Analyses of Proposed Alternative Growth Management Programs for the US Dairy Industry

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Executive Summary

Motivated by concerns about low and variable milk prices and farm incomes, a number of dairy industry groups have expressed interest in programs to manage growth in US milk production and enhance dairy supply chain coordination. This study evaluated the impacts of different configurations of "Growth Management Programs" intended to modify the trajectory of growth in US milk production. Growth Management Programs (GMP) specify an allowable production increase (API) and market access fees (MAF) paid by farms that exceeded that growth. We assessed the potential impact of the implementation of GMP with different assumptions about their operation, assuming that the programs would have been implemented in January 2014. We evaluated a variety of farm-level and dairy market outcomes during 2014 to 2021 using a detailed dynamic simulation model of the global dairy supply chain.

Our key findings are:

- The programs would reduce variation in milk prices, enhance average milk prices and margin over feed costs to varying degrees, and increase average net farm operating income (NFOI) for operations staying within API for all farm sizes compared to a Baseline scenario with existing policies. Average annual milk prices were increased between $0.73/cwt and $1.41/cwt depending on the design of the GMP. Including refund payments for farms within API limits, average milk revenue would be higher by $1.15/cwt to $2.13/cwt. Reduction in the average variation in milk prices ranged from $0.16/cwt to $0.21/cwt;
- Compared to the Baseline scenario, GMP would slow growth in average annual US milk production (from 2.5% to 2.1% per year for the most restrictive program), increase US retail fluid prices by as much as fifteen cents per gallon, increase average prices for other dairy products by 3% to 11%, slow the average annual growth of US dairy product exports by 2%, reduce domestic dairy product sales by 1% to 3% and reduce US government expenditures on dairy supports by as much as $2.5 billion.
- Entry of 60 new farms per year with milk production up to 5 million lbs per year could be accommodated with a three-year grace period without payment of Market Access Fees and without substantive effects on the operation of the GMP (see Appendix A4);
- An initial assessment suggests that GMP would not have mitigated the prices shocks experienced in the first months of the Covid-19 pandemic but would have reduced the number of farms experiencing negative Net Farm Operating Income (see Appendix A5).

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- An average Wisconsin grazing dairy staying within allowable growth is simulated to experience an increase in average annual Net Farm Operating Income (NFOI) of up to 74% ($23,000). NFOI for an average Wisconsin grazing dairy is simulated to increase even with growth above the API for four of the five of the GMP designs analyzed.

Introduction and Objectives

Previous analyses in 2010 and 2019[2] provided evidence that programs to manage growth in milk supplies such as those proposed in the late 2000s by the Holstein Association (later modified and introduced in Congress by Representative Costa and Senator Sanders as the Dairy Price Stabilization Program) and as an initial component of Foundation for the Future program proposed by the National Milk Producers Federation could reduce milk price variability, make farm incomes more stable and reduce the likelihood of negative NFOI during the low-price periods of the dairy price cycle. Other previous work[3] has also suggested that the milk price cycles arise primarily due to the supply decisions by dairy farms and related time delays, that is, due to a lack of supply chain coordination matching milk supply and demand. Although the magnitude of the variations in milk prices during the cycle vary[4], the cycle continues to influence milk prices to a notable extent. Extended periods of lower-than-average milk prices and more recently Covid-19 demand shocks have resulted in significant management challenges to many dairy operations.

Although previous analyses suggested these programs could be effective in the market environment of the early 2010s, a number of changes have occurred since that time, including a) increased US participation in export markets so that US milk prices are more integrated with those in other exporting regions, b) exit of many (especially smaller) US dairy farms and a greater proportion of milk production from larger operations, c) modifications to federal dairy programs such as replacing price supports with risk management tools under MPP-Dairy now Dairy Margin Coverage, DMC), and d) reductions in per capita fluid milk demand, despite increased overall dairy product consumption. Although cyclical variation in milk prices has been less since 2015, this was accompanied by four years of margins frequently below $10/cwt, resulting in ongoing profitability challenges for many dairy farms. These challenges have contributed to increased rate of farm exits. The reasons above provide a motivation to re-visit the effectiveness of programs that propose to improve coordination between supply and demand with the objective of reducing variability in prices[5] and increasing farm profitability.

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[2] Nicholson, C. F. and M. W. Stephenson. 2010. Analysis of Proposed Programs to Mitigate Price Volatility in the U.S. Dairy Industry. Project report for consortium of dairy industry organizations administered by the Milk Producers Council. September. (http://dairy.wisc.com) and Nicholson, C and M. Stephenson. 2019. Analyses of Selected Dairy Programs Proposed to Reduce Variability in Milk Prices and Farm Income, Program on Dairy Markets and Policy Working Paper Series, Working Paper 19-01, March (https://dairymarkets.org/PubPod/Pubs/WP19-01.pdf)

[3] Nicholson, C. F. and M. W Stephenson. 2015. Price Cycles in the U.S. Dairy Supply Chain and their Management Implications. *Agribusiness: An International Journal*, 31:507-520.

[4] For example, an analysis of price cycles indicates that the price "peaks" in 2011 and 2017 were small compared to the price peaks in 2008 and 2014.

[5] Both 'variability' and 'volatility' are used to characterize changes in milk prices. Because the emphasis of GMP is on reducing *cyclical* variation (not seasonal variation or response to short-term shocks) in milk prices, we use 'variability' in this document.

With this background, our objective is to analyze likely market and income impacts of selected[6] Growth Management Programs (GMP) to address profitability and price variability challenges in the U.S. dairy industry. Using a dynamic simulation model of the global dairy supply chain, we assess how difference configurations of GMPs would have affected key outcomes if they had been in operation beginning in 2014. Our focus is on how the programs would have affected the level and variability in the All-Milk price, but we also consider a variety of other impacts, including net farm operating income (NFOI), government expenditures on the DMC, and the value of US dairy exports and imports.

This study was developed in consultation with Wisconsin dairy farmers and their organizations, who provided input on program design principles and intended objectives. It was organized by the University of Wisconsin Center for Integrated Agricultural Systems and supported by grants from the University of Wisconsin Baldwin Wisconsin Idea seed grant and USDA projects on cover cropping and grazing initiatives. The group convened by the University of Wisconsin Center for Integrated Agricultural Systems met 12 times over the course of 18 months to discuss goals and objectives and review progress. The project began shortly before COVID19 disrupted supply chains across many sectors and became motivated in part by these disruptions. This study is not intended to promote or recommend any specific program or other government intervention to address the issues of supply chain instability and low margins. Rather, the purpose of this study is to provide information relevant for decision-making by industry stakeholders.

Specific Objectives:

Given the above, our objective is to assess the impact on various farm-level and dairy market outcomes for GMP in continuous operation during 2014 to 2021. All of the GMP analyzed are configured to have an allowable annual growth in milk production per farm (an "allowable production increase", API), a payment on milk production on farms that exceed that allowable growth (a "market access fee", MAF) and distribution of the collected funds to farms that grow milk production less than the allowable amount. We assess programs with differing values of allowable annual growth and market access fees, and whether the market access fees are paid on all milk production or only on additional milk production. Each of the GMP analyzed has two tiers of allowable growth, where allowed growth and market access fees are lower for Tier 1 than for Tier 2. This is a key difference with our previous analyses, which assumed only one value of allowable growth. (See Table 1 for how the Tiers are defined in the different GMP design scenarios modeled in this analysis.)

Outcomes Examined

A variety of potential impacts of these proposed programs are of interest to dairy industry stakeholders. We examine outcomes reported by Nicholson and Stephenson in 2019, in this case for the period 2014 to 2021, including:

[6] The selection of programs was by the authors with input from a committee working with Center for Integrated Agricultural Systems at the University of Wisconsin. Other programs have been suggested but are beyond the scope of this study.

- *Prices:* Average All-milk price, Federal Milk Marketing Order (FMMO) class prices and product prices for American cheese, dry whey, butter and NDM;
- *Farm price variability:* Average absolute deviation from average All-milk price, which indicates the average difference between prices in each month from the overall average milk price. A small average difference indicates less variability in prices around an overall average;
- *Farm profitability:* Net farm operating income, $/farm/year, for eight types of farms based on four size categories and two locations (CA and rest of US);
- *Milk production:* Total milk produced and marketed;
- *US dairy product exports and imports:* The total value of US dairy product exports and imports;
- *Government impacts:* Cumulative government program expenditures;
- *Dairy product sales:* Total domestic product sales for fluid milk, cheese, dry whey, butter and NDM.

Description of Programs Analyzed

Program with Allowable Annual Growth Limits and Market Access Fees (Growth Management Program)

The principal elements of the GMP include an allowable annual growth in milk production (API), and a market access fee (MAF) per hundredweight to be paid on either all milk or additional milk production if the producer does not limit milk production to within the program-allowable annual rates. This program can be implemented continuously with fixed values of API and the MAF or these could be modified based on dairy market performance thresholds. Based on input from farmer organizations, we evaluate five alternative GMP designs[7] that assume different values for the API and MAF (Table 1). Although other program designs with different values could be evaluated, these five provide assessment of a range of GMP features that are relevant for informing decisions about design features. These designs differ by features such as:

1) whether the Allowable Production Increase (API) is specified as a percentage or a fixed amount of additional milk production;
2) whether Market Access Fees (MAF) are based on farm size;
3) whether MAF and API are adjusted based on market conditions (the margin used by the Dairy Margin Coverage program[8];
4) whether Market Access Fees are paid on all milk production or only on additional milk (in previous program proposals, "marginal milk" production).

Farm Size Categories

[7] Each program design is evaluated with a different model "scenario" in which API and MAF are specified in alternative ways.
[8] How the MAF and API are adjusted for values of the DMC margin is shown in Appendix Table A1.

Similar to our previous work, we delineate different types of farms based on volume of milk production and location. In these analyses, farms are categorized by volume of milk production—rather than cow numbers as in our previous modeling analyses. This modification was made to emphasize that the scenarios are about milk production rather than cow numbers. These four categories are:

1) less than 1 million lbs per year;
2) 1 to 5 million lbs per year;
3) 5 to 20 million lbs per year;
4) more than 20 million lbs per year.

This analysis also includes a new farm category, grazing dairies, with different cost structures and seasonal patterns of production than is common on conventional dairy farms. Our representation of farms includes those located California[9] and those in all other parts of the US, with each of the farm sizes and grazing farms represented for each region.

Tiered Growth Categories and Allowable Growth

To analyze the GMP designs, we separate the decision-making of farms that will limit production to stay within the allowable growth in a given year from those that will increase production by more than the allowable growth, dividing these latter into Tier 1 and Tier 2 amounts of growth (See Table 1 for how the Tiers are defined in the different GMP design scenarios modeled in this analysis). The proportion of farms in each group is determined based on a distribution of farms centered on the average annual amount of growth in milk per farm for each size category (1.1, 1.4, 1.7 and 2.4% per year, respectively), adjusted based on the difference in NFOI between farms limiting production and those not limiting production. That is, larger MAF would encourage a greater number of farms to limit production, because their NFOI would be reduced by MAF payments[10].

Because in a given year many farms will not be expanding milk production by a significant amount, many farms will "limit" production to be within the allowable growth without the need for reductions. Farms that must actively limit production to stay within the growth allowed by the program are assumed to adjust culling rates (cow numbers) to stay within the allowable amounts but continue to increase milk production per cow consistent with average annual milk per cow growth rates. Farms increasing production above the allowable growth thresholds for Tier 1 and Tier 2 will pay the market access fee on all milk (or for one program design) only on the amount of increased milk production.

[9] California farms were originally separated to allow representation the different pricing provision under the California state marketing order. We retain the farm categories for CA but modify the pricing provisions to those of a Federal Milk Marketing Order in November 2018.
[10] Appendix A2. provides additional discussion of the farm-level incentives that are modeled here as aggregated probability distributions.

New Farm Entry

Because one concern related to the design of a GMP is whether it can be structured to allow entry of new farms, we examine the impacts of allowing up to 60 new farms per year (five new farms each month for the entire period simulated) of two sizes (< 1 million lbs per year and 1 to 5 million lbs per year) without paying market access fees on production growth during the first three years of operation. The number 60 farms per year is set arbitrarily given the challenges of assessing how a GMP would affect incentives and ability for entry by new farms. This assumption can be modified, but the scenarios with assumed entry are designed to provide information about the extent to which entry with MAF payments would affect outcomes under a GMP and thus insights about how GMP designs could allow new farms. Our previous model analyses did not allow for net growth in the number of farms in the smallest two farm size categories, given historical patterns of declining farm numbers, but it did allow farms to move from one farm size category to another. A summary of the results for scenarios with new farm entry is reported in Appendix A4.

Table 1. Assumptions for Baseline and Five Growth Management Program Designs Evaluated

GMP Design, Farm Size	Within Allowable		Tier 1		Tier 2	
	Allowable Growth	Market Access Fee, $/cwt	Allowable Growth	Market Access Fee, $/cwt	Allowable Growth	Market Access Fee, $/cwt
Baseline (No GMP)	Any	None	N/A	N/A	N/A	N/A
#1 Fixed API and MAF All Farm Sizes						
All farm sizes	< 1%	None	1 to 4%	0.625	> 4%	1.25
#2 Fixed MAF with API Percentage Limits						
by Farm Size (after expansion)						
< 1 mil lbs per yr	< 1%	None	1 to 4%	0.25	> 4%	0.50
1 to 5 mil lbs per yr	< 1%	None	1 to 4%	0.50	> 4%	1.00
5 to 20 mil lbs per yr	< 1%	None	1 to 4%	0.75	> 4%	1.50
> 20 mil lbs per yr	< 1%	None	1 to 4%	1.00	> 4%	2.00
#3 Fixed MAF with API Volume Limits						
by Farm Size (after expansion)						
< 1 mil lbs per yr	< 1 mil lbs	None	1 to 4 mil lbs	0.25	> 4 mil lbs	0.50
1 to 5 mil lbs per yr	< 1 mil lbs	None	1 to 4 mil lbs	0.50	> 4 mil lbs	1.00
5 to 20 mil lbs per yr	< 1 mil lbs	None	1 to 4 mil lbs	0.75	> 4 mil lbs	1.50
> 20 mil lbs per yr	< 1 mil lbs	None	1 to 4 mil lbs	1.00	> 4 mil lbs	2.00
#4 API and MAF Adjusted by Margin[a]						
by Farm Size (after expansion)						
< 1 mil lbs per yr	<0.5 to <1.1%	None	0.5 to 4.4%	0.1875 to 0.375	> 2% to >4.4%	0.375 to 0.75
1 to 5 mil lbs per yr	<0.5 to <1.1%	None	0.5 to 4.4%	0.375 to 0.75	> 2% to >4.4%	0.75 to 1.50
5 to 20 mil lbs per yr	<0.5 to <1.1%	None	0.5 to 4.4%	0.5625 to 1.125	> 2% to >4.4%	1.125 to 2.25
> 20 mil lbs per yr	<0.5 to <1.1%	None	0.5 to 4.4%	0.75 to 1.50	> 2% to >4.4%	1.50 to 3.00
#5 Fixed API and MAF on Additional Milk						
by Farm Size (after expansion)						
< 1 mil lbs per yr	< 1%	None	1 to 4%	2.50	> 4%	5.00
1 to 5 mil lbs per yr	< 1%	None	1 to 4%	5.00	> 4%	10.00
5 to 20 mil lbs per yr	< 1%	None	1 to 4%	7.50	> 4%	15.00
> 20 mil lbs per yr	< 1%	None	1 to 4%	10.00	> 4%	20.00

Note: Allowable Growth is the increase in annual milk production during a given calendar year compared to the previous calendar year.
[a] Adjustments are made based on whether the DMC margin is above or below $8/cwt. The range values shown for this program design are for DMC margins of $4/cwt (lower values of allowed growth and higher values for market access fees) to $12/cwt (higher values of allowed growth and lower values for market access fees). Margin values between $4/cwt and $8/cwt are scaled linearly between the values shown, and a complete table is provided in the Appendix A1.

Assumptions Regarding Other Programs and Market Impacts

For both programs, our analysis assumes operation of the MPP-Dairy/Dairy Margin Coverage program as implemented from 2014 to 2018 (MPP-Dairy) and re-structured in the 2018 Farm Bill (DMC). We assumed relatively low participation in MPP-Dairy prior to 2018, with the largest proportion of producers in all four size categories and both regions (California and the rest of US) signing up for catastrophic margin coverage at the $4/cwt level, and small amounts of sign-up at the $6.50/cwt and $8/cwt margin values. For the more generous DMC program, we assumed that 75% of producers would sign up for $9.50/cwt margin coverage, and another 20% would sign up at the $5/cwt margin level. We also incorporated changes to the definition of the Class I Mover under Federal Milk Marketing Orders (FMMO) in January 2019 from the provisions of 2018 Farm Bill and the transition of California from state marketing order regulation to a FMMO in November 2018. The model scenarios do not include other authorized risk management programs currently (such as the Livestock Growth Margin-Dairy and the Dairy Revenue Protection program) because these and (other risk management programs) are likely to have limited market impact on price variability, although they can affect government expenditures.

With regard to developments due to trade disputes or new trade agreements, we retained NAFTA provisions for trade with Mexico and Canada (given relatively small differences between them and the USMCA). We used actual NASS-reported corn and soybean prices through October 2018 for the calculation of the margin values, and trend projections from the Chicago Mercantile Exchange (CME) through various months in 2021. Alfalfa prices were assumed to increase at a rate of 1% per year from October 2018 values. We represented other effects of the trade dispute with China via a 25% initial reduction in US exports of all tradable dairy products to China beginning in June 2018. Direct payments to dairy farmers to compensate for trade losses were modeled for December 2018 with $0.04/cwt paid on total milk production during June to December 2018.

It is also important to note that we do not consider the administrative arrangements and specific program provisions appropriate to enforce the analyzed programs. Rather, we assume that these can be developed and implemented in a manner that will allow the programs to be effective.

Results

Our analyses indicate that many of the programs can reduce the degree of price variation, but generally only to a moderate degree for three reasons: the lower degree of price variability during 2014 to 2018; the programs have price-enhancing effects that can tend to increase variability compared to the Baseline without GMP; and because there is natural seasonal variation in milk production that contributes to price volatility. All five GMP designs had farm price-enhancing (and margin-enhancing) effects, and the magnitude of these effects was associated with the size or nature of the assumed MAF and API structures. Table 2 provides detailed results for analyzed outcomes, and Tables 3 and 4 report differences and percentage differences between the Baseline and program outcomes. Key specific results include:

- All of the analyzed GMP configurations increased the average all-milk price during 2014 to 2021, with a range of $0.73/cwt to $1.41/cwt (Figure 1). Design #3*, (Fixed MAF with API Volume Limits)* had the largest price-enhancing effects, and design #5 (*Fixed API and MAF on Additional Milk*) with MAF payments paid on additional (marginal) milk resulted in the smallest price enhancement. Although average All Milk prices with GMP are higher, prices are higher without a GMP during the cyclical price peak that was simulated during 2017-2018[11].
- Under all GMP designs analyzed, the changes in the milk price would be accompanied by refund payments averaging between $0.42/cwt and $1.09/cwt, increasing the total revenue per cwt (from price and refunds combined) $1.15/cwt and $2.13/cwt.
- Price variation measured by the Mean Absolute Deviation (MAD) would decrease under all GMP analyzed, with a range between $0.16/cwt and $0.21/cwt (Figure 3). For example, the deviation from the average all-milk price during 2014 to 2021 in the Baseline scenario was $0.45/cwt[12], whereas this was reduced to $0.24/cwt for the GMP with API based on volume of milk production.
- GMP programs tend to reduce the impact of a three-year cycle on variation in milk prices. The remaining variation is largely seasonal (12 months with lower prices in the Spring and higher prices in the Fall).
- All GMP programs analyzed would increase the average retail price of fluid milk, with a range from $0.09/gallon to $0.15/gallon (3.2% to 5.3%) during 2014-2021 (Figure 4). GMP programs would increase the average wholesale price of American cheese by $0.05/lb to $0.11/lb (Figure 5).
- GMP would reduce the average annual value of US dairy product exports during 2014-2021 by 17 to 26% compared to no GMP, depending on the degree of price enhancement (Figure 6). However, these mean values reflect a reduction in the *rate of growth* of the value of US dairy exports (Figure 7) *not an absolute reduction* in the volume of exports. The value of US dairy product imports would increase 2.9% to 4.8% due to price enhancement. The increase in imports does not completely offset increases in the All Milk price due to continued US import trade restrictions, particularly for products containing butterfat.
- Government expenditures (net of MPP-Dairy/DMC premium payments) during 2014-2021 under the Baseline are projected to be $ 5.9 billion, much of which is due to indemnity payments under the DMC program during 2019 to 2021. All but one GMP configuration would reduce government expenditures by $0.6 billion to $2.6 billion. The program with MAF based on additional milk would result in an increase in government expenditures due to lower prices during 2019-2021 than other GMP.
- All GMP designs increase the average Net Farm Operating Income (NFOI) for all types of farms if they stay within the limits set by the API, often by substantial percentages (see example for farms with 1-5 million lbs of production, Figure 10). Farms expanding more

[11] This price peak can be determined from actual as well as simulated data and was smaller than previous cyclical price peaks.
[12] This is value comes from calculating the average all-milk price for the Baseline scenario and calculating the average of the absolute value (making negative values positive) of all of the difference from that average during 2014 to 2021.

than the API but still in Tier 1 would experience average NFOI generally still higher than without a GMP given higher milk prices that offset to some extent the payment of market access fees. Farms expanding by amounts that place them in Tier 2 would generally see reduced average NFOI compared to average NFOI without a GMP. However, an individual expanding farm would see this decrease only in the year of expansion[13], and as for Tier 1 farms, the market access fee would be offset to some extent by higher milk prices. NFOI is always higher with GMP than without GMP for farms staying within API (Figure 11), but NFOI for farms in Tier 1 and Tier 2 can be lower during some months than without a GMP;

- An average Wisconsin grazing dairy staying within allowable growth is simulated to experience an increase in average annual Net Farm Operating Income (NFOI) of up to 74% ($23,000). An average Wisconsin grazing dairy is simulated to see increased NFOI even with growth above the API for most of the GMP designs analyzed;
- Total average annual milk marketed in the US during 2014 to 2021 decreased under the GMP compared to the Baseline scenario without GMP, by 5.6% to 9.4%. However, as for the value of US dairy product exports, this lower average does not mean that milk production decreases. Rather, there is slower growth in US milk production than without GMP;
- Consistent with the impact on farm milk prices, the GMP increase FMMO class prices and other dairy product prices, with larger percentage impacts on Class IV and Class II prices (due to larger impacts on butter and NDM prices, as these are assumed to be the uses of skim and cream that balance supply and demand in a current month).
- US domestic dairy product sales are generally decreased under GMP, from very small amounts to usually less than 3% even for the GMP with the largest price-enhancing effects.

References

Nicholson, C., and M. Stephenson. 2019. Analyses of Selected Dairy Programs Proposed to Reduce Variability in Milk Prices and Farm Income. Program on Dairy Markets and Policy Working Paper19-01, March.

Nicholson, C. F. and M. W Stephenson. 2015. Price Cycles in the U.S. Dairy Supply Chain and their Management Implications. Agribusiness: An International Journal, 31:507-520.

Nicholson, C. F. and M. W. Stephenson. 2010. Analysis of Proposed Programs to Mitigate Price Volatility in the U.S. Dairy Industry. Project report for consortium of dairy industry organizations administered by the Milk Producers Council. September.

Acknowledgements

We gratefully acknowledge the considerable efforts of Tom Kriegl to assist in development of the analysis of grazing farms in WI. Sarah Lloyd and Michelle Miller of the University of

[13] A example of how the payment of MAF and receipt of MAF funds would work over 3 years for a farm expanding from 4 million lbs per year to 5 million lbs per year is provided in Appendix 3.

Wisconsin Center for Integrated Agricultural Systems provided relevant inputs for model structure modifications and GMP program designs to be analyzed.

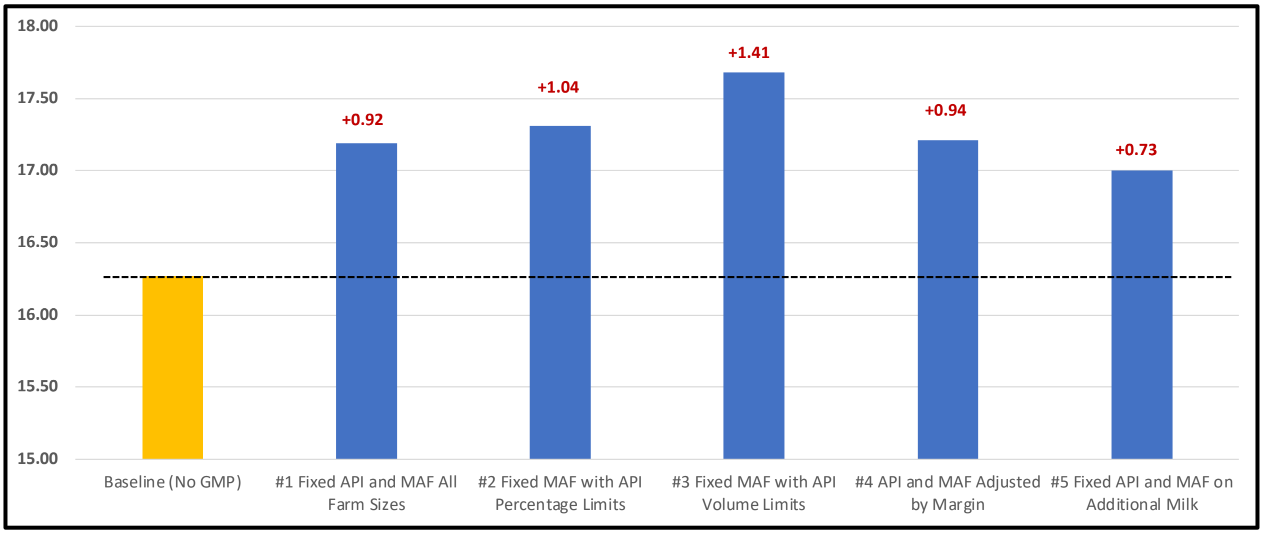

Figure 1. Simulated Average All Milk Prices for Baseline and Five GMP Programs, 2014-2021, $/cwt

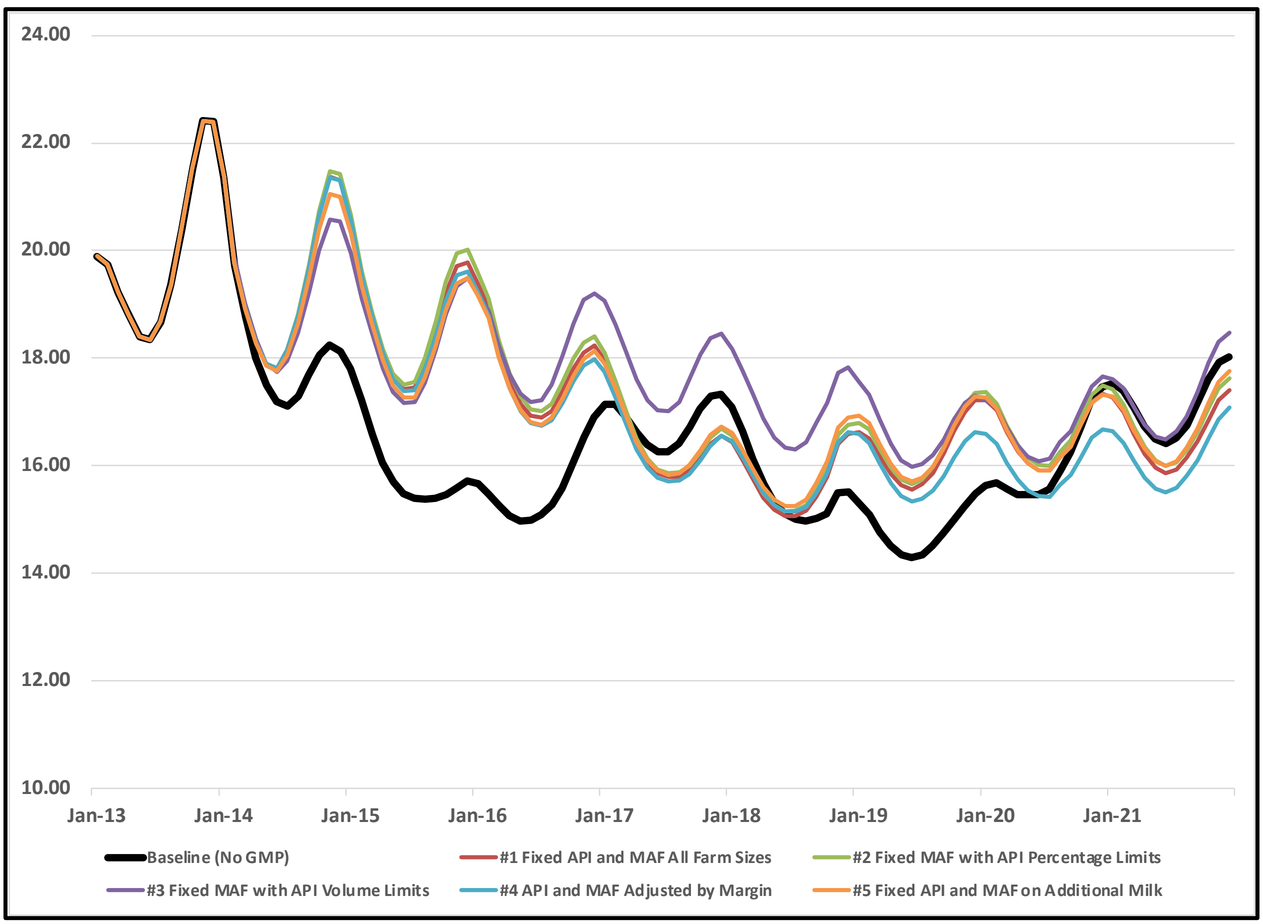

Figure 2. Simulated All Milk Prices for Baseline and Five GMP Programs, 2014-2021, $/cwt

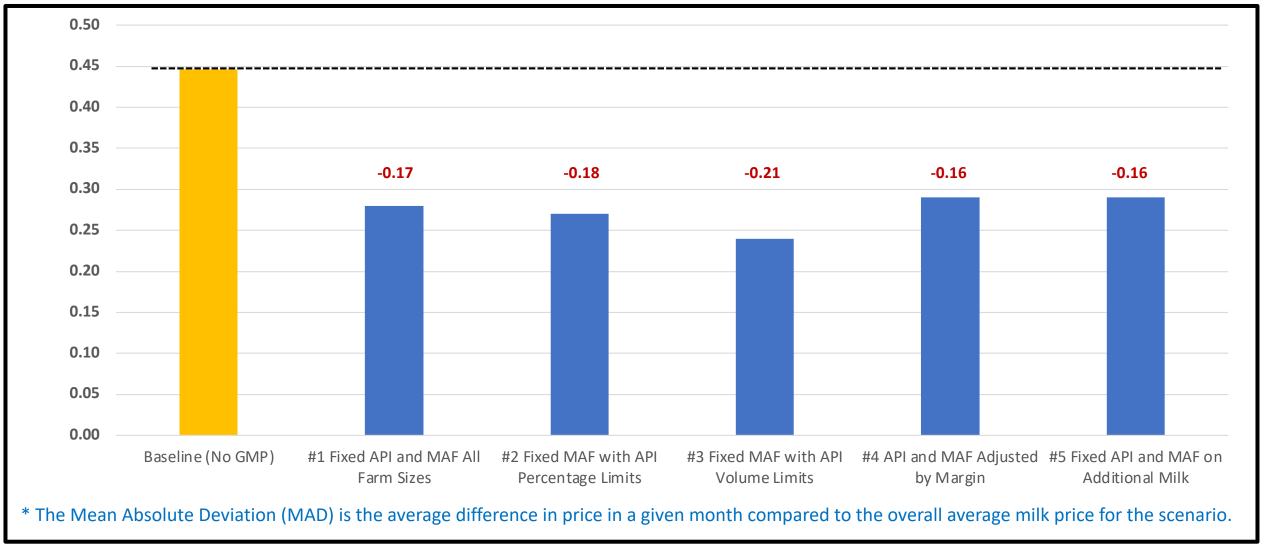

Figure 3. Simulated Average Mean Absolute Deviation[14] in All Milk Price, for and Five GMP Programs, 2014-2021, $/cwt

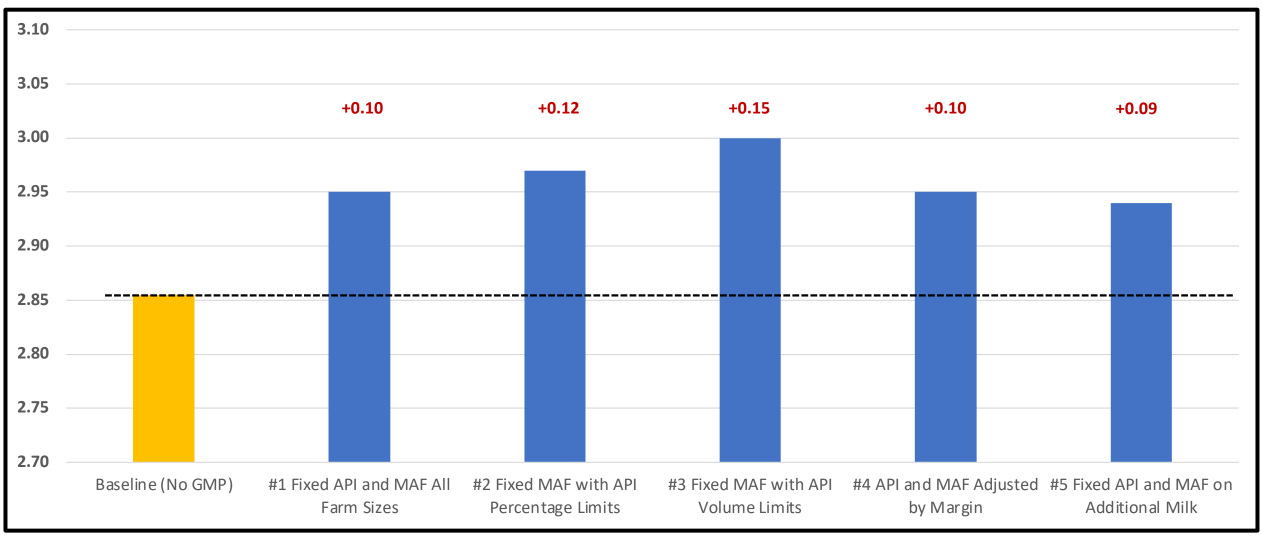

Figure 4. Simulated Average Retail Fluid Milk Price for Baseline and Five GMP Programs, 2014-2021, $/gallon

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[14] The mean absolute deviation is the average value in $/cwt by which the milk price differs from its overall average during 2014-2021. Mathematically, $MAD = \frac{\sum_{n=1}^{N} ABS(All\ Milk\ Price_n - Mean\ All\ Milk\ Price)}{N}$.

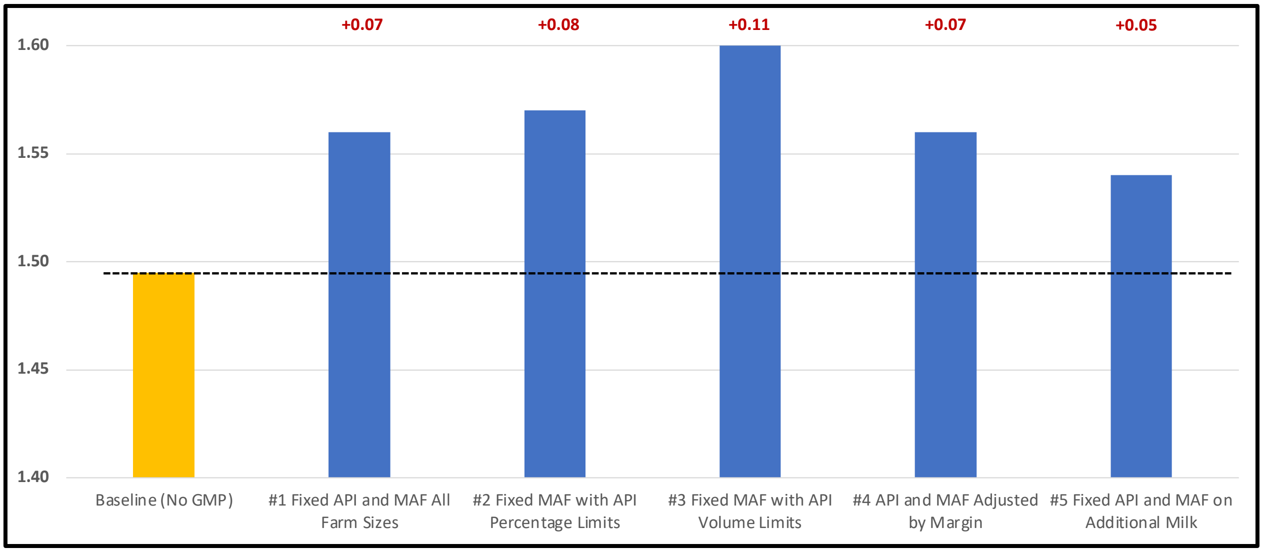

Figure 5. Simulated Average Wholesale American Cheese Price for Baseline and Five GMP Programs, 2014-2021, $/lb

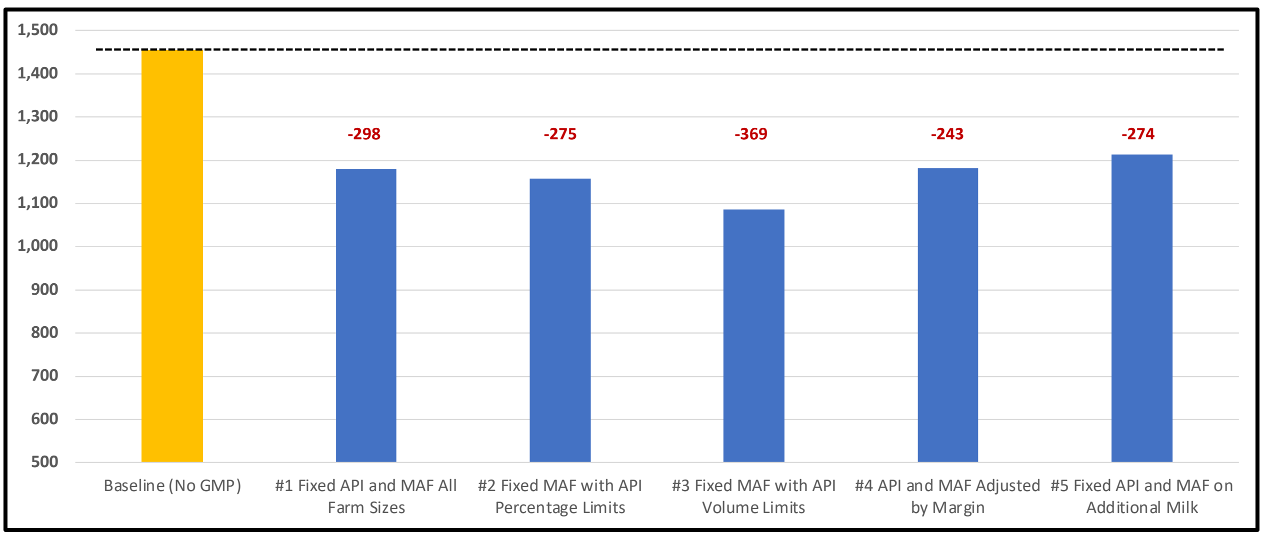

Figure 6. Simulated Average Total Value of Dairy Product Exports, Baseline and Five GMP Programs, 2014-2021, $ million/month

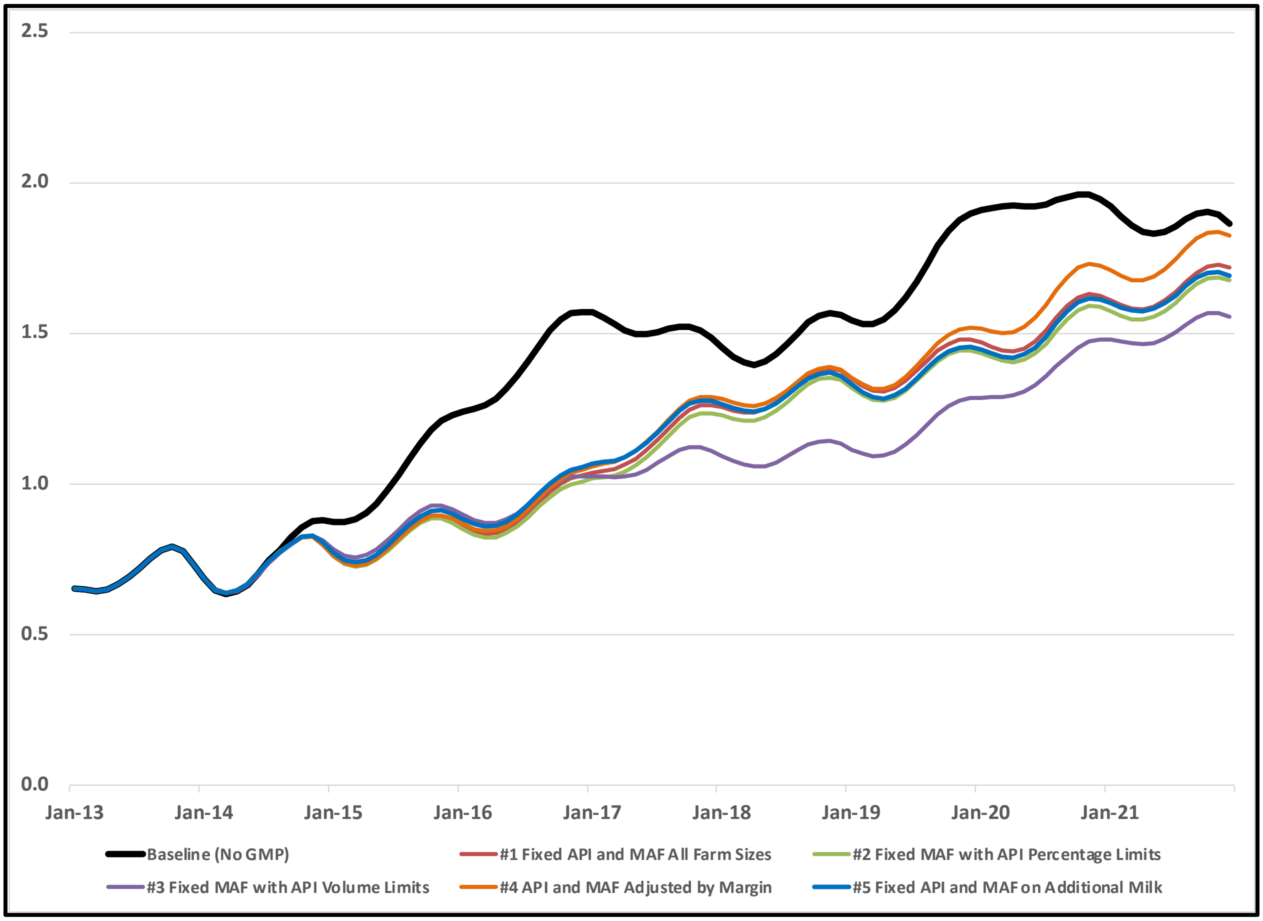

Figure 7. Simulated Total Value of Dairy Product Exports for Baseline and Five GMP Programs, 2014-2021, $ million/month

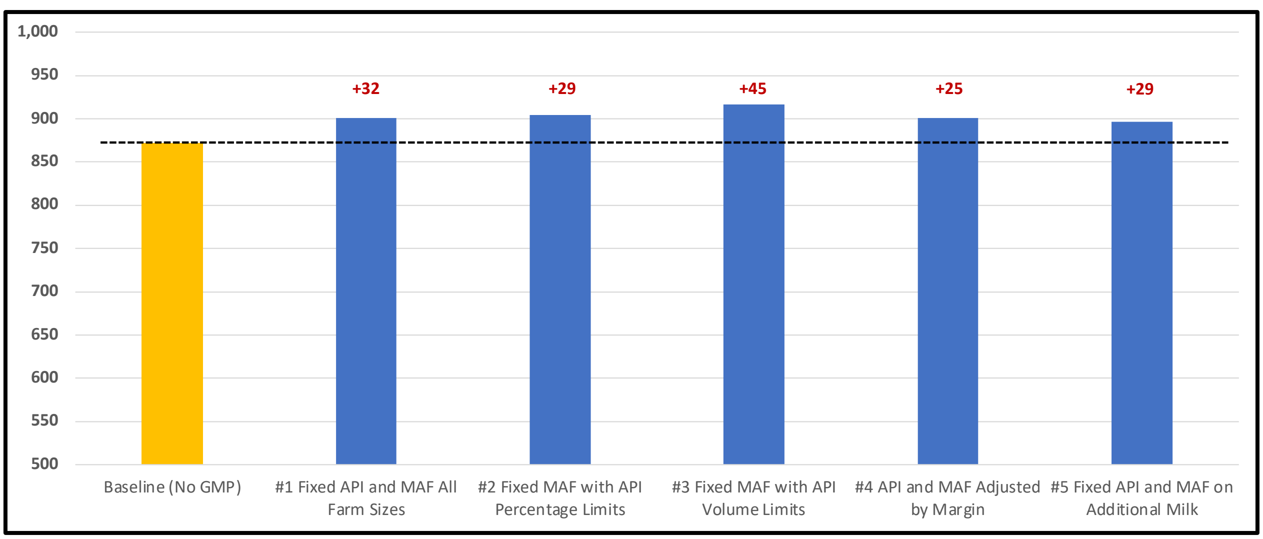

Figure 8. Simulated Average Total Value of Dairy Product Imports, Baseline and Five GMP Programs, 2014-2021, $ million/month

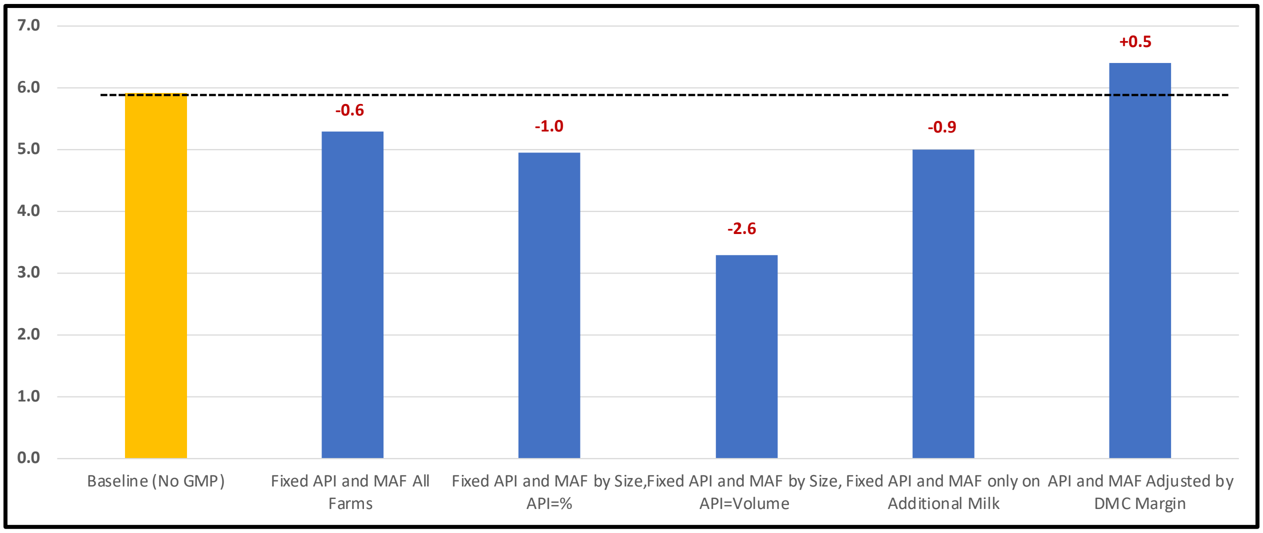

Figure 9. Simulated Total Government Expenditures on the Dairy Margin Coverage Program during 2014 to 2021, Baseline and Five GMP Programs, $ billion

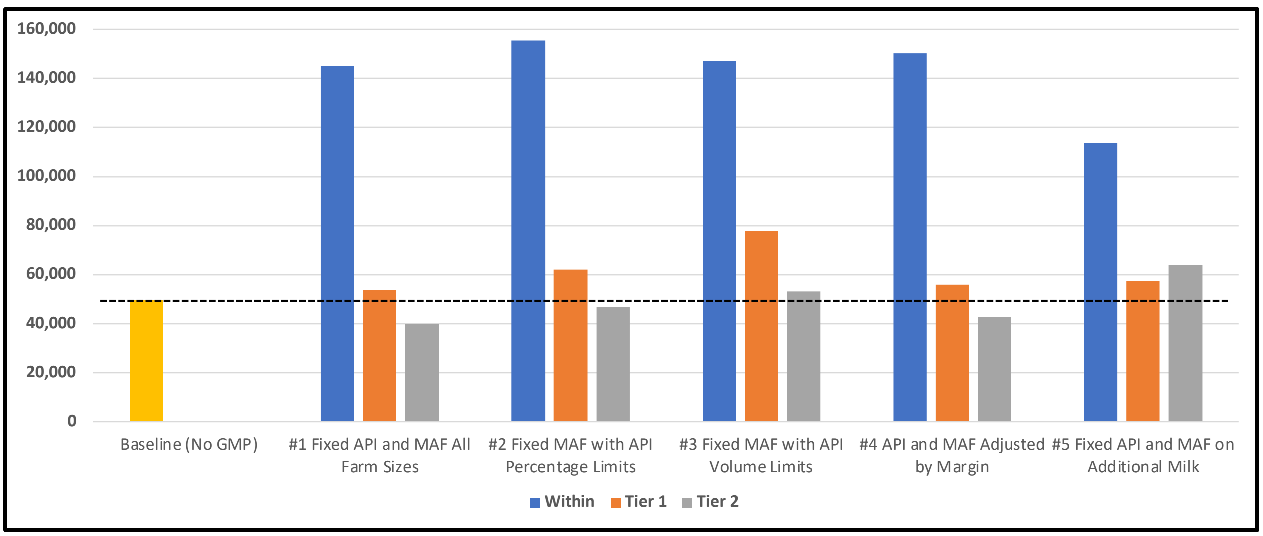

Figure 10. Simulated Average Annual Net Farm Operating Income for a Farm with Milk Production of 4 Million lbs per year, Baseline and Five GMP Programs, By GMP Tier, 2014-2021, $/farm/year

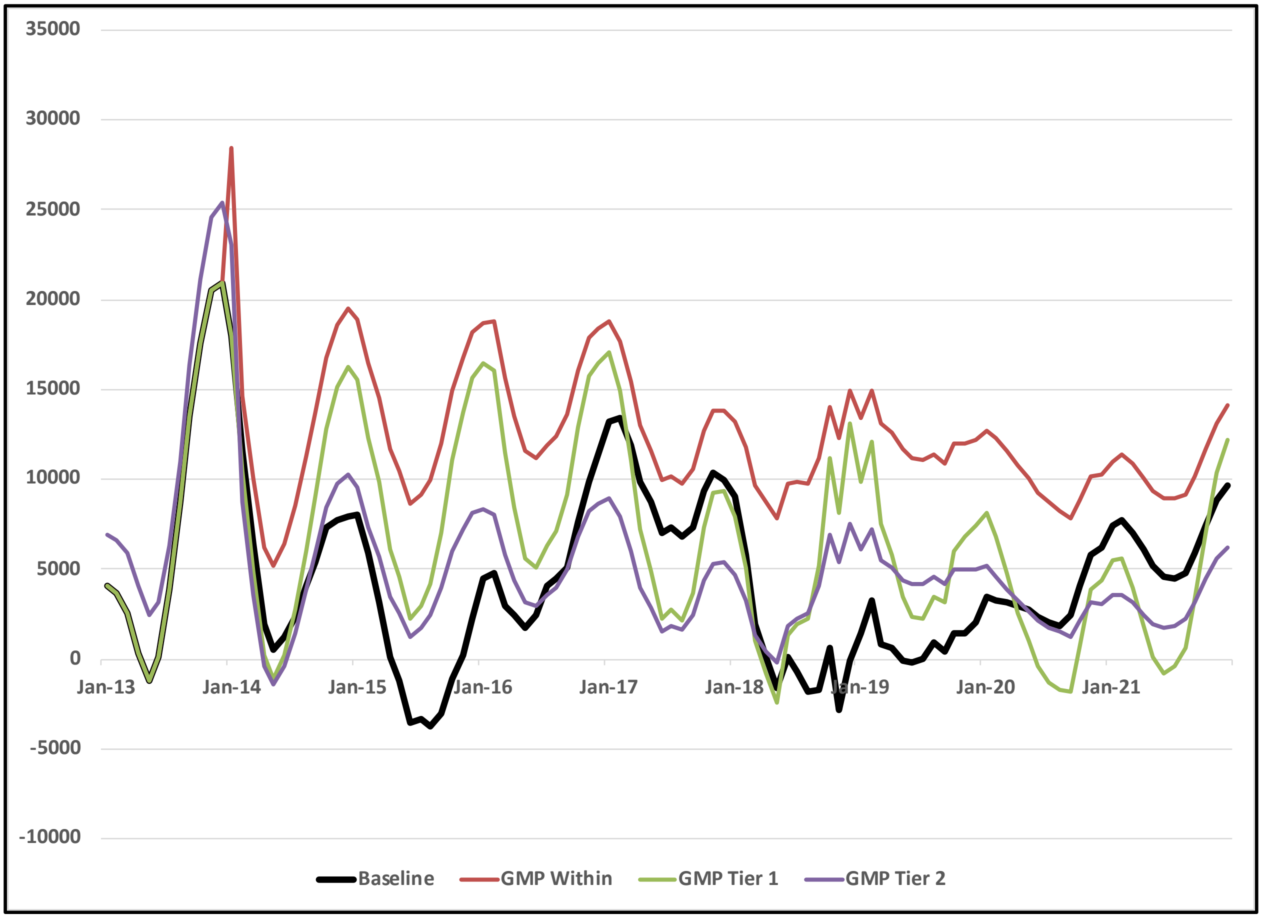

Figure 11. Simulated Net Farm Operating Income for a Farm with Milk Production of 4 Million lbs per year, Baseline for Design #3 *Fixed MAF with API Volume Limits*, By GMP Tier, 2014-2021, $/farm/month

Table 2. Selected Simulated Outcomes, Baseline and Five Proposed Programs, Average 2014-2021

Outcome	Units	Baseline (No GMP)	#1 Fixed API and MAF All Farm Sizes	#2 Fixed MAF with API Percentage Limits	#3 Fixed MAF with API Volume Limits	#4 API and MAF Adjusted by Margin	#5 Fixed API and MAF on Additional Milk
Description			*API 1-4% MAF $0.625 or $1.25*	*API 1-4% MAF $0.25 to $2.00*	*API 1 – 4 mil lbs $0.25 to $2.00*	*API 1-4% MAF $0.19 to $3.00*	*API 1-4% MAF $2.50 to $20.00*
US All Milk Price	$/cwt	16.27	17.19	17.31	17.68	17.21	17.00
Refund for Farms Within Allowable Growth	$/cwt	0.00	0.98	1.09	0.60	1.08	0.42
Milk Revenue for Farms Within Allowable Growth	$/cwt	16.27	18.18	18.40	18.28	18.29	17.42
Average Deviation After Program	$/cwt	0.45	0.28	0.27	0.24	0.29	0.29
Average Margin Over Feed Costs	$/cwt	7.28	8.20	8.32	8.70	8.22	8.00
NFOI, <1 mil lbs, US, Within	$/farm/year	35,672	61,565	63,608	60,306	62,404	55,180
NFOI, < 1 mil lbs, US, Tier 1	$/farm/year	35,672	34,746	39,734	42,098	38,634	39,476
NFOI, < 1 mil lbs, US, Tier 2	$/farm/year	35,672	31,339	37,591	38,370	36,994	40,920
NFOI, 1-5 mil lbs, US, Within	$/farm/year	49,343	145,024	155,510	147,085	150,067	113,542
NFOI, 1-5 mil lbs, US, Tier 1	$/farm/year	49,343	53,821	61,973	77,695	55,831	57,484
NFOI, 1-5 mil lbs, US, Tier 2	$/farm/year	49,343	39,979	46,579	53,058	42,869	63,975
NFOI, 5-20 mil lbs, US, Within	$/farm/year	310,122	726,686	771,301	732,130	751,220	591,121
NFOI, 5-20 mil lbs, US, Tier 1	$/farm/year	310,122	398,588	387,332	466,351	376,134	419,407
NFOI, 5-20 mil lbs, US, Tier 2	$/farm/year	310,122	202,858	190,516	223,213	181,362	297,814
NFOI, >20 mil lbs, US, Within	$/farm/year	1,476,900	3,573,144	3,777,228	3,887,496	3,682,320	2,966,304
NFOI, >20 mil lbs, US, Tier 1	$/farm/year	1,476,900	2,346,840	2,096,220	3,433,200	1,982,316	2,286,204
NFOI, >20 mil lbs, US, Tier 2	$/farm/year	1,476,900	1,049,915	825,046	1,148,959	797,335	1,484,292
NFOI, Grazing dairy, US, Within	$/farm/year	31,548	52,434	54,758	51,471	53,279	45,521
NFOI, Grazing dairy, US, Tier 1	$/farm/year	31,548	31,177	36,858	40,164	35,559	37,696
NFOI, Grazing dairy, US, Tier 2	$/farm/year	31,548	26,866	32,610	33,174	32,495	36,416

Outcome	Units	Baseline (No GMP)	#1 Fixed API and MAF All Farm Sizes	#2 Fixed MAF with API Percentage Limits	#3 Fixed MAF with API Volume Limits	#4 API and MAF Adjusted by Margin	#5 Fixed API and MAF on Additional Milk
NFOI, < 1 mil lbs, CA, Within	$/farm/year	25,775	50,988	53,381	47,637	51,655	43,428
NFOI, < 1 mil lbs, CA, Tier 1	$/farm/year	25,775	29,365	31,663	28,301	29,789	30,823
NFOI, < 1 mil lbs, CA, Tier 2	$/farm/year	25,775	24,260	27,661	25,767	27,604	31,148
NFOI, 1-5 mil lbs, CA, Within	$/farm/year	44,982	139,816	153,328	132,276	145,484	101,541
NFOI, 1-5 mil lbs, CA, Tier 1	$/farm/year	44,982	51,283	62,779	53,278	59,541	71,946
NFOI, 1-5 mil lbs, CA, Tier 2	$/farm/year	44,982	41,924	47,254	28,091	41,982	71,947
NFOI, 5-20 mil lbs, CA, Within	$/farm/year	269,873	808,058	870,948	798,460	835,056	602,345
NFOI, 5-20 mil lbs, CA, Tier 1	$/farm/year	269,873	348,103	347,854	364,643	316,180	375,475
NFOI, 5-20 mil lbs, CA, Tier 2	$/farm/year	269,873	152,816	136,562	121,824	117,516	265,162
NFOI, >20 mil lbs, CA, Within	$/farm/year	1,080,811	3,365,064	3,590,136	3,376,932	3,458,628	2,630,472
NFOI, >20 mil lbs, CA, Tier 1	$/farm/year	1,080,811	1,499,496	1,302,936	1,551,900	1,187,100	1,580,064
NFOI, >20 mil lbs, CA, Tier 2	$/farm/year	1,080,811	791,713	485,285	497,384	418,357	1,214,844
Total Milk Formally Marketed	bil lbs/year	255.8	239.0	237.2	231.8	238.6	241.6
Class I Price	$/cwt	18.26	19.15	19.26	19.50	19.15	18.97
Class II Price	$/cwt	15.35	16.33	16.45	16.79	16.34	16.14
Class III Price	$/cwt	15.13	15.79	15.87	16.17	15.81	15.64
Class IV Price	$/cwt	14.62	15.59	15.72	16.06	15.61	15.40
Retail Fluid Milk Price	$/gal	2.85	2.95	2.97	3.00	2.95	2.94
American Cheese Price	$/lb	1.49	1.56	1.57	1.60	1.56	1.54
Other Cheese Price	$/lb	1.55	1.61	1.61	1.64	1.61	1.59
Dry Whey Price	$/lb	0.57	0.57	0.57	0.57	0.57	0.57
Butter Price	$/lb	1.32	1.42	1.43	1.47	1.42	1.39
NDM Price	$/lb	1.30	1.37	1.38	1.40	1.37	1.36

Outcome	Units	Baseline (No GMP)	#1 Fixed API and MAF All Farm Sizes	#2 Fixed MAF with API Percentage Limits	#3 Fixed MAF with API Volume Limits	#4 API and MAF Adjusted by Margin	#5 Fixed API and MAF on Additional Milk
Total Value of US Exports	$ bil/year	17.5	14.2	13.9	13.0	14.2	14.6
Total Value of US Imports	$ bil/year	10.5	10.8	10.8	11.0	10.8	10.8
Cumulative US Government Expenditures	$bil	5.9	5.3	5.0	3.3	5.0	6.4
Fluid Milk Sales	bill lbs/year	58.4	57.9	57.8	57.7	57.9	58.0
American Cheese Sales	bil lbs/year	4.75	4.61	4.59	4.53	4.60	4.64
Other Cheese Sales	bil lbs/year	8.08	7.90	7.88	7.79	7.89	7.95
Butter Sales	bil lbs/year	2.14	2.11	2.10	2.08	2.11	2.12
Dry Whey Sales	bil lbs/year	0.44	0.44	0.44	0.43	0.44	0.44
NDM Sales	bil lbs/year	1.03	1.00	1.00	1.00	1.00	1.01

Note: In the NFOI rows reported above, “US” means farms other than in California and “CA” means California Farms. For the MAF programs, “Within” means limiting milk production growth to the allowable annual increase. “Tier 1” means farms that increase production by more than the allowable annual increase for Tier 1 but less than Tier 2, and thus pay the Tier 1 market access fee on their milk production. “Tier 2” means farms that increase production by more than the allowable annual increase for Tier 2 and thus pay the Tier 2 market access fee on their milk production.

Table 3. Selected Simulated Outcomes, Baseline and Differences from Baseline for Five Proposed Programs, Average 2014-2021

Outcome	Units	Baseline (No GMP)	#1 Fixed API and MAF All Farm Sizes	#2 Fixed MAF with API Percentage Limits	#3 Fixed MAF with API Volume Limits	#4 API and MAF Adjusted by Margin	#5 Fixed API and MAF on Additional Milk
Description			*API 1-4% MAF $0.625 or $1.25*	*API 1-4% MAF $0.25 to $2.00*	*API 1 – 4 mil lbs $0.25 to $2.00*	*API 1-4% MAF $0.19 to $3.00*	*API 1-4% MAF $2.50 to $20.00*
US All Milk Price	$/cwt	16.27	0.92	1.04	1.41	0.94	0.73
Refund for Farms Within Allowable Growth	$/cwt	0	0.98	1.09	0.60	1.08	0.42
Milk Revenue for Farms Within Allowable Growth	$/cwt	16.27	1.91	2.13	2.01	2.02	1.15
Average Deviation After Program	$/cwt	0.45	-0.17	-0.18	-0.21	-0.16	-0.16
Average Margin Over Feed Costs	$/cwt	7.28	0.92	1.04	1.42	0.94	0.72
NFOI, <1 mil lbs, US, Within	$/farm/year	35,672	25,893	27,936	24,634	26,732	19,508
NFOI, < 1 mil lbs, US, Tier 1	$/farm/year	35,672	-926	4,062	6,426	2,962	3,804
NFOI, < 1 mil lbs, US, Tier 2	$/farm/year	35,672	-4,333	1,919	2,698	1,322	5,248
NFOI, 1-5 mil lbs, US, Within	$/farm/year	49,343	95,681	106,167	97,742	100,724	64,199
NFOI, 1-5 mil lbs, US, Tier 1	$/farm/year	49,343	4,478	12,630	28,352	6,488	8,141
NFOI, 1-5 mil lbs, US, Tier 2	$/farm/year	49,343	-9,364	-2,764	3,715	-6,474	14,632
NFOI, 5-20 mil lbs, US, Within	$/farm/year	310,122	416,564	461,179	422,008	441,098	280,999
NFOI, 5-20 mil lbs, US, Tier 1	$/farm/year	310,122	88,466	77,210	156,229	66,012	109,285
NFOI, 5-20 mil lbs, US, Tier 2	$/farm/year	310,122	-107,264	-119,606	-86,909	-128,760	-12,308
NFOI, >20 mil lbs, US, Within	$/farm/year	1,476,900	2,096,244	2,300,328	2,410,596	2,205,420	1,489,404
NFOI, >20 mil lbs, US, Tier 1	$/farm/year	1,476,900	869,940	619,320	1,956,300	505,416	809,304
NFOI, >20 mil lbs, US, Tier 2	$/farm/year	1,476,900	-426,985	-651,854	-327,941	-679,565	7,392
NFOI, Grazing dairy, US, Within	$/farm/year	31,548	20,886	23,210	19,923	21,731	13,973
NFOI, Grazing dairy, US, Tier 1	$/farm/year	31,548	-371	5,310	8,616	4,011	6,148

Outcome	Units	Baseline (No GMP)	#1 Fixed API and MAF All Farm Sizes	#2 Fixed MAF with API Percentage Limits	#3 Fixed MAF with API Volume Limits	#4 API and MAF Adjusted by Margin	#5 Fixed API and MAF on Additional Milk
NFOI, Grazing dairy, US, Tier 2	$/farm/year	31,548	-4,682	1,062	1,626	947	4,868
NFOI, < 1 mil lbs, CA, Within	$/farm/year	25,775	25,213	27,606	21,862	25,880	17,653
NFOI, < 1 mil lbs, CA, Tier 1	$/farm/year	25,775	3,590	5,888	2,526	4,014	5,048
NFOI, < 1 mil lbs, CA, Tier 2	$/farm/year	25,775	-1,515	1,886	-8	1,829	5,373
NFOI, 1-5 mil lbs, CA, Within	$/farm/year	44,982	94,834	108,346	87,294	100,502	56,559
NFOI, 1-5 mil lbs, CA, Tier 1	$/farm/year	44,982	6,301	17,797	8,296	14,559	26,964
NFOI, 1-5 mil lbs, CA, Tier 2	$/farm/year	44,982	-3,058	2,272	-16,891	-3,000	26,965
NFOI, 5-20 mil lbs, CA, Within	$/farm/year	269,873	538,185	601,075	528,587	565,183	332,472
NFOI, 5-20 mil lbs, CA, Tier 1	$/farm/year	269,873	78,230	77,981	94,770	46,307	105,602
NFOI, 5-20 mil lbs, CA, Tier 2	$/farm/year	269,873	-117,057	-133,311	-148,049	-152,357	-4,711
NFOI, >20 mil lbs, CA, Within	$/farm/year	1,080,811	2,284,253	2,509,325	2,296,121	2,377,817	1,549,661
NFOI, >20 mil lbs, CA, Tier 1	$/farm/year	1,080,811	418,685	222,125	471,089	106,289	499,253
NFOI, >20 mil lbs, CA, Tier 2	$/farm/year	1,080,811	-289,098	-595,526	-583,427	-662,454	134,033
Total Milk Formally Marketed	bil lbs/year	255.8	-16.8	-18.6	-24.0	-17.2	-14.2
Class I Price	$/cwt	18.26	0.89	1.00	1.24	0.89	0.71
Class II Price	$/cwt	15.35	0.98	1.10	1.44	0.99	0.79
Class III Price	$/cwt	15.13	0.66	0.74	1.04	0.68	0.51
Class IV Price	$/cwt	14.62	0.97	1.10	1.44	0.99	0.78
Retail Fluid Milk Price	$/gal	2.85	0.10	0.12	0.15	0.10	0.09
American Cheese Price	$/lb	1.49	0.07	0.08	0.11	0.07	0.05
Other Cheese Price	$/lb	1.55	0.06	0.06	0.09	0.06	0.04
Dry Whey Price	$/lb	0.57	0.00	0.00	0.00	0.00	0.00

Outcome	Units	Baseline (No GMP)	#1 Fixed API and MAF All Farm Sizes	#2 Fixed MAF with API Percentage Limits	#3 Fixed MAF with API Volume Limits	#4 API and MAF Adjusted by Margin	#5 Fixed API and MAF on Additional Milk
Butter Price	$/lb	1.32	0.10	0.11	0.15	0.10	0.07
NDM Price	$/lb	1.3	0.07	0.08	0.10	0.07	0.06
Total Value of US Exports	$ bil/year	17.5	-3.3	-3.6	-4.5	-3.3	-2.9
Total Value of US Imports	$ bil/year	10.5	0.3	0.3	0.5	0.3	0.3
Cumulative US Government Expenditures	$bil	5.9	-0.6	-0.9	-2.6	-0.9	0.5
Fluid Milk Sales	bill lbs/year	58.4	-0.5	-0.6	-0.7	-0.5	-0.4
American Cheese Sales	bil lbs/year	4.75	-0.14	-0.16	-0.22	-0.15	-0.11
Other Cheese Sales	bil lbs/year	8.08	-0.18	-0.20	-0.29	-0.19	-0.13
Butter Sales	bil lbs/year	2.14	-0.03	-0.04	-0.06	-0.03	-0.02
Dry Whey Sales	bil lbs/year	0.44	0.00	0.00	-0.01	0.00	0.00
NDM Sales	bil lbs/year	1.03	-0.03	-0.03	-0.03	-0.03	-0.02

Note: In the NFOI rows reported above, "US" means farms other than in California and "CA" means California Farms. For the MAF programs, "Within" means limiting milk production growth to the allowable annual increase. "Tier 1" means farms that increase production by more than the allowable annual increase for Tier 1 but less than Tier 2, and thus pay the Tier 1 market access fee on their milk production. "Tier 2" means farms that increase production by more than the allowable annual increase for Tier 2 and thus pay the Tier 2 market access fee on their milk production.

Table 4. Selected Simulated Outcomes, Baseline and Percentage Differences from Baseline for Five Proposed Programs, Average 2014-2021

Outcome	Units	Baseline (No GMP)	#1 Fixed API and MAF All Farm Sizes	#2 Fixed MAF with API Percentage Limits	#3 Fixed MAF with API Volume Limits	#4 API and MAF Adjusted by Margin	#5 Fixed API and MAF on Additional Milk
Description			*API 1-4% MAF $0.625 or $1.25*	*API 1-4% MAF $0.25 to $2.00*	*API 1 – 4 mil lbs $0.25 to $2.00*	*API 1-4% MAF $0.19 to $3.00*	*API 1-4% MAF $2.50 to $20.00*
US All Milk Price	$/cwt	16.27	5.7%	6.4%	8.7%	5.8%	4.5%
Refund for Farms Within Allowable Growth	$/cwt	0					
Milk Revenue for Farms Within Allowable Growth	$/cwt	16.27	11.7%	13.1%	12.4%	12.4%	7.1%
Average Deviation After Program	$/cwt	0.45	-37.8%	-40.0%	-46.7%	-35.6%	-35.6%
Average Margin Over Feed Costs	$/cwt	7.28	12.6%	14.3%	19.5%	12.9%	9.9%
NFOI, <1 mil lbs, US, Within	$/farm/year	35,672	72.6%	78.3%	69.1%	74.9%	54.7%
NFOI, < 1 mil lbs, US, Tier 1	$/farm/year	35,672	-2.6%	11.4%	18.0%	8.3%	10.7%
NFOI, < 1 mil lbs, US, Tier 2	$/farm/year	35,672	-12.1%	5.4%	7.6%	3.7%	14.7%
NFOI, 1-5 mil lbs, US, Within	$/farm/year	49,343	193.9%	215.2%	198.1%	204.1%	130.1%
NFOI, 1-5 mil lbs, US, Tier 1	$/farm/year	49,343	9.1%	25.6%	57.5%	13.1%	16.5%
NFOI, 1-5 mil lbs, US, Tier 2	$/farm/year	49,343	-19.0%	-5.6%	7.5%	-13.1%	29.7%
NFOI, 5-20 mil lbs, US, Within	$/farm/year	310,122	134.3%	148.7%	136.1%	142.2%	90.6%
NFOI, 5-20 mil lbs, US, Tier 1	$/farm/year	310,122	28.5%	24.9%	50.4%	21.3%	35.2%
NFOI, 5-20 mil lbs, US, Tier 2	$/farm/year	310,122	-34.6%	-38.6%	-28.0%	-41.5%	-4.0%
NFOI, >20 mil lbs, US, Within	$/farm/year	1,476,900	141.9%	155.8%	163.2%	149.3%	100.8%
NFOI, >20 mil lbs, US, Tier 1	$/farm/year	1,476,900	58.9%	41.9%	132.5%	34.2%	54.8%
NFOI, >20 mil lbs, US, Tier 2	$/farm/year	1,476,900	-28.9%	-44.1%	-22.2%	-46.0%	0.5%
NFOI, Grazing dairy, US, Within	$/farm/year	31,548	66.2%	73.6%	63.2%	68.9%	44.3%

Outcome	Units	Baseline (No GMP)	#1 Fixed API and MAF All Farm Sizes	#2 Fixed MAF with API Percentage Limits	#3 Fixed MAF with API Volume Limits	#4 API and MAF Adjusted by Margin	#5 Fixed API and MAF on Additional Milk
NFOI, Grazing dairy, US, Tier 1	$/farm/year	31,548	-1.2%	16.8%	27.3%	12.7%	19.5%
NFOI, Grazing dairy, US, Tier 2	$/farm/year	31,548	-14.8%	3.4%	5.2%	3.0%	15.4%
NFOI, < 1 mil lbs, CA, Within	$/farm/year	25,775	97.8%	107.1%	84.8%	100.4%	68.5%
NFOI, < 1 mil lbs, CA, Tier 1	$/farm/year	25,775	13.9%	22.8%	9.8%	15.6%	19.6%
NFOI, < 1 mil lbs, CA, Tier 2	$/farm/year	25,775	-5.9%	7.3%	0.0%	7.1%	20.8%
NFOI, 1-5 mil lbs, CA, Within	$/farm/year	44,982	210.8%	240.9%	194.1%	223.4%	125.7%
NFOI, 1-5 mil lbs, CA, Tier 1	$/farm/year	44,982	14.0%	39.6%	18.4%	32.4%	59.9%
NFOI, 1-5 mil lbs, CA, Tier 2	$/farm/year	44,982	-6.8%	5.1%	-37.6%	-6.7%	59.9%
NFOI, 5-20 mil lbs, CA, Within	$/farm/year	269,873	199.4%	222.7%	195.9%	209.4%	123.2%
NFOI, 5-20 mil lbs, CA, Tier 1	$/farm/year	269,873	29.0%	28.9%	35.1%	17.2%	39.1%
NFOI, 5-20 mil lbs, CA, Tier 2	$/farm/year	269,873	-43.4%	-49.4%	-54.9%	-56.5%	-1.7%
NFOI, >20 mil lbs, CA, Within	$/farm/year	1,080,811	211.3%	232.2%	212.4%	220.0%	143.4%
NFOI, >20 mil lbs, CA, Tier 1	$/farm/year	1,080,811	38.7%	20.6%	43.6%	9.8%	46.2%
NFOI, >20 mil lbs, CA, Tier 2	$/farm/year	1,080,811	-26.7%	-55.1%	-54.0%	-61.3%	12.4%
Total Milk Formally Marketed	bil lbs/year	255.8	-6.6%	-7.3%	-9.4%	-6.7%	-5.6%
Class I Price	$/cwt	18.26	4.9%	5.5%	6.8%	4.9%	3.9%
Class II Price	$/cwt	15.35	6.4%	7.2%	9.4%	6.4%	5.1%
Class III Price	$/cwt	15.13	4.4%	4.9%	6.9%	4.5%	3.4%
Class IV Price	$/cwt	14.62	6.6%	7.5%	9.8%	6.8%	5.3%
Retail Fluid Milk Price	$/gal	2.85	3.5%	4.2%	5.3%	3.5%	3.2%
American Cheese Price	$/lb	1.49	4.7%	5.4%	7.4%	4.7%	3.4%
Other Cheese Price	$/lb	1.55	3.9%	3.9%	5.8%	3.9%	2.6%

Outcome	Units	Baseline (No GMP)	#1 Fixed API and MAF All Farm Sizes	#2 Fixed MAF with API Percentage Limits	#3 Fixed MAF with API Volume Limits	#4 API and MAF Adjusted by Margin	#5 Fixed API and MAF on Additional Milk
Dry Whey Price	$/lb	0.57	0.0%	0.0%	0.0%	0.0%	0.0%
Butter Price	$/lb	1.32	7.6%	8.3%	11.4%	7.6%	5.3%
NDM Price	$/lb	1.3	5.4%	6.2%	7.7%	5.4%	4.6%
Total Value of US Exports	$ bil/year	17.5	-18.9%	-20.6%	-25.7%	-18.9%	-16.6%
Total Value of US Imports	$ bil/year	10.5	2.9%	2.9%	4.8%	2.9%	2.9%
Cumulative US Government Expenditures	$bil	5.9	-10.2%	-15.3%	-44.1%	-15.3%	8.5%
Fluid Milk Sales	bill lbs/year	58.4	-0.9%	-1.0%	-1.2%	-0.9%	-0.7%
American Cheese Sales	bil lbs/year	4.75	-2.9%	-3.4%	-4.6%	-3.2%	-2.3%
Other Cheese Sales	bil lbs/year	8.08	-2.2%	-2.5%	-3.6%	-2.4%	-1.6%
Butter Sales	bil lbs/year	2.14	-1.4%	-1.9%	-2.8%	-1.4%	-0.9%
Dry Whey Sales	bil lbs/year	0.44	0.0%	0.0%	-2.3%	0.0%	0.0%
NDM Sales	bil lbs/year	1.03	-2.9%	-2.9%	-2.9%	-2.9%	-1.9%

Note: In the NFOI rows reported above, "US" means farms other than in California and "CA" means California Farms. For the MAF programs, "Within" means limiting milk production growth to the allowable annual increase. "Tier 1" means farms that increase production by more than the allowable annual increase for Tier 1 but less than Tier 2, and thus pay the Tier 1 market access fee on their milk production. "Tier 2" means farms that increase production by more than the allowable annual increase for Tier 2 and thus pay the Tier 2 market access fee on their milk production.

Appendix A1

Values of allowable growth and market access fees for the program design that adjusts these based on the DMC margin (#4 *API and MAF Adjusted by Margin*)

	Market Access Fee		Allowable Growth			
DMC Margin, $/cwt	Tier 1	Tier 2	Within	Tier 1 Min	Tier 1 Max	Tier 2 Min
4.00	0.375	0.75	0.5%	0.5%	2.0%	2.0%
4.00	0.75	1.50	0.5%	0.5%	2.0%	2.0%
4.00	1.125	2.25	0.5%	0.5%	2.0%	2.0%
4.00	1.50	3.00	0.5%	0.5%	2.0%	2.0%
8.00	0.25	0.50	1.0%	1.0%	4.0%	4.0%
8.00	0.50	1.00	1.0%	1.0%	4.0%	4.0%
8.00	0.75	1.50	1.0%	1.0%	4.0%	4.0%
8.00	1.00	2.00	1.0%	1.0%	4.0%	4.0%
12.00	0.1875	0.375	1.1%	1.1%	4.4%	4.4%
12.00	0.375	0.75	1.1%	1.1%	4.4%	4.4%
12.00	0.5625	1.125	1.1%	1.1%	4.4%	4.4%
12.00	0.75	1.50	1.1%	1.1%	4.4%	4.4%

Appendix A2

Discussion of Farm-level Incentives Under GMP

Modeling the effects of a GMP program on farm incentives can be challenging given the diversity of farm types and intended expansion paths. Our analysis uses expected distributions of growth by farm size category based on analysis of historical data on farm production growth, which determines the percentages of farms within the API, in Tier 1 and in Tier 2 in the absence of any MAF payments for expansion or receipt of payments. The percentages in these categories are then adjusted based on the differences in expected average annual Net Farm Operating Income (NFOI) for farms in each of the categories. The model thus tracks the "average farm" in each of the three GMP categories over time (for example, see reported average NFOI income values in Table 1 for the three GMP categories for each of the farm types) to make this assessment. The higher expected incomes earned by farms staying within the API compared to those in Tier 1 and Tier 2 are incentives that induce more farms to stay within the API. Appendix A3 indicates this set of incentives considering the average farm with annual milk production between 1 and 5 million lbs.

This formulation is logical in the sense that it captures the core effect of a GMP expansion. However, it does not represent the motivations, constraints or financial calculations that might be relevant for any individual farm. The calculations in Appendix 3 suggest that a GMP program would provide strong incentives to avoid "incremental" growth that would require MAF payments each year (and foregoing receipt of potential MAF payments to the farm). Faster expansions (completed within a year or two) would reduce MAF payments for expansion and allow farm to more quickly receive MAF payments once expansion is completed and they return to growth within the API.

The impacts of a GMP on "non-incremental" expansions is a bit more complex because these depend on a number of factors not modeled directly based on the use of probability distributions. Depending on the price-enhancement effects of a GMP and the costs of production on a farm, some farms may perceive additional incentives for "non-incremental" expansion under a GMP, because they pay for MAF and can re-coup over time at least some of those MAF through higher milk prices and receipt of MAF when they stay within the API. Our modeling work does not capture these incentive effects directly. This is in part because additional incentives for expansion with a GMP would require a) farms to perceive (and predict accurately) the impacts GMP on milk prices, b) to accurately predict future values of MAF receipts, c) to have a sufficiently long-term perspective on the investment in new production capacity to be willing to repeatedly pay MAF, and d) to face no other constraints in terms of management, motivations or financing. Because these conditions are likely to apply to only a limited number of farms, we believe that the approach using farm-growth distributions modified by incentives under GMP designs is adequate for an initial proof-of-concept analysis such as is reported herein. However, future more detailed work (probably using experimental approaches and agent-based model) on farm-level incentives could be appropriate for more specific GMP implementation proposals.

Appendix A3

Examples of Market Access Fees and Net Milk Revenue per Hundredweight under GMP (#3 *Fixed MAF with API Volume Limits*) by Size and Tier based on Additional Milk Production Volume

Growth Strategy, Year	Milk Production, cwt/yr	Increase in Milk Production, cwt/yr	% Increase in Milk Production	Tier for GMP	MAF Payment, $/cwt	MAF Payment, $/farm	MAF Receipt, $/cwt	MAF Receipt, $/farm, year	Milk Revenue including MAF, $/cwt
Expansion of 1 million lbs per year in Year 1									
Initial	40,000								
Year 1	50,000	10,000	25.0%	Tier 2	1.50	75,000	0.00	0	16.20
Year 2	50,000	0	0.0%	Within	0.00	0	0.60	30,000	18.30
Year 3	50,000	0	0.0%	Within	0.00	0	0.60	30,000	18.30
Average									17.60
No Expansion									
Initial	40,000								
Year 1	40,000	0	0.0%	Within	0.00	0	0.60	24,000	18.30
Year 2	40,000	0	0.0%	Within	0.00	0	0.60	24,000	18.30
Year 3	40,000	0	0.0%	Within	0.00	0	0.60	24,000	18.30
Average									18.30
Expansion of 1 million lbs over three years									
Initial	40,000								
Year 1	43,333	3,333	8.3%	Tier 2	1.00	43,333	0.00	0	16.70
Year 2	46,667	3,333	7.7%	Tier 2	1.00	46,667	0.00	0	16.70
Year 3	50,000	3,333	7.1%	Tier 2	1.50	75,000	0.00	0	16.20
Average									16.53

Appendix A4

Summary of Scenarios with New Farm Entry and MAF Grace Period

Scenarios that assume entry of 60 farms each year during the analysis are used to assess whether providing a three-year grace period for that number of new farms would have a substantive effect on the outcomes of a GMP. We use the GMP program with Fixed MAF by farm size and API thresholds of 1% for Tier 1 and 4% for Tier 2, respectively. New farm entry with a grace period has a modest effect on the simulated average All Milk price (Table A4.1), and quite limited impacts MAF refunds or average price deviation.

Our analysis assumes that new farms have essentially the same production volumes and cost structures as existing farms of these two types. Thus, it is a simplification of the reality of how milk production patterns and costs might evolve on a start-up farm. Because we assume existing production levels on the two farm types for which entry is assumed, our approach is also a simplification compared to how a GMP might allow new entrants with up to a certain volume of milk to enter a grace period from MAF period. However, the analysis suggests that volumes of milk up to 5 million lbs per year could be granted a grace period of 3 years without substantive effects on GMP operation or outcomes. This assumes that sufficient legal protections can be put in place to ensure that new operations are in fact new entrants rather than re-organization by existing farms.

Table A4.1. Selected Simulated Outcomes, Baseline and GMP #2 (*Fixed MAF with API Percentage Limits*) No New Farm Entry and Two Scenarios Allowing New Farm Entry and 3-year Grace Period from MAF Payment, Average 2014-2021

Assumption, Outcome	Units	Baseline (No GMP)	#2 Fixed MAF with API Percentage Limits	#2 Fixed MAF with API Percentage Limits with New Farms	#2 Fixed MAF with API Percentage Limits with New Farms
Description of GMP design			*API 1-4% MAF $0.25 to $2.00*	*API 1-4% MAF $0.25 to $2.00*	*API 1-4% MAF $0.25 to $2.00*
Assumption for new farms		*None*	*None*	*60 with < 1 mil lbs per yr*	*60 with 1-5 mil lbs per yr*
Grace period for new farms		*N/A*	*N/A*	*3 years*	*3 years*
US All Milk Price	$/cwt	16.27	17.31	17.24	17.27
Refund for Farms Within Allowable Growth	$/cwt	0.00	1.09	1.09	1.09
Milk Revenue for Farms Within Allowable Growth	$/cwt	16.27	18.40	18.33	18.36
Average Deviation After Program	$/cwt	0.45	0.27	0.28	0.27

Appendix A5

Initial Assessment of GMP and Covid-19 Demand Impacts

The Covid-19 pandemic resulted in substantial disruptions to segments of the US dairy industry, particularly during the first months when a larger number of schools and restaurants were not operating on normal schedules. A relevant question is the extent to which a GMP would have had a stabilizing influence. An initial assessment that imposed demand shocks on fluid milk and cheese that replicated All Milk price patterns observed during the first six months of the pandemic suggests that a GMP would not have mitigated the price impacts resulting from the pandemic's impact on demand (Figure A5.1). However, this analysis suggests for a farm with 1 to 5 million lbs of milk production that was operating within API, the GMP program would have prevented Net Farm Operating Income from being negative during the demand impacts of the pandemic (Figure A5.2). The higher average level of NFOI during the years preceding the onset of the pandemic may also have provided additional reserves to farms during the six-month period of demand shocks and price impacts.

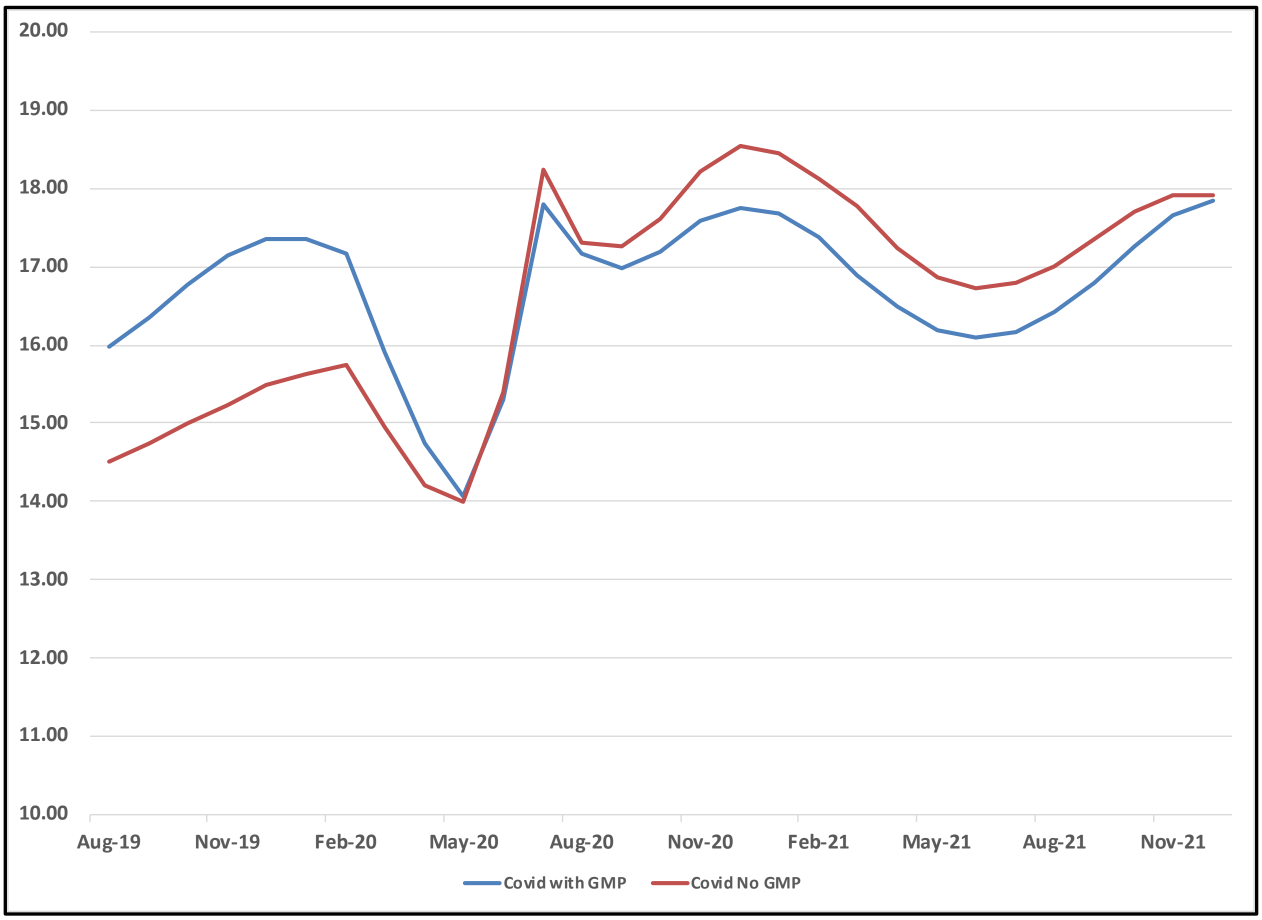

Figure A5.1 US All Milk with Simulated Covid-19 Demand Shocks, $/cwt

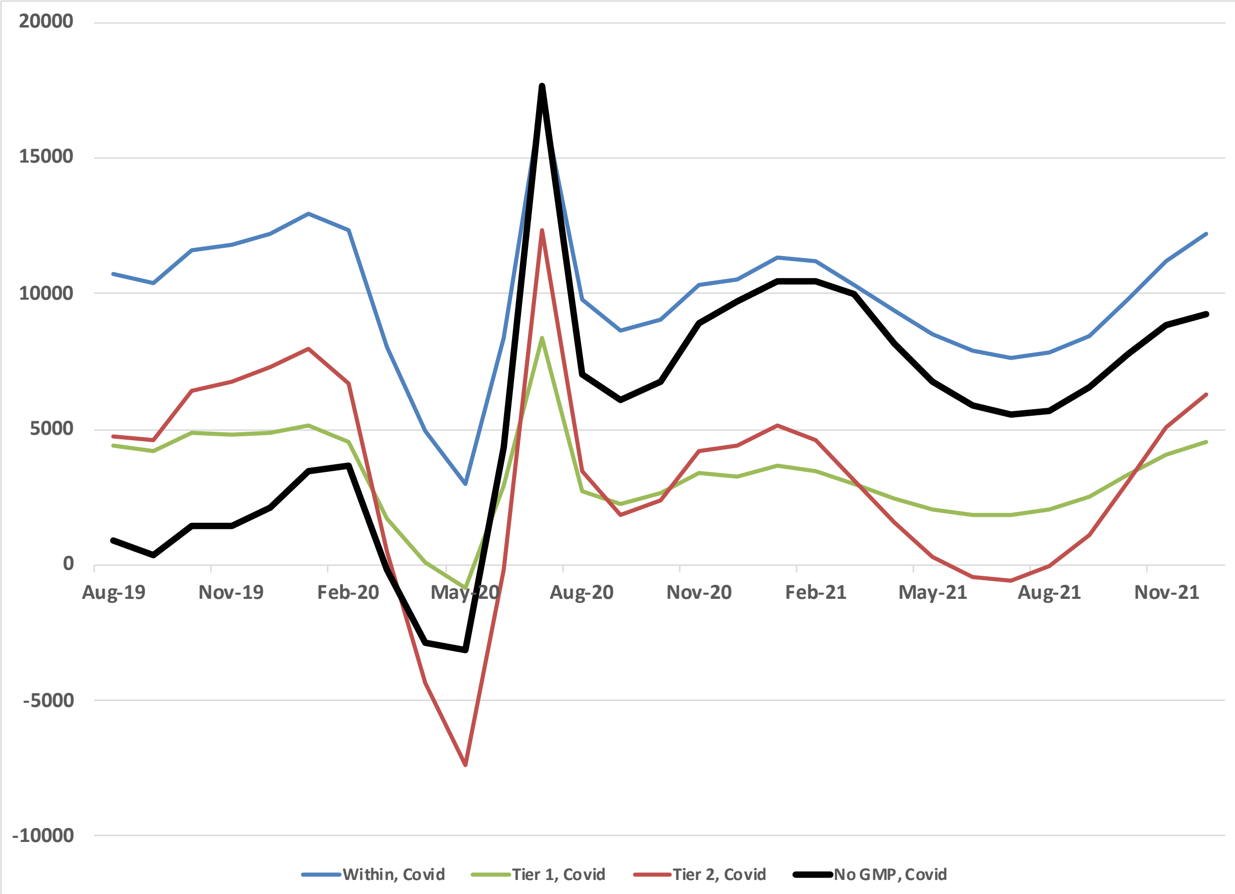

Figure A5.2 Net Farm Operating Income for Farm with 1 to 5 million lbs Annual Milk Production with Simulated Covid-19 Demand Shocks, $/farm/month

Additional Model Description[15]

Methods and Data

Given the potential instability in supply chains and its hypothesized causes, an analytical approach is required that is capable of replicating the types of behaviors observed in the industry under normal conditions and under large shocks. In particular, the model must be capable of producing variation in prices and other variables on a relevant time scale (in this case monthly) with an amplitude similar to that observed in the past. We have chosen to build a mathematical model for our analyses based on the commodity supply chain model described in Sterman (2000), which has been applied previously to numerous commodities that demonstrate cyclical production and profitability. (An early application to agriculture is a model of hog cycles by Meadows (1970)). Moreover, our approach is consistent with recent recommendations that the analysis of food systems and agricultural policies is best done using dynamic systems methods (Pinstrup-Andersen and Watson, 2010). This commodity model represents the essential elements of the stock, flow and feedback structure that is common to the supply chain for many commodities. It contains many features common to economic models, such as demand and supply responses, but represents them in a way that explicitly recognizes the inherent delays and limited information available to industry decision makers.

This commodity model used in this analysis has been developed and adapted to the U.S. dairy industry over a number of years, and many model details are provided in Nicholson and Fiddaman (2003), Pagel (2005), Nicholson and Stephenson (2007), Stephenson and Nicholson (2007), Nicholson and Kaiser (2008) and Nicholson and Stephenson (2009). The model employed under this project was adapted from previous modeling work, and relevant model elements were combined mathematically to allow analysis of major proposed programs. The key modification since the 2010 analysis was the expansion of the model to include explicit representation of other global trading regions. A detailed model description is available at www.dairymarkets.org in the document entitled "Global Dairy Trade Model Description." Our assessment of the impacts of global trade policy changes uses a detailed empirical SD model of the U.S. dairy supply chain adapted from the commodity supply chain model described in Sterman (2000), which builds on an initial formulation by Meadows (1970). This model has been developed and adapted to the U.S. dairy industry during the past 10 years, and the feedback structure relevant for this analysis was discussed below (Figure 1). More detailed description of the model is provided in the below, but the basic structure for key model components is described below. The base year for the model is 2013, meaning that 2013 data on milk production and dairy product consumption and trade are used to initialize the model. The model simulates monthly outcomes from 2013 to the end of 2018 (when the current farm legislation will be revisited). The model comprises modules that represent farm milk supply, farm milk pricing, dairy product processing, inventory management and trade, and dairy policies including the margin insurance implemented in 2014). Each of these is discussed in detail below.

[15] This section is adapted from previous reports, including Nicholson and Stephenson (2019) and Nicholson and Stephenson (2010).

Model Regions

The Dynamic Global Dairy Supply Chain Model includes representations for 15 regions, two for the US (California and Rest of US), and 13 non-US regions including the ASEAN countries (10 countries), Oceania (Australia and New Zealand), the EU (28 countries), Russia, China, Mexico, India, Canada, former Soviet Union countries (11 countries), Middle East and North Africa (MENA; 19 countries), major South American milk producers (Brazil, Argentina, Uruguay), Other Net Importing Countries (described below) and Other Net Exporting Countries (described below).

Farm Milk Supply

The milk supply components of the model are based on up to four farm-type categories based per region. In the US, farm-types are based on numbers of cows owned for both the rest of U.S. and California. (California is modeled separately because it is the largest milk producing state and maintains a state-level system of milk price regulation different from the rest of the U.S.) For each farm-type category, the total number of farms is modeled[16], as is the average financial situation (both elements of the income statement and the balance sheet) for each farm category. The cost structure of farms in the different herd size categories is different, as is the responsiveness to profitability signals. Based on genetic improvement rates over the past 20 years, milk per cow[17] is assumed to grow at a potential rate of 2% per year, but is adjusted in the short run based on the margin between farm milk prices and feed prices. This is similar to the approach in Bozic et al., (2012), who used a linear trend in yield, but the yield increment varied with margins.

The number of cows for each farm size category is treated as a productive asset, and the evolution of cow numbers depends on heifers entering the herd (which depends on previous breeding decisions) and culling decisions (which can be voluntary or involuntary). Involuntary culling rates depend on the desired number of cows for each farm size category, which is modeled using an “anchoring and adjustment” approach based on Sterman (2000). This anchoring and adjustment mechanism assumes that desired cow numbers for each farm size category respond to expectations of future Net Farm Operating Income (NFOI) relative to a benchmark NFOI, both of which are updated over time. NFOI equals total revenues less variable costs for feed, labor, and other expenses. When the desired number of cows changes, the voluntary culling rate is adjusted. Changes in the culling rate in response to profitability changes are asymmetric: proportional changes in the voluntary culling rate are larger when desired cow numbers are below current cow numbers than when current cow numbers are larger than current cow numbers.

Farm Milk Pricing

The U.S. government and many other countries maintain regulations that set minimum allowable farm milk prices based on market prices of dairy product prices and the product for which the

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[16] For some regions, the number of farms is assumed to be one, effectively aggregating the country’s milk production response.
[17] The model also represents buffalo milk production for India and Pakistan in addition to milk from cattle.

farm milk is used. The details for the US are provided in Nicholson and Stephenson (2010) and are not discussed here. For other countries, we assume that milk prices will be derived from dairy product prices, in a manner similar to that in the US but without minimum classified prices based on milk use. Milk prices affect both milk per cow and NFOI and therefore influence cow numbers. A standard measure of the farm milk price in the U.S. is the "All-milk" price reported for the entire U.S. (including California) by the National Agricultural Statistics Service, and this is included in the model as a benchmark price, with a similar indicator price calculated for other countries.

Dairy Processing

The dairy-processing component of the dynamic model incorporates 23 products, 20 of which are "final" products (have explicit demand curves) and 13 of which are "intermediate" products that are used in the manufacture of other dairy products (Table 1). Non-storable products (fluid, yogurt, ice cream and cottage cheese) are assumed manufactured in the month in which they are consumed. Storable products have inventories, and the value of inventory in each region relative to sales (called "inventory coverage") is used in setting prices for these products. Milk is allocated preferentially to fluid, soft and cheese manufacturing, with the remaining milk allocated to nonfat dry milk (NDM) and butter manufacture. The model explicitly tracks skim milk and cream quantities to ensure component (mass) balance between sources (farm milk) and uses (dairy product demand). To represent potential substitutability among intermediate products as relative prices change, the lowest cost of three potential ingredient combinations (for example, NDM versus milk protein concentrates (MPC) used in cheese manufacturing) is calculated and adjustments in intermediate product use occur over the course of a month following a change in the lowest-cost combination. The proportional utilization of existing manufacturing capacity for storable products depends on current profit margins, calculated on an aggregated enterprise basis. The manufacturing capacity for each U.S. region was assigned based on production shares in California and the U.S. in 2013. Capacity for cheese and whey products changes over time in response to long-term changes in profitability for those products.

Dairy Product Demand

Dairy product demand for final products is represented separately for each region. U.S. fluid milk consumption is based on fluid utilization from California and sales from the Federal regulatory bodies that determine minimum regulated farm milk prices using data for 2013. Consumption of other products was calculated as national U.S. commercial disappearance (production + imports – exports – dairy industry use) and allocated on the basis of regional population. The impacts of product prices on demand are modeled using constant elasticity demand functions, which also are assumed to shift over time in response to population and income growth. Intermediate product demand is determined by the use of dairy components in the production of other dairy products, based on relative costs. Cross-price effects for intermediate products are included for NDM, MPC products, casein products and whey products but not for others. The quantity demanded adjusts over time in response to price changes, rather than instantaneously, to account for delays required for buyers to form price expectations, find substitutes, redesign products or for the expiration or renegotiation of contractual obligations with suppliers. Retail prices for fluid milk products, yogurt, cottage cheese and ice cream are modeled using constant proportional mark-ups over milk ingredient costs. Wholesale prices for storable products, as noted earlier, depend on inventory coverage.

Table A1. Dairy Product Categories Included in the Dynamic Global Dairy Supply Chain Model

Product Category	Final Product	Intermediate Product	Tradable Product
Fluid Milk	X		X
Yogurt	X		X
Frozen Desserts	X		X
Cottage Cheese	X		
American-type Cheeses	X		X
Other Cheeses	X		X
Fluid Whey		X	
Separated Whey		X	
Whey Cream		X	
Dry Whey	X	X	X
Whey Protein Concentrate 34% Protein	X	X	X
Whey Protein Concentrate 80% Protein	X	X	X
Lactose	X	X	X
Butter	X		X
Anhydrous Milk Fat (AMF)	X		X
Nonfat Dry Milk	X	X	X
Infant Formula	X		X
Condensed Skim Milk	X	X	
Other Evaporated, Condensed & Dry products	X		X
Casein	X	X	X
Caseinates	X	X	X
MPC, < 50% protein	X	X	X
MPC, >= 50% protein	X	X	X

Dairy Product Trade

The model includes a detailed international trade component, consistent with its purpose. Imports and exports are represented for 18 tradable dairy product categories (Table 1). Imports for each region are calculated separately for each origin (exporting region) and based on whether imports were subject to Tariff Rate Quota (TRQ) or "over-quota" restrictions. The TRQ specify a total annual amount of allowable imports at a relatively low tariff rate. We have ignored the country- and region-specific import restrictions (e.g., import licenses or TRQ allocations) associated with some products imported into the US. "Over-quota" imports are not limited in quantity but generally face higher tariff rates. Both *ad valorem* (percentage based on value) and specific (per unit) tariffs are represented for both categories of imports. The model uses 2013 trade data as base, and imports and exports in future years are determined based on the growth in demand in the ROW, relative prices in the importing and exporting regions, transportation costs and import restrictions. Total exports for each region and product are calculated as the sum of the product imported by all other regions from the origin region.

Dairy Policies

As noted in the discussion of programs analyzed above The suite of U.S. dairy policies implemented during 2013 to 2020 is represented in the model, including the MPP-Dairy/Dairy Margin Coverage program. We also include U.S. policies unchanged by the Agricultural Act of 2014, such as minimum farm milk price regulation under federal and California milk marketing orders, including relevant timing of pricing decisions. For regions other than the U.S., dairy policy (other than trade policy) is represented by intervention purchase programs in the EU, and supply management programs in the EU and Canada (for which more details are provided below); other policies and programs related to dairy in other countries are ignored. We include the policy structure of the model to account for the major impacts of MPP-Dairy in the U.S.

Data Sources and Qualifications

The model base year is 2013. The model data come from a variety of sources including, but not limited to, various branches of the U.S. Department of Agriculture (NASS, AMS, FAS), the Food and Agriculture Organization of the United Nations (FAO), the International Farm Comparison Network (IFCN), Eucolait (the European Association of Dairy Trade), CLAL (Italian Dairy Economic Consulting), Dairynz, Dairy Australia, and the Global Trade Atlas (GTIS). Where possible, it is useful to collect data from a single source such as FAOstat. This not only minimizes data collection efforts, but it may mean that the source aggregator has made the effort to report data in a unified way. However, it is also important to know what the data are reported as and being used for.

The Dynamic Global Dairy Supply Chain Model is interested in projecting dairy cow and buffalo milk production and consumption of milk and dairy products around the globe. And, to facilitate the transformation of milk into consumable dairy products, the model needs to estimate what dairy products are processed and where and how much of those dairy products are traded between countries of the world. Estimates are available for many country’s dairy statistics, but these estimates break down where there is no formal market for the products. FAO may try to estimate consumption by country, but in many countries where the informal dairy sector thrives with milk production consumed on the farm or is informally traded outside of reported statistics, a mass balance estimate of production and consumption estimates will not equate. The FAOstat database[18] is used as the source for several pieces of data. The FAO database also provides estimates of agricultural trade. However, it is felt that this is not a very complete source of trade data and GTIS data are sourced and used instead. The GTIS trade flow data are available for most countries. These data are monthly, but 6 digit HTS code and are reported by the exporting country and/or the importing country. The GTIS data list the reporting country and the partner country for both imports and exports. Only one of these are needed and to minimize duplicate trade flow reporting, we use the export data.

[18] http://faostat3.fao.org/

Model Evaluation

Sterman (2000; pp. 859-861) describes 12 model evaluation processes that are relevant for most models, not just SD models. We undertook selected components of all 12 tests during model development and evaluation. These processes are summarized in below (Table 2), with a brief discussion of their implementation in the U.S. dairy supply chain model. An additional comment regarding sensitivity analysis is appropriate here. A common feature of feedback-rich models such as SD models is that relatively few feedback loops determine system behavior. That is, a small number of feedback loops demonstrate “feedback loop dominance”, which can be evaluated using methods such as those in Olivia (2014). This characteristic suggests that only parametric values contained within dominant feedback loops have the potential to effect large-magnitude changes in the numerical or behavioral results of the model. Thus, it is not surprising that our model is not sensitive to many of the parameter values other than those related to the dominant feedback processes (which appear to be those for milk supply). This result also suggests that not all information (or assumptions) have equal weight in determining system outcomes, so model behavior often is not strongly influenced by most of the parameters assumed in a dynamic model. We find that to be the case for our model of the U.S. dairy supply chain.

The behavioral pattern and values of the US All-milk price was reasonably well captured by the model (Figure 3), particularly from 2015 to 2018. The average percentage difference between the model all-milk values and the actual values during 2013 to 2018 was 8.2%, which compares favorably to forecasting performance for many supply chains (which often experience values of 30% or more). For 2015 to 2018, the average percentage difference was better—4.9%--and the average difference between the actual and model-predicted price was $0.83/cwt. In addition, the model captures the basic pattern (but not the duration) of high prices in 2014, and lower but oscillating prices after that year. Given that the model base year is 2013, this is quite good forecasting of monthly prices over a six-year time horizon.

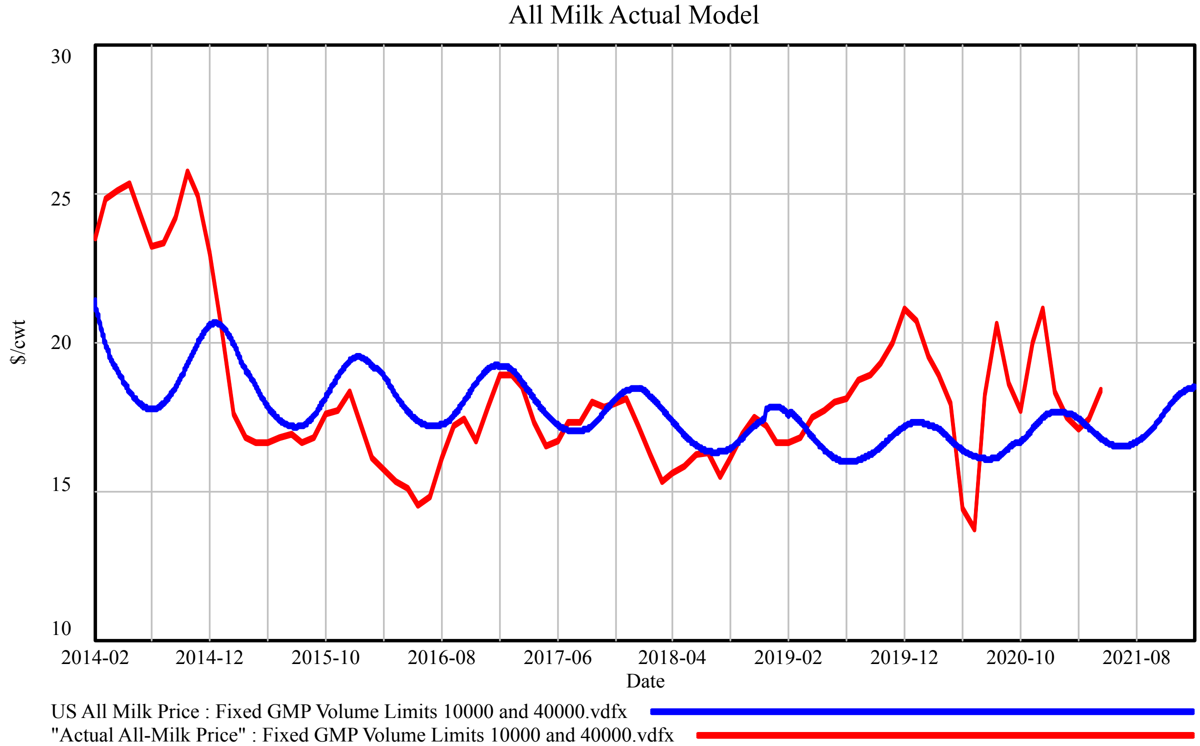

Figure A1. Comparison of Model-Simulated and Actual Farm Milk Prices, 2013 to 2021

Table A2. Summary of Model Evaluation Testing Procedures

Model Evaluation Test	Purpose and Description	Implementation in Global Dairy Supply Chain Model
Boundary adequacy	Are important concepts endogenous? Does model behavior changed when model boundary assumptions are modified?	Relevant concepts were endogenized consistent with generic commodity supply chain model. Model boundary was assessed formally for inclusion of an endogenous trade component and this did not change the behavioral mode for milk prices.
Structure assessment	Is the model structure consistent with relevant descriptive knowledge of the system, at an appropriate level of aggregation, decision rules capture the behavior of agents in the system?	System structure was developed based on previous models, previous literature, descriptive knowledge, statistical analysis of dairy industry data and through group discussions with industry decision makers.
Dimensional consistency	Is each equation dimensionally consistent? (Are units consistent without the use of parameters without real-world meaning?)	All equations were tested using routines in Vensim Professional software to ensure consistent units. There currently are 8 "units errors" of which 3 are warnings about the use of dimensioned arguments in LOOKUP functions and the others are related to time units in MODULO or SAMPLE IF TRUE functions. None affects model function or indicates an incorrectly specified equation.
Parameter assessment	Are the parameter values consistent with relevant descriptive and numerical knowledge of the system?	Parameter values developed based on previous models, previous literature, descriptive knowledge, statistical analysis of dairy industry data and through group discussions with industry decision makers. For milk supply response parameters, qualitative assessments with industry professionals about relative magnitudes of asymmetric responses by farm size and region were complemented with Vensim Professional optimization routines to determine values consistent with the observed periods and amplitudes of price cycles.
Extreme conditions	Do all equations make sense at extreme values? Does the model respond plausibly to extreme shocks, policies and parameters?	Model was evaluated for consistency with extreme shocks (e.g., large domestic supply and demand reductions or increases, rapid increases in U.S. exports) and responded plausibly to these conditions. Large increases in milk production would likely have exceeded available production capacity for NDM and butter in the short-term, given our assumption of no capacity constraints for these products.
Integration error	Are the results sensitive to the choice of time step for numerical integration?	The model was evaluated for integration error using the process identified in Sterman (2000) that progressively reduces the time step, until limited behavioral changes resulted. A time step of 0.125 months was used for all simulations.

Model Evaluation Test	Purpose and Description	Implementation in Global Dairy Supply Chain Model
Behavior reproduction	Does the model reproduce the behavior of interest in the system? Does the model generate modes of behavior observed?	The model generated oscillatory behavior in milk price and margins consistent in period and amplitude with those observed in 2000-2014, consistent with the analysis of Nicholson and Stephenson (2015). A previous model version assessed point prediction during 2012-2013 and appropriately represented patterns and turning points in observed data (more below).
Behavior anomaly	Do anomalous behaviors result when assumptions of the model are changed or deleted?	Assessed the assumption that milk components used in NDM and butter are residual claimants on the milk supply by modifying model structure. Relationships between Class III and IV prices in the FMMO system demonstrated anomalous behavior in response to this modification.
Family member	Can the model generate the behavior observed in other instances of the same system?	No formal analysis of other systems undertaken, but Bergmann et al., (2013) note that cyclical behavior with properties similar to that in the U.S. has emerged in the EU and international dairy product markets, which they attribute in part to the reduction in support under the CAP—similar to the emergence of greater cyclical behavior in the U.S. when the DPSP became largely inactive.
Surprise behavior	Does the model generate previously unobserved or unrecognized behavior?	Model analyses indicate that increases in regulated milk prices can demonstrate "dynamic complexity," i.e., that short-term increases can be more than offset by longer-term decreases in price. The model also suggests that a reason for increasing amplitude of price cycles is structural change, if the assumption that larger farms have a greater supply responsiveness to expected profitability than do small farms.
Sensitivity analysis	Numerical, behavioral and policy sensitivity to parameters, boundary and aggregation are varied over a plausible range of uncertainty?	The model demonstrates numerical sensitivity in the sense that simulated results change in response to changes in a variety of assumed parameter values. However, the model was only behaviorally sensitive to large changes in the model parameters affecting the responsiveness of milk supplies (desired cows, culling rates) to expected profitability. Alternative values of these parameters could generate very limited or very large oscillations that were not consistent with the behavior observed since 2000.
System improvement	Can the model suggest means to improve system outcomes	This evaluation is more typical of modeling efforts to support management changes, but previous versions of the model have been used to suggest the benefits (and limits) or dairy product promotion to the industry or changes in regulated pricing formulae.