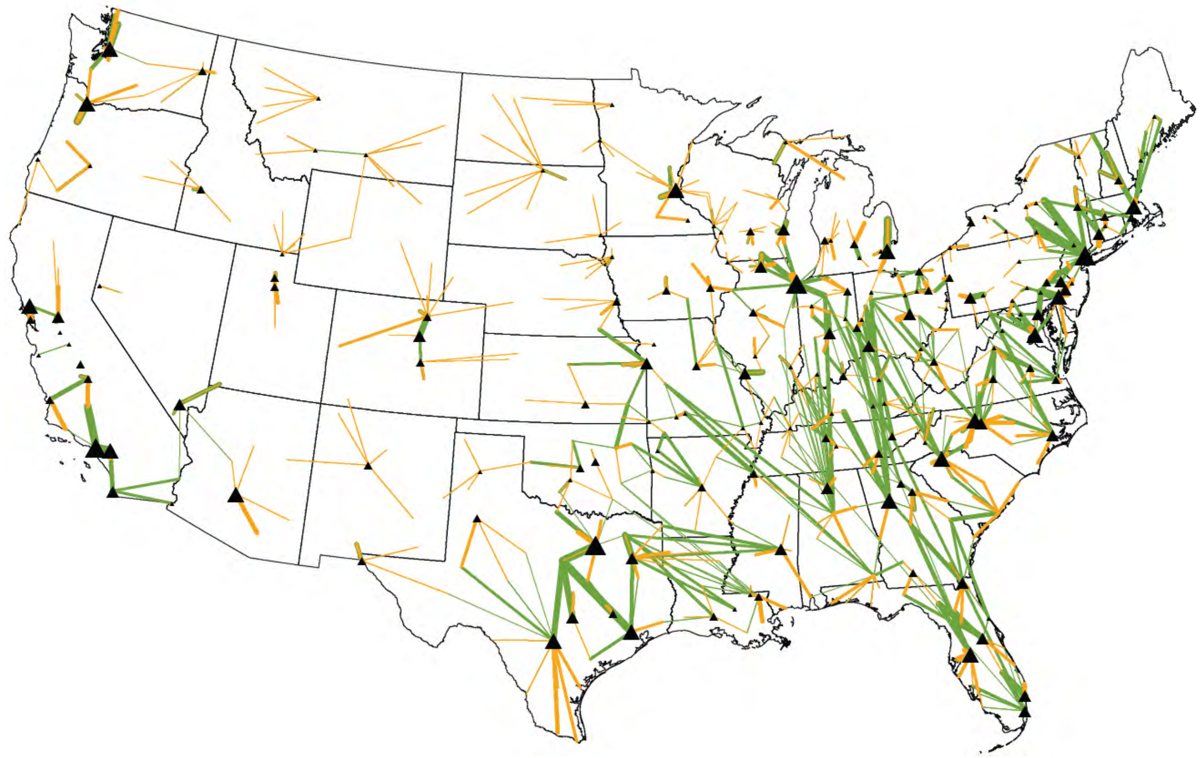

Figure 5. Milk Assembly at Fluid Plants and Packaged Milk Flows (small USDSS model), May 2021

The primal solution of cheese plants for May 2021 (Figure 6) indicates a different spatial pattern than for fluid plants. Cost-minimization in that case favors a more local milk supply and more distant distribution of finished products than is the case for fluid milk plants (Figure 5). 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.

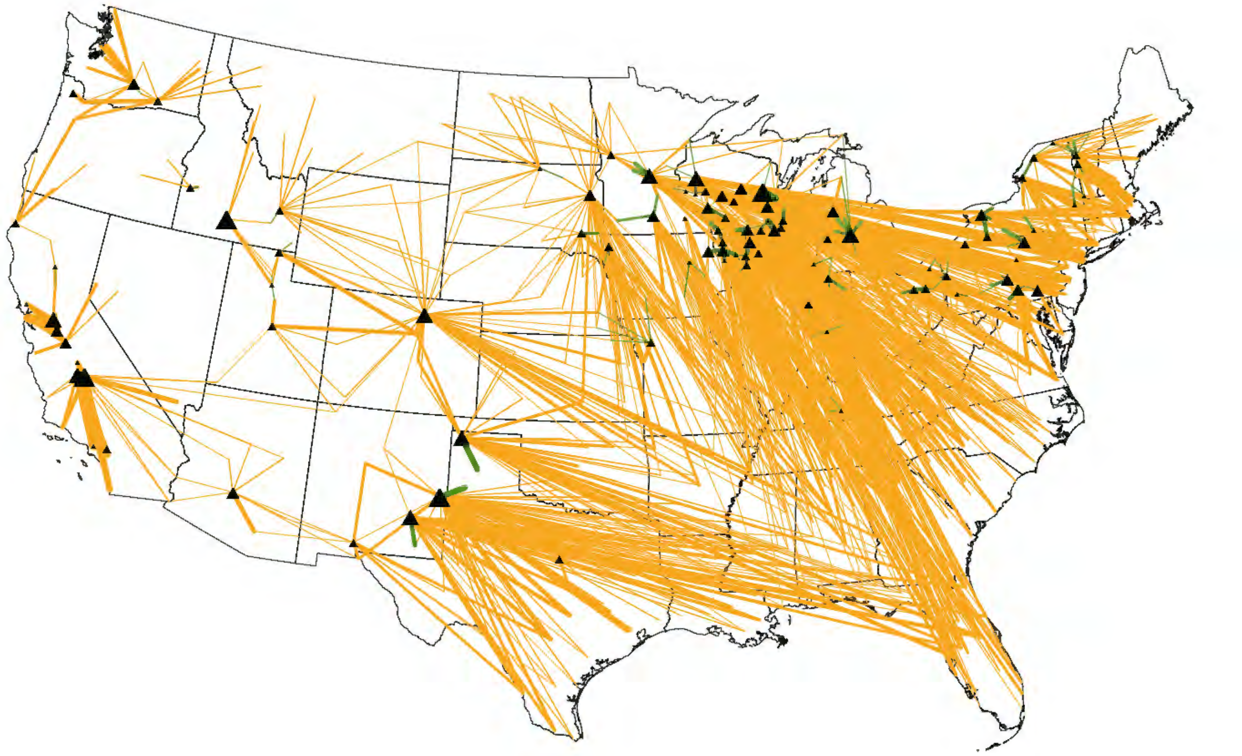

Figure 6. Milk Assembly at Cheese Plants and Product Distribution Flows (small USDSS model), October 2021

It is important to note that the USDSS is designed to analyze the least-cost spatial organization of the entire US dairy industry. That is, USDSS results serve as a competitive benchmark for the lowest possible systemwide costs, which also indicates the economic pressures for processing particular products at particular locations. The USDSS is NOT designed to replicate exactly existing patterns of milk processing and distribution. Any quantitative model is, by definition, a simplification of reality, and the USDSS does not directly represent existing commercial relationships that can be important determinants of the locations and volumes processed in existing operations. For example, 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—it is much easier to go with the flow than against it. Finally, the model does not represent the impact on processing locations and milk movements that derive from the incentives under Federal Milk Marketing Orders. To reiterate, the USDSS provides a competitive benchmark for spatial organization of the US dairy industry and thus for spatial milk values.

Despite the USDSS not being designed to replicate existing spatial patterns of farm milk assembly, processing and product distribution, the model has represented spatial patterns in the US dairy industry reasonably well. For example, a previous analysis compared the model-generated volume of five dairy products to those produced in regions of the U.S. based on the monthly Dairy Products report from the National Agricultural Statistics Service using data from 2011[7]. 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 as 0.99 for many products such as cheese. Moreover, the model results are not sensitive to changes of plus or minus 5% in demand values or estimated transportation costs. Both outcomes suggest a high degree of confidence in the sensibility of the model outcomes.

3.2 The Dual Solution

The dual solution shows the spatial value of milk, or more specifically, the "marginal value" of milk at a processing location or at a supply location as for raw milk. Here, "marginal" is used to express the idea of a small change in the volume of milk at a particular location. 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 location 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.

Thus, the "dual values" provide estimates of the spatial value of milk, and are key results reported for the purposes of this component of the hearing. Dual values are calculated by the USDSS at all milk plant locations across the country, although our focus here is on the values for fluid milk processing plants. Individual values at fluid milk processing locations are used as inputs into spatial mapping software (in this case, ArcGIS) to develop a continuous "price surface" by interpolating the values between the points with what is called a Kriging algorithm and then projecting values for each U.S. county. This price surface indicates estimated spatial values of milk for each county location in the contiguous United States, consistent with the spatial aggregation used for Class I differentials.

However, the indicated spatial milk values should not be interpreted directly as Class I differentials. The values should be thought of as "price relatives", that is, the difference in values across locations. As an example, consider the March 2011 value from previous modeling work. In most of Wisconsin, the dual value is about $2.00 whereas in southern Florida the value is about $6.25, which suggests 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 be consistent with a $4.25 relative price difference. In this case, the model results are

[7] Nicholson, C. F., X. He, M. I. Gómez, H. O. Gao and E. Hill. 2015. Environmental and Economic Analysis of Regionalizing Fluid Milk Supply Chains in the Northeastern U.S. *Environmental Science and Technology*, 49:12005–12014. DOI: 10.1021/acs.est.5b02892

consistent with the Federal Order price difference between southern Florida and the Upper Midwest. The Agricultural Marketing Service (AMS) of the USDA used previous model results as input in the 1998 Federal Order hearings. Differences between the model-generated relative spatial values of milk compared to those for current Class I differentials suggest a potential need to modify Class I differentials.

4 Factors Affecting Price Relatives in the USDSS

The USDSS shows the spatial milk values at a given point in time, but it is also relevant to consider the drivers of changes in these values. Three factors constitute the important causes of change in the spatial milk values—the price relatives. These factors are 1) changes in the milk supply, 2) changes in the composition and locations of demand for dairy products, and 3) changes in transportation costs.

Milk is still produced in all 50 states. However, NASS no longer reports milk production in Hawaii or Alaska because of confidentially issues. Some 26 percent of states have fewer than 10,000 cows in total. NASS does report milk production estimates for all 48 contiguous states on a quarterly basis, but it reports monthly milk production estimates for 24 of our largest milk producing states. In fact, these 24 states represent about 96 percent of total U.S. milk production. The fact is that states are specializing either into, or out of, milk production over time. Even within states, there are significant changes regarding where milk is produced.

The change in county level milk production is estimated for the decade from 2011 to 2021 (Figure 7). In this map, the grey color represents almost no change in milk production while shades of red indicate losses and green shows growth. There has been relatively strong growth in western New York, Michigan, Wisconsin and the I-29 corridor. There have been intensive pockets of growth north of Denver, Colorado, the Texas Panhandle and southwest Idaho. But California has demonstrated large losses of production in the Imperial Valley and growth in the Central Valley. In general, the Southeast has generally shown losses and only isolated counties in that region have grown.

Regional changes over time are easier to see in a graph (Figure 8). Here growth is clearly seen in the Western and Midwest states. The Northeast as a whole has shown modest growth while the Southeast region has shown modest loss of milk production.

Total milk equivalent demand, on a per capita basis, for dairy products has seen modest growth over time. But there have been very different outcomes for some product categories. Cheese has been the poster child for growth while fluid milk has been in a significant downturn for some time. It has been said that we are no longer drinking milk—we are eating it.

Milk needed to support per capita dairy demand has shown modest increases, but population growth has been an even bigger factor. The West and Southeast have increased at a compound annual growth rate (CAGR) of about 1.0 percent while the Midwest and the Northeast have grown at a slower CAGR of about 0.3 percent (Figure 9).

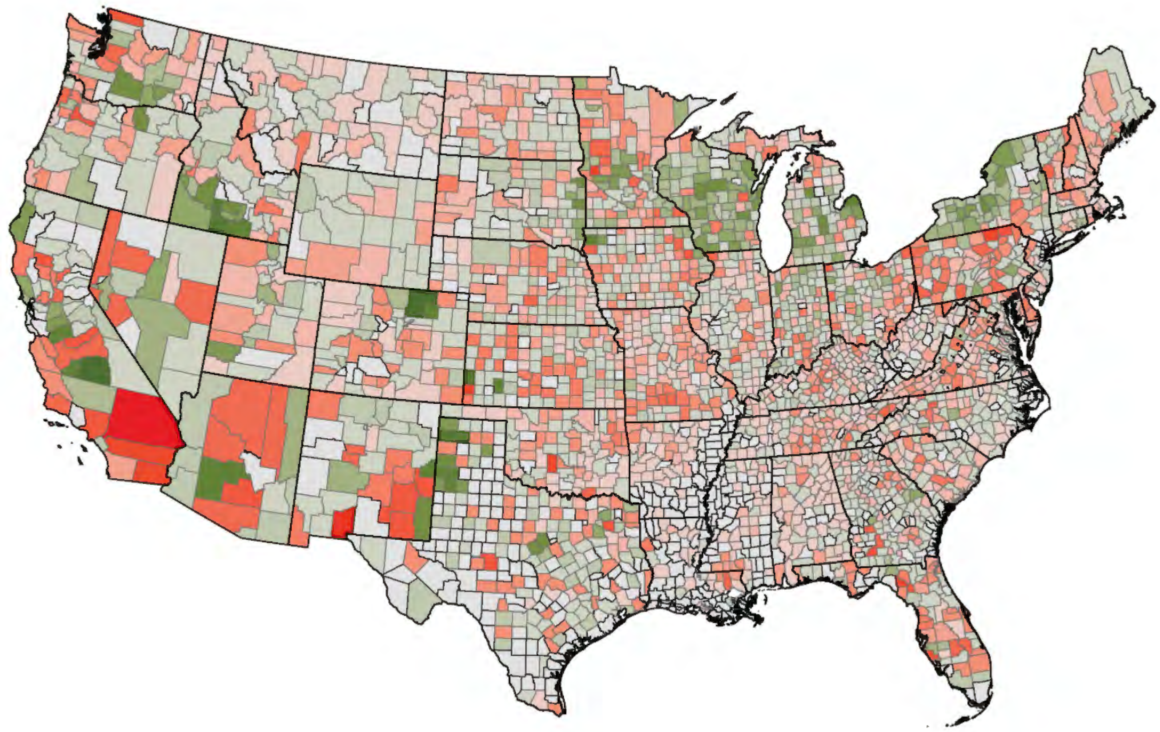

Figure 7. County-Level Change in Milk Production, 2011 - 2021

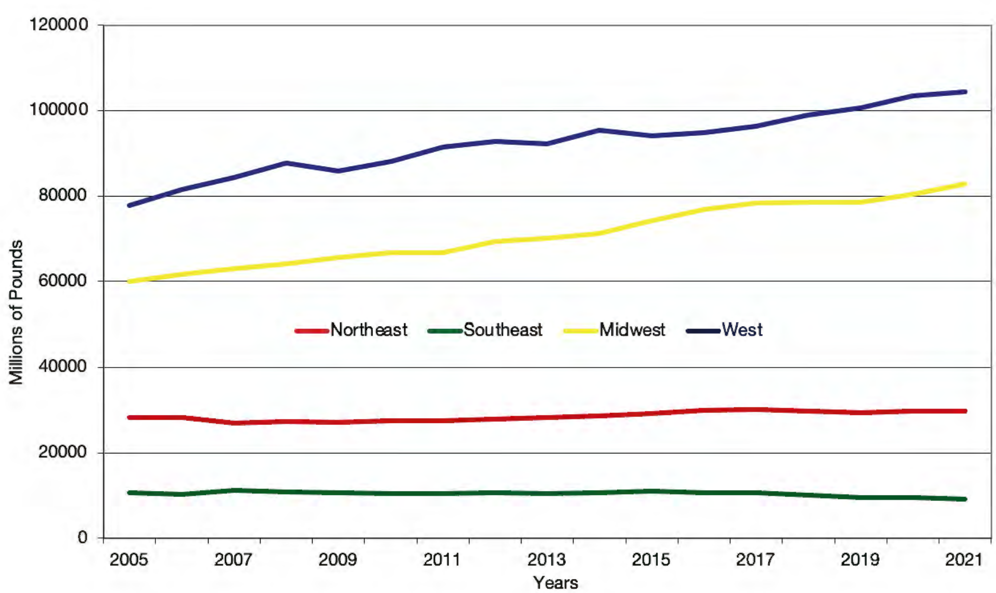

Figure 8. Milk Production by Region of the U.S. 2005 - 2021

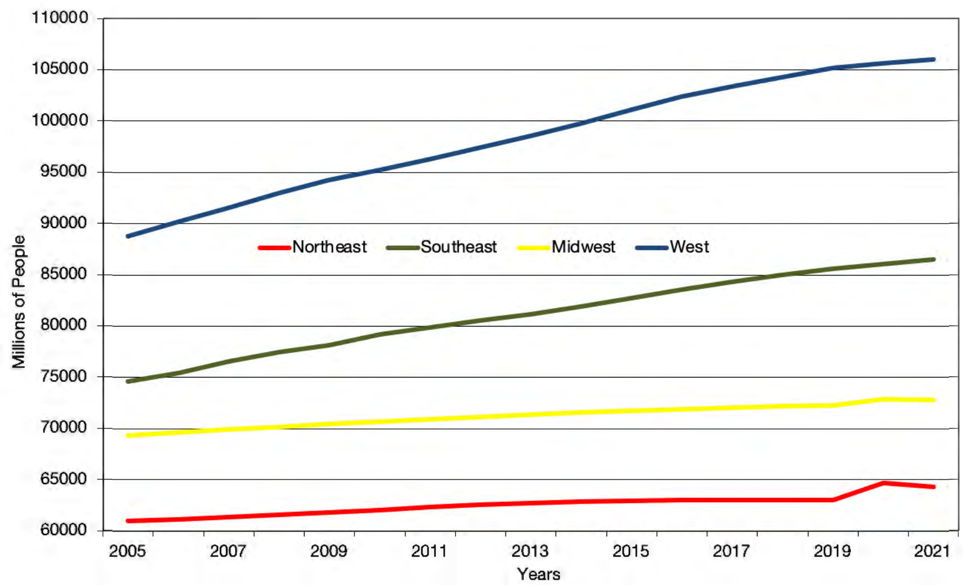

Figure 9. Population Growth by Region of the U.S. 2005 - 2021

We also can make estimates of the surplus or deficit in milk supply at the county level (Figure 10). Such a calculation is really only useful as a means of considering just how "local" our milk production can be regardless of plant processing capacity in the area. We can also look at the regional impacts of changes in milk production and dairy product demand over time to see whether the milk surplus or deficit has been changing (Figure 11).

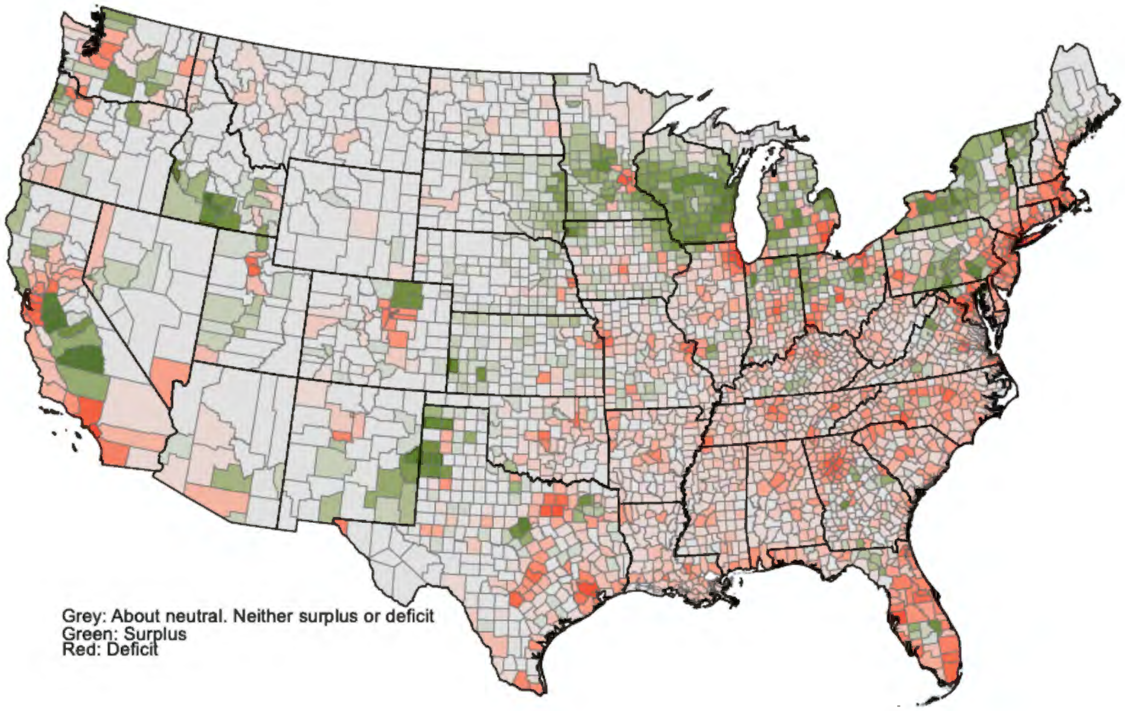

Figure 10. Milk Surplus or Deficit by County, 2021

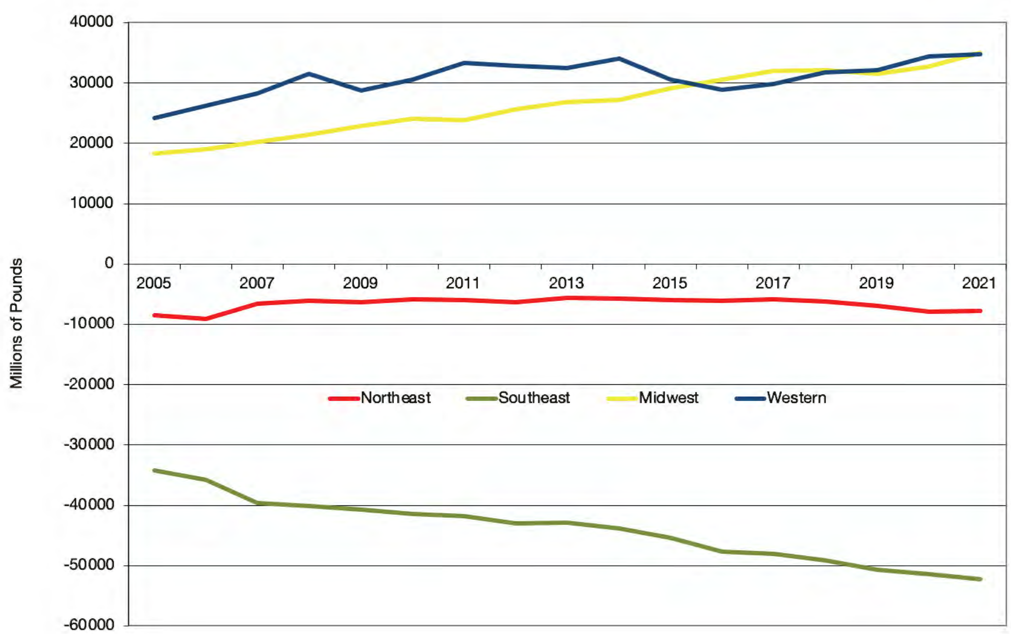

Figure 13. Regional Milk Surplus or Deficit, 2005 to 2021

The most intensely deficit areas seen in Figure 10 are locations of major cities. This is most apparent in the Boston–New York–Washington DC corridor along the east coast. The maps of the primal solution (Figures 5 and 6) show how the model chooses to satisfy these demands with milk from northern Vermont, central New York, and Pennsylvania. However, milk from Pennsylvania has been changing and is not as available as it was several years ago to fill the need (Figure 7).

Visually, the entire Southeast is largely deficit, (Figure 11), with an annual deficit is more than 50 billion pounds of milk and increasing. The Southeast's deficit has nearly doubled in the last two decades and has been growing at about 2.7 percent CAGR. Because milk production in that region has been flat to slightly down, the biggest factor in the increasing deficit has been population growth.

The western states have had population growth at about the same pace as the Southeast, but milk production in the West has grown even more rapidly than the population. As such, the surplus milk production in the West has been growing about 2.3% CAGR.

The Midwest's population has been growing very modestly while their milk production has increased at a pace similar to the West's. Consequently, the surplus of that region has grown at a CAGR of 4.2% making this region's supply an important source of raw milk and dairy product for the Southeast.

The Northeast has experienced population and milk production shifts internally, but the slow growth in population has about matched the slow growth of milk production in the region and the deficit is small (about 8 billion pounds annually) and holding steady.

The USDSS model is capable of sorting out many more complexities and provides estimates of the regional value of milk (the dual values) but looking at the changing factors of milk supply and dairy product demand suggests that milk has become more valuable in the Southeast with its growing deficit versus the regions where the surplus has grown.

The third factor which will modify the relative spatial values of milk in the U.S. is the cost of transporting raw milk to plants and distributing finished dairy products to satisfy domestic and export demands.

The vast majority of milk and dairy product movements are made by truck. The USDSS models transportation costs for raw milk assembly across actual road miles from all points of supply to plants. Interplant transfers of ingredients are similarly valued. Distribution of finished products by reefer or van must also traverse actual road miles but have different costs per mile based on transportation research.

Transportation costs have changed over time. As a proportion of total costs, wages and benefits have changed the most (Figure 12), but the cost of purchase or lease of the vehicle has also increased substantially. The ATRI[8] has surveyed the trucking industry since 2008, and they

---

[8] Leslie, Alex and Dan Murray. *An Analysis of the Operational Costs of Trucking: 2021 Update*. American Transportation Research Institute. November, 2021.

have used a consistent methodology to determine the average marginal cost per mile. Their findings from 2011 through 2021 (Figure 13) with an estimated update for 2022 based on changes in truck driver wages and benefits for 2022 (Bureau of Labor Statistics) and fuel costs (Department of Energy). There have been substantial recent increases in freight, but the USDSS only reflects changes through 2021.

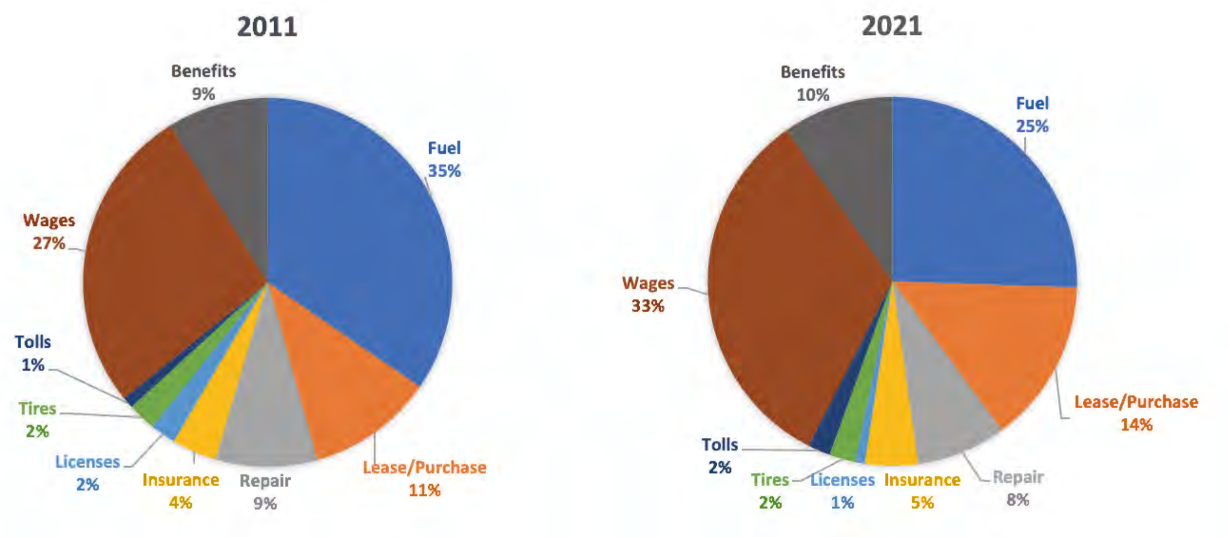

Figure 12. Change in the Percentage of Costs for Trucking, 2011 and 2021

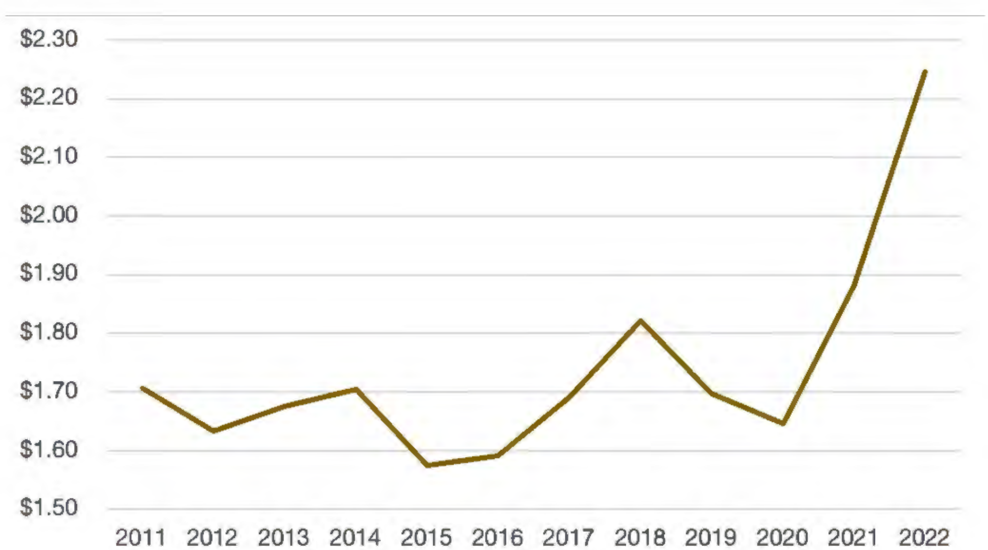

Figure 13. Changes in the Average Marginal Cost per Mile of Trucking

The increases in transportation costs will increase the price relative values of milk over the U.S., interacting with the changes in the spatial surplus and deficit milk production deriving from regional supply and demand shifts.

5 Regulated Pricing and Class I Differentials

The Dairy Program is the branch of the Agricultural Marketing Service of the U.S. Department of Agriculture which administers the Federal Milk Marketing Orders. The Dairy Program does many things but a primary function has been to announce and enforce minimum class milk prices on regulated dairy plants. Minimum pricing incorporates the monthly "discovery" of the value of milk. The monthly changes in the class prices are uniform across the country, but the Dairy Program has used Class I Differentials to reflect the spatial value of price relatives. Class I is the only class that imposes these price differences, but the price relative differences in Class I differentials are also used to "zone" the blend price back to producers within each order.

Class I differentials are updated infrequently—usually through a Federal Order hearing process—when market conditions appear to indicate a need for change. In 2000 under congressionally mandated Federal Order reform, Class I differentials were evaluated and updated across the contiguous 48 states. In 2008, there were updates to Class I differentials in the Southeast to address problems with milk movements into that region. However, the price surface has not been evaluated or changed since that time. Current Class I differentials (Figure 14) do reflect the higher value milk in the Southeast, but given the structural changes in population, milk production and transportation costs, it is reasonable to scrutinize Class I differentials again.

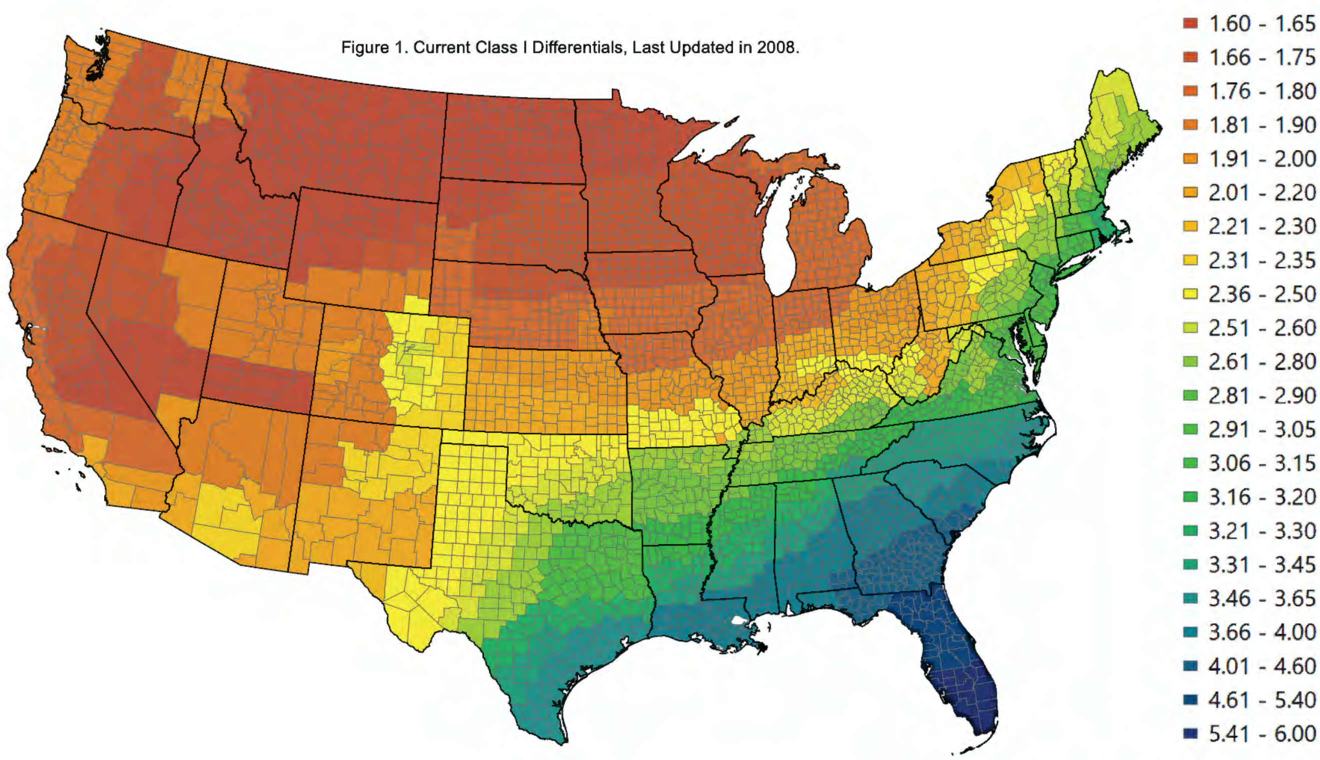

Figure 14. Current Class I Differentials, Last Updated in 2008.

Class I differentials, or the zoned prices, are never meant to completely cover the costs of transporting milk. If these values were larger than the costs of transportation, then "disorderly" market conditions could result with excess milk trying to find its way to the higher-value plants. Class I differentials are meant to encourage milk to move in a direction where it is most needed.

Current Class I differentials have a minimum of $1.60 in parts of California, Idaho, Minnesota, Montana, Nevada, North Dakota, Oregon, Utah, and Wyoming—all states with substantially surplus milk production. For our analyses, we assume that dollar amount is needed to service fluid plants in surplus regions. We add an increment to the dual values such that the lowest Class I differential is equal to $1.60/cwt and allow the price relatives to express a Class I differential from that minimum value. That is, our analyses show the relative spatial values of milk at Class I fluid plants given $1.60/cwt as the lowest value. Analyses with the USDSS do not assess the economic rationale for this particular value of the minimum.

6 USDSS Results for Spatial Milk Values

The USDSS was simulated using both the smaller (multi-county) and large (county-level) versions with 2021 data, with similar quantitative results and patterns. The models are run for the months of May 2021 and October 2021 to represent both the flush and short months of the year. Milk supplies and components produced are estimated at the county level in the large model and aggregated to multi-county regions in the small model. Milk components at the state and national levels are fully accounted for. The same is true for dairy product consumption, imports, exports, and changes in stocks of dairy products. A mass balance on components is then run to ensure data integrity. Because there were excess components, especially in the October data, small adjustments were made to reduce the excess to levels to be more nearly equivalent to industry shrink. Transportation costs are equal to those of the 2021 model year. These analyses accounted for recent or near-term expected plant closures, openings or expansions to represent current processing capacity by county. That is, one exception to the use of 2021 data for the model analysis is that we did not allow processing at a few locations where fluid plants have ceased operation since 2021 or are scheduled to close very shortly. Examples of the primal solutions are shown in Figures 5 and 6, but complete product flows are a product of the model solution.

A key focus of the analysis is the dual solution values for fluid milk processing plant locations. Spatial milk values are calculated by adding a fixed increment to the dual values of milk used at Class I processing plants. The value of this fixed increment is exactly the value required to equal $1.60 at the minimum value in the model solution. This allows the calculation of a spatial milk value at all Class I processing locations used in the model.

The USDSS can choose to process fluid milk at any of 282 plant locations, but a cartographic method called Kriging is employed to interpolate between the actual geographic plant locations to estimate the spatial milk values over a continuous spatial field. While there are a few other methods of spatial interpolation, Kriging gives the best linear unbiased prediction at unsampled locations. These continuous spatial estimates are then projected back down over the underlying boundaries of the counties to calculate the average Class I value in each county. Finally, the county values are rounded to the nearest $0.10/cwt.

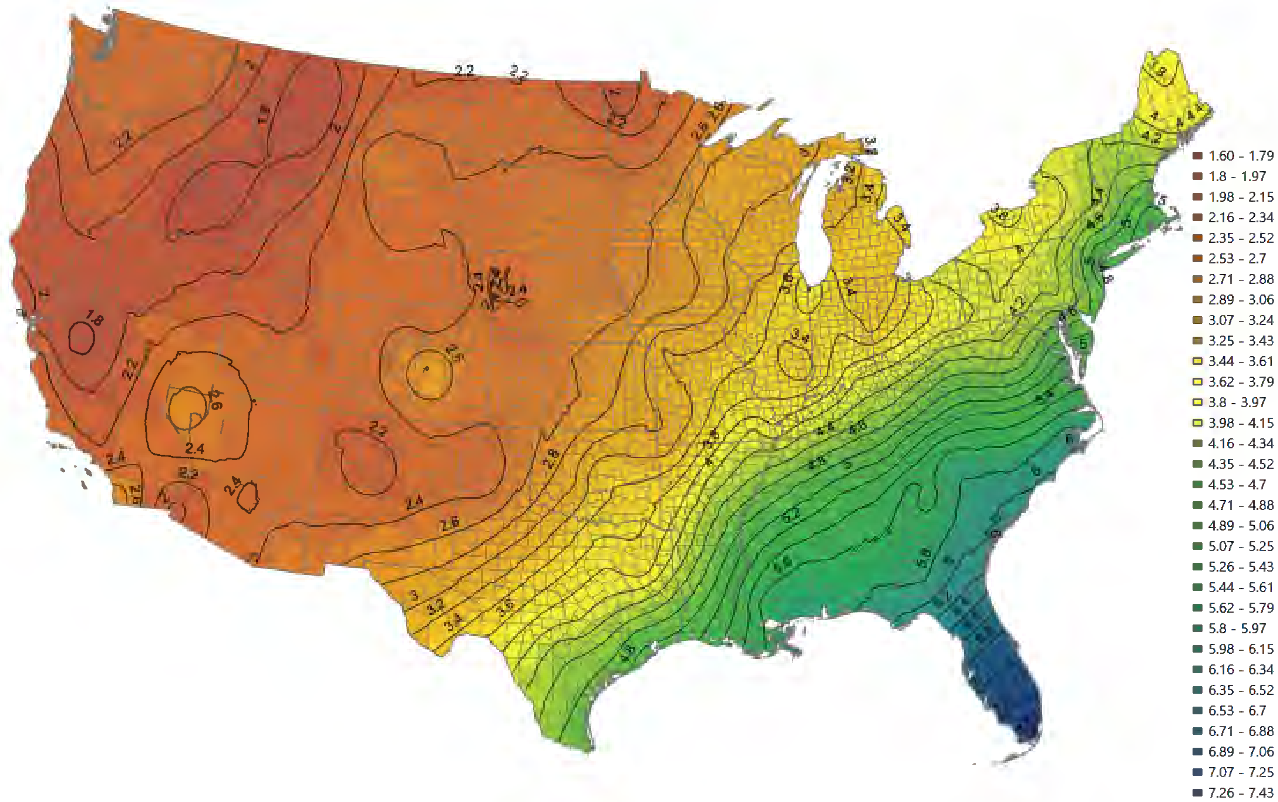

Figure 15. USDSS Estimated May 2021 Spatial Milk Values at Fluid Plants

Spatial milk values are estimated for the May 2021 data (Figure 15). The general pattern is lower values in the north and western regions and rising into the south and eastern area of the U.S. The pattern of these values mirrors the current Class I differential structure and reflects the relative surplus and deficit regions of milk. However, the current Class I differentials range from $1.60 to a high of $6.00 while the model suggests that the price surface is steeper moving towards the Southeast (high values more than $7.00) reflecting both changing regional production and demand, and higher transportation costs.

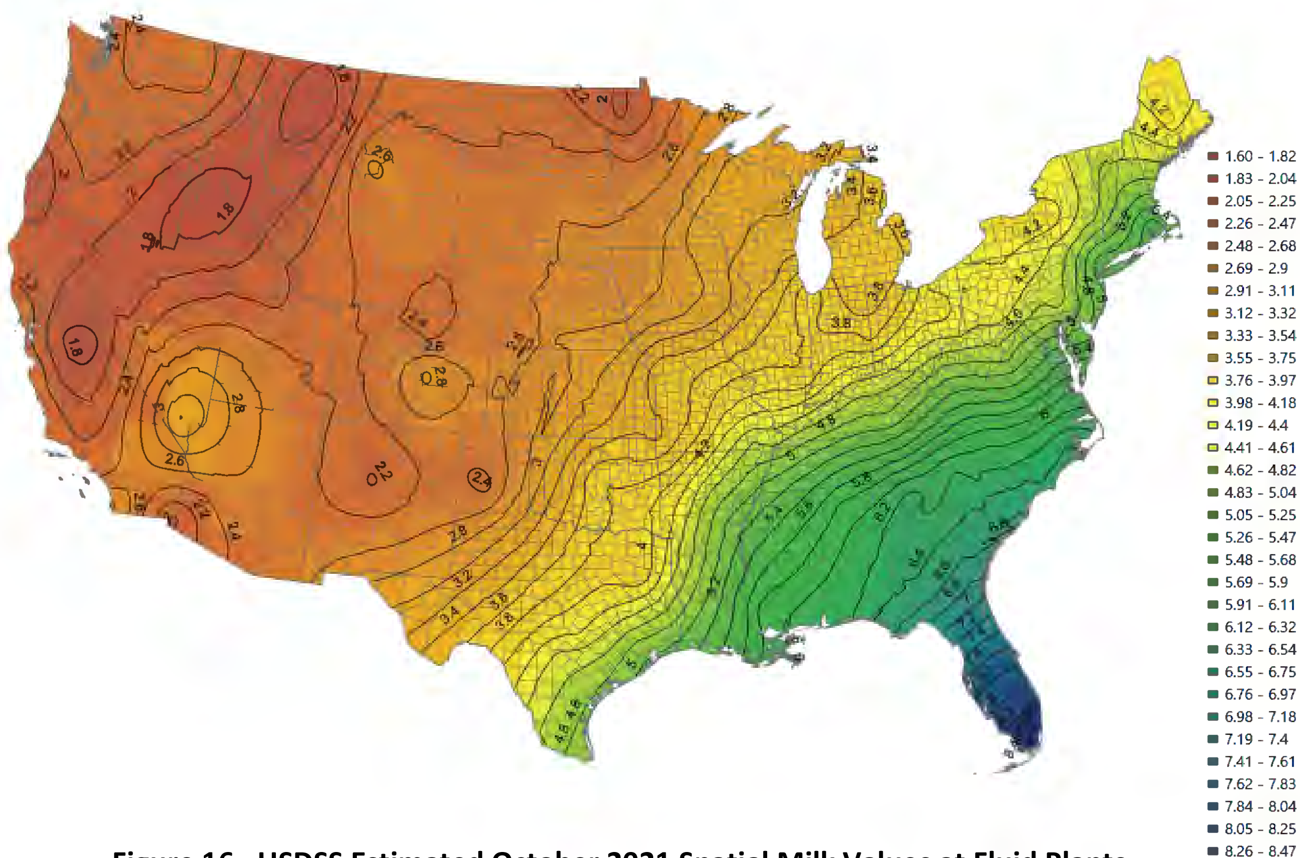

Figure 16. USDSS Estimated October 2021 Spatial Milk Values at Fluid Plants

Spatial milk values for October 2021 (Figure 16) have a pattern similar to that in May 2021, but with spatial values into the Southeast indicating an even steeper price surface and reaching a maximum value of more than $8.00. The seasonal differences in value (Figure 17) indicate a fairly steep rise in values from St. Louis through Atlanta and down to Miami along the I-75 corridor. The western portions of the U.S. show very few seasonal differences in the calculated spatial values of milk.

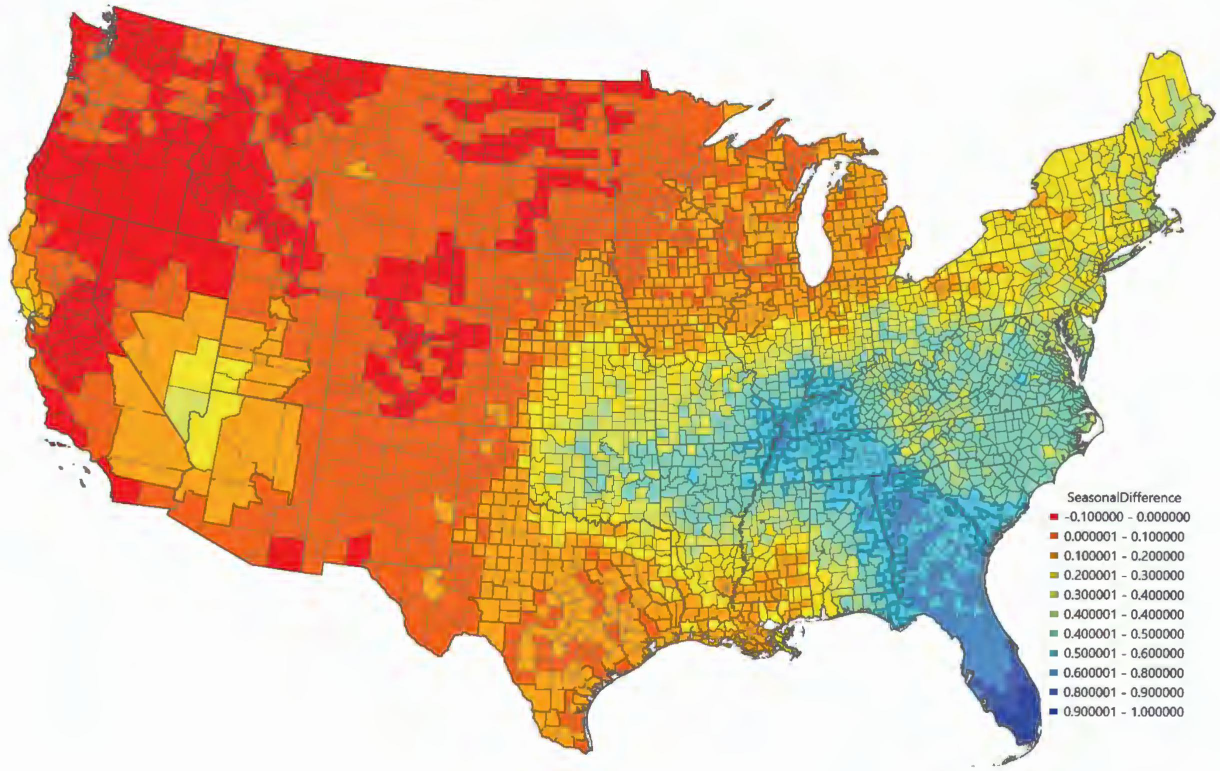

Figure 17. Difference between USDSS October and May 2021 Class I Differentials

Class I differentials across the 48 contiguous states were carefully considered in a national federal order hearing at the time of the full reform in 2000. Since that time, a federal order hearing in 2008 addressed difficulties in moving milk in the Southeast with increases in differentials in parts of that region. However, there has been no consideration of changing spatial values for milk since that time.

The differences between the May 2021 spatial milk values and the current Class I differentials are considerable (Figure 18). In particular, there is a band from about Norfolk, Virginia through Montgomery, Alabama where current Class I differentials appear to be well below the model-calculated spatial value of milk at the assumed $1.60/cwt minimum differential. There are also a few cities, such as Charleston, West Virginia, Cleveland, Ohio, and Chicago where current Class I differentials are considerably below USDSS model estimated spatial milk values. The U.S. is roughly divided between east and west (approximately along the Mississippi River) which separates regions where differentials are modestly low (West—up to about $0.80/cwt) to areas where the difference may cause difficulties encouraging milk to move to where it is needed. Probably the reason that there is a ridge where there is a northern ridge in the Southeast where current differentials are significantly below calculated values is because of the changes made in

2008 to the 2000 differentials. At that time, the biggest changes (up to $1.80/cwt) were made to Florida values. More modest increases were made to Georgia and Alabama and even less to states further north.

A similar pattern of differences exists between USDSS calculated differentials for October 2021 and the current Class I differentials (Figure 19), but with somewhat smaller differences in Florida, Georgia, Tennessee and Kentucky.

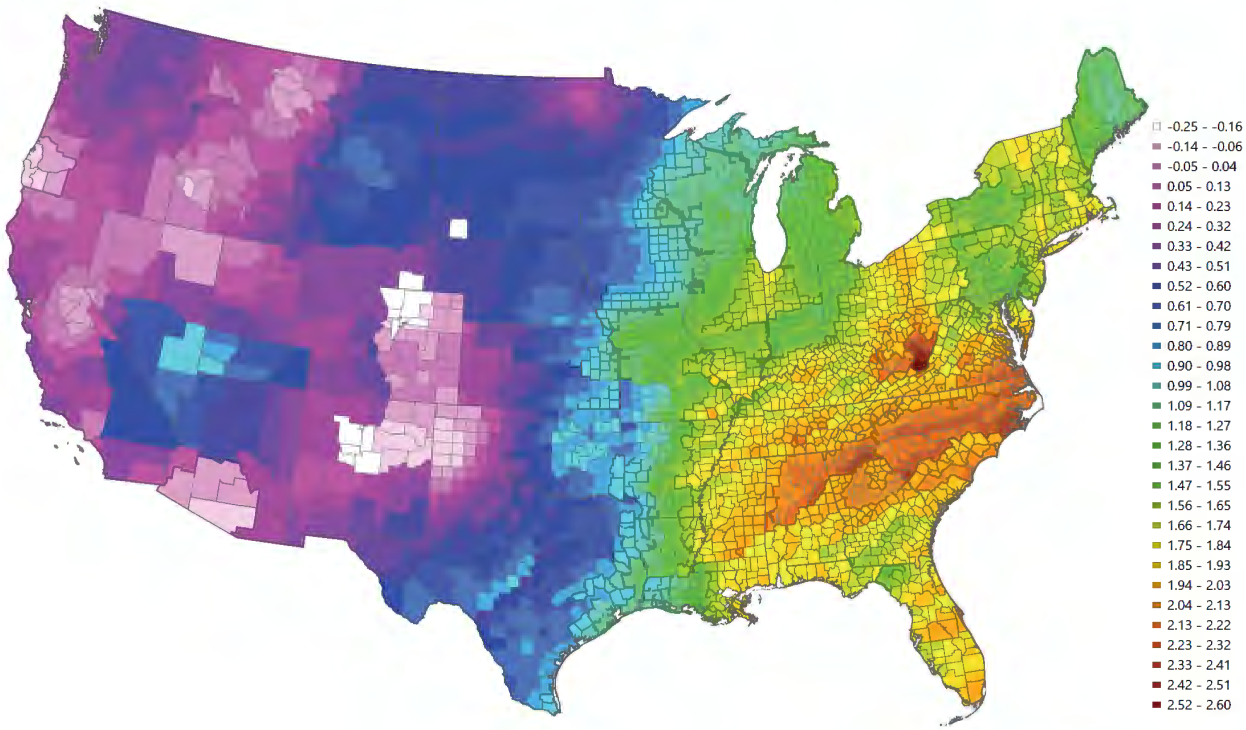

Figure 18. Difference Between USDSS Estimated May 2021 Spatial Milk Values and Current Class I Differentials

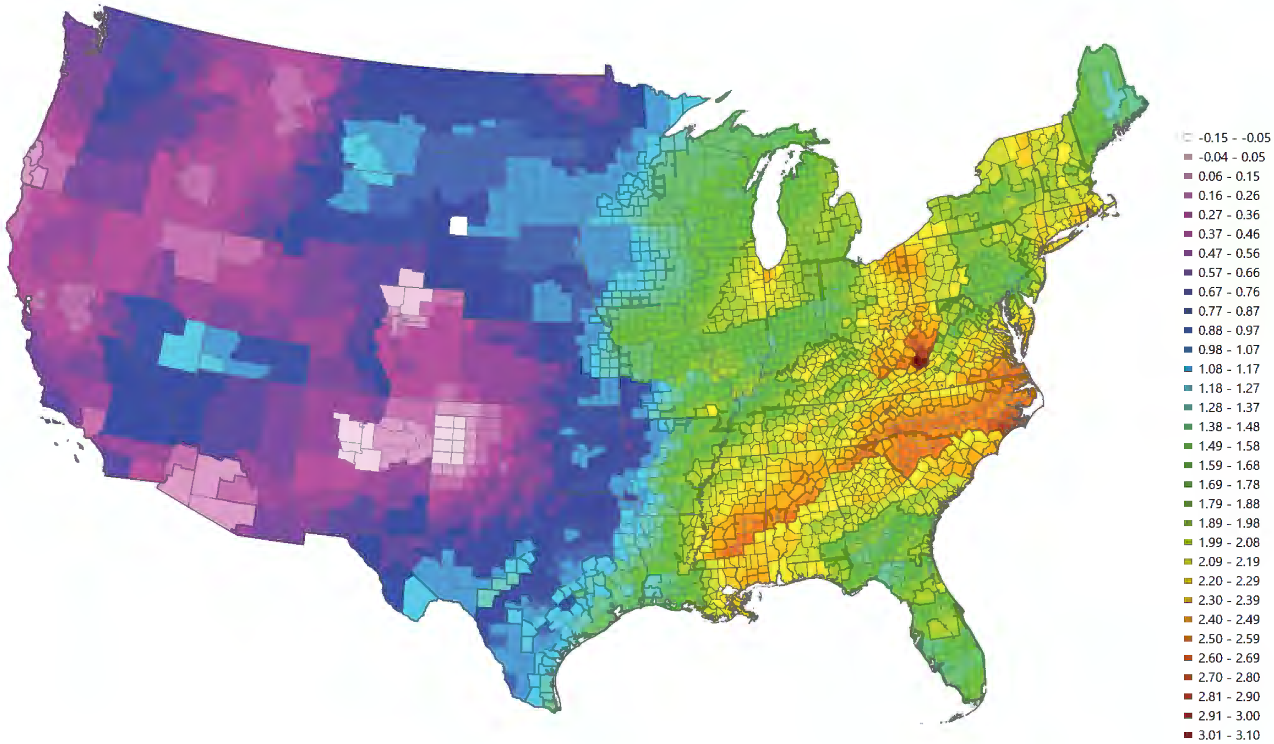

Figure 19. Difference Between USDSS Estimated October 2021 Spatial Milk Values and Current Class I Differentials

7 Concluding Comments

There have been formal studies of the spatial value of U.S. milk for about a century. However, it has been approaching three decades since nationwide spatial values of milk have been systematically evaluated using the U.S. Dairy Sector Simulator (USDSS) model. Over this time, there have been considerable changes to where milk is produced and where population growth has taken place. There have also been substantial changes to transportation costs. Milk supply, demand and transportation costs all have an impact on the spatial value of milk. Increasingly, we are seeing the industry moving raw milk and manufactured dairy products further than the past to accommodate the degree of surplus or deficit in various regions of the U.S.

Federal Milk Marketing Orders (FMMOs) have relied on Class I differentials to encourage milk to move in the directions where it is most needed. For example, raw milk needs to move from areas like central New York, northern Vermont and eastern Pennsylvania into fluid plants along the major metropolitan concentrations of the northeastern coast. At a more macro level, milk may need to move 1,000 miles into the very deficit Southeast.

The economically efficient solution for the industry will move more concentrated dairy products, like cheese and butter, longer distances from surplus regions in the West and Upper Midwest to the more populated regions further away. The complex solution of an efficient market creates spatial differences in milk value that will always be less than the actual cost of transportation. The USDSS captures much of that market complexity to estimate spatial differences and from these we calculate spatial milk values that can inform the setting of Class I differentials.

Maintaining the current minimum Class I differential of $1.60, the USDSS estimates the highest Class I differential to be located at the southern tip of Florida. The model determines that value to be $7.40 for May of 2021 and $8.40 for October of 2021—the flush and short months respectively. The Class I differential for that same area was raised from $4.30 to the current level of $6.00 after an FMMO hearing in 2008.

There is a ridge of where calculated 2021 spatial milk values from Virginia to Louisiana are consistently higher than current Class I differential values which is also true for a few metropolitan areas. Another ridge exists from St. Louis to Miami where seasonal differences in the value of Class I milk are more pronounced. There could be a danger in elevating Class I differentials to mimic the October solution values as flush season milk may be over-valued. However, it might be rational to consider an increase of existing Class I differentials to something like the USDSS May values with a seasonal adjuster to the area previously noted.

My key concluding points are the following:

The USDSS provides a competitive benchmark for the differences in spatial milk values, and analysis for two months in 2021 indicates considerable differences from current Class I differentials. As noted, the differences arise from the combined effects of changes in the locations and amounts of milk supply, changes in the nature and location of dairy product demand, changes in the locations and capacity of dairy processing facilities and changes in transportation costs.

The USDSS provides evidence of the need for change in Class I differentials because it represents a spatial economic benchmark, but other factors such as existing commercial relationships can be important determinants of spatial organization. The model results provide relevant input for differences in county values but may need to be adjusted based on additional information about the special characteristics of particular locations. In fact, a review of model results for key locations and adjustment process was employed by AMS to specify differentials in 1998. My understanding is that this approach to adjustment is similar to the process used by NMPF to develop its proposed Class I differential values. There is an analogy here to use of models that generate the weather forecasts familiar to all of us. The outputs of weather models are used as key inputs, but forecasters often adjust the “model guidance” with professional judgment to arrive at a more accurate forecast for a particular locality.