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Negative Producer Price Differentials in Federal Milk Marketing Orders: Explanations, Implications and Policy Options

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Executive Summary

In Federal Milk Marketing Orders which are based on multiple component pricing schema, producers are paid for delivered quantity of butterfat, protein and other solids, plus a producer price differential (PPD). The PPD captures the difference between the total handler obligations to the pool and total component value of milk. In 2020, record negative PPDs caused widespread frustration among dairy farmers. The primary objective of this research is to provide a comprehensive review of factors that impact PPDs and to quantify their relative importance. We find that long-term trends in utilization and component tests have substantially reduced PPDs over the past decade. Class I milk pricing reform of 2018 exacerbated negative PPDs in 2020, but we find the PPDs would have been negative anyway. The greatest contributor to recent negative PPDs is the spread between cheese and milk powder prices, caused by shifts in demand due to the pandemic and USDA intervention cheese purchases through the Farmers for Families Food Box program. We examine a range of policy modifications proposed to address negative PPDs and evaluate their potential to do so effectively.

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Introduction

Federal Milk Marketing Orders (FMMOs) are one of the primary dairy policies in the United States. Over the 2015-2019 period, 64.3% of milk produced in the United States was pooled on FMMOs. In those orders, where most of the milk is utilized in manufactured dairy products, dairy farmers are paid based on butterfat, protein, and other solids content of their milk, and Producer Price Differential (PPD). PPD reconciles the difference between component valuation of milk, and available revenue derived from the market value of dairy products in which milk was utilized. Historically, a substantial share of milk was utilized in beverage milk products. Per FMMO rules, beverage milk is priced at a premium relative to milk utilized for manufactured dairy products. This normally suffices to make the average milk value higher than the component milk value, resulting in positive PPD. The PPD is thus often interpreted by dairy producers as a financial measure of benefit of FMMO regulations. In 2020, record low negative PPDs caused consternation and frustration among dairy farmers and ignited widespread mistrust in the milk pricing system. Several factors were blamed, including recent changes to beverage milk pricing rules, reduced beverage milk consumption, and dairy processors leaving the FMMOs during the COVID-19 pandemic. In 2021, many in the U.S. dairy sector are calling for dairy policy reforms to address negative PPDs.

This paper addresses the causes of negative PPDs. We develop a framework to identify and quantify the relative importance of six factors driving PPDs: utilization milk by dairy product type, rise of butterfat and protein content of milk, variability in dairy product prices, advanced pricing of beverage milk, beverage milk pricing reforms enacted in the 2018 Farm Bill, and depooling. The framework we develop is used to evaluate the potential of a range of policy modifications to alleviate negative PPDs.

Paggi and Nicholson (2012) provide a recent summary of literature on FMMOs, revealing that negative PPDs were not a focus of earlier research efforts. In the rare circumstances when they were observed, Jesse and Cropp (2008) explained, negative PPDs were a short-term consequence of sudden rally in manufacturing milk price, after beverage milk price for the month has already been determined. Stephenson and Novakovic (2020) explored how COVID-19 pandemic affected PPDs and milk prices and suggested that producer price differentials printed on milk checks may reflect milk price deductions not related to FMMO regulations, due to additional costs processors incurred because of disturbance to supply chains in the pandemic economy.

This paper makes three contributions. First, we develop a set of models based on formal FMMO accounting rules to quantify impacts of each factor contributing to PPD. This allows us to estimate long-term negative trends in PPDs due to the shrinking share of raw milk utilization in production of beverage milk products as well as the impact of USDA intervention programs introduced during the pandemic. Second, our paper is the first to derive conditions under which negative PPDs can persist for many months. Finally, we use the modelling framework to evaluate several policy reform proposals currently being contemplated.

The next section reviews core principles of FMMOs and pricing formulas used to derive milk component prices. The third section provides framework for calculating PPDs. In the fourth section we evaluate each factor affecting PPDs. The fifth section explores potential dairy policy reforms and quantifies their effects on PPDs.

Overview of Federal Milk Marketing Orders

Federal Milk Marketing Orders (FMMOs) are a collective bargaining institution created nearly a century ago in geographically defined regional fluid-milk demand areas (CRS, 2018). FMMOs regulate minimum prices paid for raw milk by all distributors of fluid milk products and promote uniform participation by all area dairy producers in market sales value of fluid milk (Nourse, 1962). At their peak number in 1962, there were 83 Federal Milk Marketing Orders. Currently, there are 11 FMMO's with California being the most recent area to join in November 2018. In areas regulated under FMMOs, milk processing plants converting raw milk to beverage milk products must participate in the marketing order. For all other milk processing plants, participation is voluntary, and incentivized by the prospect of sharing in revenue generated through sales of beverage milk products. The accounting procedures used to operationalize these objectives and incentives are classified pricing and revenue pooling. Processors contribute to the revenue pool based on the class of dairy products manufactured, and class-based milk prices derived from freely established wholesale market prices of basic dairy commodities. Total milk handler obligation to the pool is referred to as classified value of milk. Order-wide pooled revenue is then distributed to dairy producers based on the attributes of their milk, such as butterfat test and somatic cell count, irrespective of the class of dairy products where their milk was utilized.

Classified Pricing

Under classified pricing, dairy manufacturers (referred to as 'handlers') participating in the order have the obligation to the pool based on the type of the dairy products where the milk is utilized. The underlying logic is processors bear the risk, and therefore capture the upside for differentiated dairy products, such as specialty cheese, branded yogurts, or customized fluid milk products. On the other hand, for commodity dairy products, it is assumed that the entire value of the dairy product, less processing cost, is attributable to value of milk solids or raw whole milk and should thus be essentially passed through to the producers. Milk is classified in four utilization classes. Class I includes all milk (butterfat and skim milk) used in fluid beverage products including whole, low-fat, and skim milk, eggnog, and buttermilk. Class II includes milk used to produce semi-solid products such a cottage cheese, milkshakes, sour cream, yogurt, and custards. Class III milk includes milk used to produce spreadable and hard cheeses, and whey byproducts. Class IV milk includes milk used to produce butter, condensed milk, and any milk product in dried form, primarily nonfat dry milk. Minimum prices for each Class of milk are derived from national surveys of wholesale dairy products prices. The products included are cheese, butter, nonfat dry milk, and dry whey. These product prices are surveyed weekly by the USDA which collects value and sales volume at the wholesale level.

Revenue Pooling

Under revenue pooling, a dairy producer shipping milk to a privately owned handler who participates in the marketing order is guaranteed a minimum price based solely on the component levels and dairy plant location. Minimum farm milk price is not dependent directly on the revenue their handler generated through sales of dairy products, as such revenue is pooled with revenue from other dairy processors participating in the marketing order.

In those FMMOs where most of the milk is utilized in manufactured dairy products, dairy farmers are paid based on butterfat, protein, and other solids (lactose and whey proteins) content of their milk. This milk pricing approach is called Multiple Component Pricing (MCP). Seven orders use multiple component pricing approach: The Northeast, Mideast, Upper Midwest, Central, Southwest, Pacific Northwest, and California Orders.[2] Over 2015-2019 period, 86.7% of the pooled milk amount was pooled on marketing orders which utilize multiple component pricing. Under MCP the producer value of milk is based on component levels including fat, protein, and other solids. Butterfat price is derived from market price for bulk butter. Protein price is derived

[2] The other four Federal Milk Market Orders—Appalachian, Arizona, Florida, and Southeast—utilize skim-fat pricing. Skim-fat pricing orders calculate the producer value of milk as the weighted average or uniform value of fat and skim. Prices are set based on the fat content in milk and everything else is categorized as skim. This means that all parts of skim milk are valued identically.

from market price for commodity cheddar cheese, and other solids price is derived from dry whey. Total component value of milk in the pool is determined by multiplying butterfat, protein and other solids total pooled pounds by their respective component prices.

The difference between total pooled revenue, and the funds allocated to dairy producers based on component value of milk, is denoted the producer price differential (PPD). When revenue remains in the pool after allocating component value of milk, producer price differential dollars are divided among dairy producers based on the pounds of milk marketed, and location adjustments based on the location of the dairy processing plant where their milk was utilized. When the component value of milk exceeds the total pooled revenue, then deductions must be applied to each producer, following the same procedures used to distribute remaining dollars when PPD is positive. To understand what may cause the total pooled revenue to exceed, or fall short of component value of milk, we first explain the accounting protocols determining handler obligations to the pool.

Producer Price Differential Calculation

Milk components priced under FMMOs are butterfat, protein, other solids, and nonfat solids. Component prices in FMMOs are determined by taking the wholesale product price less a make allowance multiplied by yield. Make allowance are credits for the cost of processing while the yield is the amount of the commodity that can be produced using one pound of the component. Minimum regulated prices for milk components are calculated as follows.

The butterfat component price is derived from the price of butter as:

$$p_{BF} = \left(p_B - 0.1715\right)\times 1.211 \tag{1}$$

where p_B is the monthly average AA butter survey price reported by the USDA, \$0.1715 is the butter make allowance, and 1.211 is the butter manufacturing yield. The Class II butterfat price is:

$$p_{BF,II} = p_{BF} + 0.007 \tag{2}$$

The protein price formula is based off of the price of cheese and butter. Protein price is derived from the protein value in cheese adjusted for any difference between the value of butterfat in butter and cheese:

$$p_{PR} = \left(p_C - 0.2003\right) \times 1.383 + \left[\left(p_C - 0.2003\right) \times 1.572 - p_{BF} \times 0.9\right] \times 1.17 \tag{3}$$

where p_C is the monthly average cheddar cheese survey price reported by the USDA, \$0.2003 is the cheese make allowance, 1.383 is the cheese yield attributable to protein, 1.572 is the cheese yield attributable to butterfat, 0.9 is the butterfat retention rate, and 1.17 is the butterfat to protein ratio in cheese (USDA AMS, 2019).

The other solids price is derived from the price of dry whey as:

$$p_{OS} = \left(p_{DW} - 0.1991\right) \times 1.03 \tag{4}$$

where p_{DW} is the monthly average dry whey survey price reported by the USDA, \$0.1991 is the dry whey make allowance, and 1.03 is the dry whey manufacturing yield.

The nonfat solids price is based on the price of nonfat dry milk:

$$p_{NFS} = \left(p_{NFDM} - 0.1678\right) \times 0.99 \tag{5}$$

where p_{NFDM} is the monthly average nonfat dry milk survey price reported by the USDA, \$0.1678 is the nonfat dry milk make allowance, and 0.99 is the nonfat dry milk manufacturing yield. These component prices are used to determine the fat and skim values for each class of milk.

In order to facilitate retail pricing, regulated prices for Class I and Class II products are set prior to the start of the month. Weighted average prices from the first two weeks of each month are used to calculate the "advanced prices" for the following month used to price Class I (fluid) and II products. Advanced prices are announced by the 23rd of the month for the following month. Advanced butterfat, protein, other solids, and nonfat solids prices are denoted respectively as $p_{BF,A}, p_{PR,A}, p_{OS,A}, p_{NFS,A}$. Advanced component prices are calculated using the same formulas as monthly average component prices, but instead of monthly average dairy commodity prices, the calculation uses advanced dairy commodity prices. These advanced component prices are used in advanced Class I, III, and IV skim milk and Class II nonfat solids price.

Advanced Class III skim milk pricing factor:

$$p_{S,III,A} = 3.1 \times p_{PR,A} + 5,9 \times p_{OS,A} \tag{6}$$

Advanced Class IV skim milk pricing factor:

$$p_{S,IV,A} = 9 \times p_{NFS,A} \tag{7}$$

Class II Nonfat Solids Price:

$$p_{NFS,II,A} = p_{NFS,A} + 0.70 / 9 \tag{8}$$

And base Class I Skim Milk Price:

$$p_{S,I,A} = \left(p_{S,III,A} + p_{S,IV,A} \right) / 2 + 0.74 \tag{9}$$

From January 2000, through April 2019, the base Class I skim milk price was calculated as the higher of the Advanced Class III Skim Milk Pricing Factor and Advanced Class IV Skim Milk Pricing Factor:

$$p_{S,I,A,2000-2018} = \max\left(p_{S,III,A}, p_{S,IV,A}\right) \tag{10}$$

Total pooled weight of milk and cream in pounds is denoted as W_M, and is equal to the sum of total pooled weight of butterfat, W_{BF}, and total pooled weight of skim milk, W_S. Total weight of skim milk utilized in class IV is denoted as $W_{S,IV}$, and similar notation is used for other classes. Skim milk utilization percentage in each class is defined as the ratio of the weight of skim milk utilized in that class and the total weight of pooled skim milk. For example, skim milk utilization rate in Class IV is $U_{S,IV} = W_{S,IV} / W_S$.

Total pooled weights of butterfat, protein and other solids components are denoted respectively as W_{BF}, W_{PR}, and W_{OS}. When protein and other solids are combined, they are referred to as nonfat solids, $W_{NFS} = W_{PR} + W_{OS}$. Pool average protein component test is $T_{PR} = W_{PR} / W_M$. Pool average other solids component test is calculated as $T_{OS} = W_{OS} / W_M$. Pool average other solids component test is calculated as $T_{NFS} = W_{NFS} / W_M$. Pool average butterfat component test is $T_{BF} = W_{BF} / W_M$. This can be rewritten as $T_{BF} = 1 - W_S / W_M$. Reorganizing, we get $W_M / W_S = 1 / \left(1 - T_{BF}\right)$. Now we can express average protein component test per unit of skim milk as $T_{PR,S} = T_{PR} / \left(1 - T_{BF}\right)$. Similarly, $T_{OS,S} = T_{OS} / \left(1 - T_{BF}\right)$ and $T_{NFS,S} = T_{NFS} / \left(1 - T_{BF}\right)$.

Handler value of milk

Each handler reports to the pool total pounds of received skim milk, butterfat, protein, skim solids other than protein (other solids), as well as utilization of milk and milk solids by class. The classified value of milk in a FMMO each month is equal to the sum of obligations to the pool across all pooled handlers. Handler Class I skim milk value is:

$$H_{I,S} = \left(p_{S,I,A} + p_{L,I}\right) \times U_{S,I} \times W_M / 100 \times \left(1 - T_{BF}\right) \tag{11}$$

where $p_{L,I}$ is the Class I differential at the principal pricing point of the order, in \$/cwt.

Handler Class I butterfat value is:

$$H_{I,BF} = \left(p_{BF,A} + p_{L,I} / 100\right) \times U_{BF,I} \times W_M \times T_{BF} \tag{12}$$

Total handler Class I value is:

$$H_I = H_{I,S} + H_{I,BF} + L_H \times W_{M,I} / 100 \tag{13}$$

where L_H is the per hundredweight weighted average location adjustment to handlers, based on the Class I differential zone where pooled plants are located.

Similarly, Class II nonfat solids value is:

$$H_{II,NFS} = p_{NFS,II,A} \times U_{S,II} \times T_{NFS} \times W_M \tag{14}$$

Class II butterfat value is calculated as:

$$H_{II,BF} = p_{BF,II} \times U_{BF,II} \times W_M \times T_{BF} \tag{15}$$

And total handler Class II value is:

$$H_{II} = H_{II,NFS} + H_{II,BF} \tag{16}$$

Class III protein value is:

$$H_{III,PR} = p_{PR} \times U_{S,III} \times T_{PR} \times W_M \tag{17}$$

Class III other solids value is:

$$H_{III,OS} = p_{OS} \times U_{S,III} \times T_{OS} \times W_M \tag{18}$$

Class III butterfat value is:

$$H_{III,BF} = p_{BF} \times U_{BF,III} \times W_M \times T_{BF} \tag{19}$$

Total handler Class III value is:

$$H_{III} = H_{III,PR} + H_{III,OS} + H_{III,BF} \tag{20}$$

Finally, Class IV nonfat solids value is:

$$H_{IV,NFS} = p_{NFS} \times U_{S,IV} \times T_{NFS} \times W_M \tag{21}$$

Class IV butterfat value is:

$$H_{IV,BF} = p_{BF} \times U_{BF,IV} \times W_M \times T_{BF} \tag{22}$$

Class IV value is:

$$H_{IV} = H_{IV,NFS} + H_{IV,BF} \tag{23}$$

Total classified value of milk, i.e., the sum of obligations to the pool across all pooled handlers is expressed as:

$$H = H_I + H_{II} + H_{III} + H_{IV} \tag{24}$$

Total producer component value of milk, denoted C is the sum of the product of butterfat pounds and butterfat price, the product of protein pounds and protein price, and the product of other solids pounds and other solids price. Total producer component value of milk is expressed as:

$$C = p_{BF} \times W_{BF} + p_{PR} \times W_{PR} + p_{OS} \times W_{OS} \quad (25)$$

The total producer price differential (TPPD) for each FMMO and month is the difference between total classified value of milk and total component value of milk, less location adjustment to producers $L_P \times W_M / 100$.

$$TPPD = H - C - L_P \times W_M / 100 \quad (26)$$

Producer price differential per hundredweight of pooled milk is, therefore:

$$PPD = \frac{TPPD}{W_M / 100} \quad (27)$$

Factors contributing to negative producer price differentials

Factors which increase handler value of milk H *relative to* producer component value C have a positive effect on the producer price differential. Likewise, factors which decrease the handler value of milk relative to producer component valuation have a negative effect on producer price differential. We can group the factors affecting PPD in six categories:

1) Changes in utilization rates due to structural changes in dairy products production within the marketing order area: $U_{S,I}, U_{BF,I}$, etc.
2) Changes in component tests: T_{BF}, T_{PR}, T_{OS}
3) Changes in announced dairy product prices: $p_B, p_C, p_{DW}, p_{NFDM}$
4) Changes in advanced dairy product prices: $p_{B,A}, p_{C,A}, p_{DW,A}, p_{NFDM,A}$

5) Changes in Class I skim milk pricing regime, i.e. from the 'higher-of' regime represented by equation (10) to 'average-of' regime expressed in equation (9).
6) Changes in utilization rates $\left(U_{S,I}, U_{BF,I}, \ldots\right)$ due to 'depooling', i.e., decision by handlers utilizing milk in Class II, III or IV dairy products to not pool that milk in the marketing order for one or more months.

To isolate and quantify the importance of these six factors, we build a series of counterfactual models which progressively relax restrictions imposed on each category. These models are summarized in the Table 1.

Step 1. Change in utilization rates due to structural changes.

Long-term trend in FMMOs is a decline in milk utilization in fluid milk products. Percent of producer milk used as Class I declined from 65.5% in 1947 to 28.0% in 2019 (USDA 2020). Total pooled Class I skim milk pounds across six federal orders analyzed declined from 2.69 billion pounds in January 2010 to 2.34 billion pounds in January 2021, a 13.3% reduction. This occurred both because beverage consumption declined over time but also because of increasing consumption of cheese, yogurt and butter, and rise in exports of cheese and milk and whey powders. From (27), the impact on PPD is given by:

$$\frac{\partial TPPD}{\partial W_{S,I}} = \left(p_{S,I,A} + p_{L,I}\right)/100 + L_H/100 - p_{PR}T_{PR}\left(1 - T_{BF}\right) - p_{OS}T_{OS}\left(1 - T_{BF}\right) - L_P/100 \quad (28)$$

Under the 'higher-of' Class I milk pricing regime represented by equation (10), assuming that advanced prices are equal to announced prices, and that per hundredweight location adjustment to handlers is equal to per hundredweight location adjustment to producers the impact is:

$$\frac{\partial TPPD}{\partial W_{S,I}} = \max\left(3.1\times p_{PR} + 5.9\times p_{OS}, 9\times p_{NFS}\right)/100 + p_{L,I}/100 - p_{PR}T_{PR,S} - p_{OS}T_{OS,S} \tag{29}$$

Assuming further that $3.1\times p_{PR} + 5.9\times p_{OS} > 9\times p_{NFS}$ the impact becomes:

$$\frac{\partial PPD}{\partial W_{S,I}} = \frac{p_{L,I}/100 - \left(T_{PR,S} - 3.1/100\right)p_{PR} - \left(T_{OS,S} - 5.9/100\right)p_{OS} - PPD}{W_M} \tag{30}$$

The expression in (30) is positive under all reasonable price and component test values. Therefore, the decline in Class I sales is expected to reduce the producer price differentials. To quantify the effect of declining fluid milk product sales on producer price differentials, we start by estimating utilization rates based on trend and seasonal factors:

$$U_t = \beta_1 + \beta_2 N_t + \beta_3 \sin\left(\frac{m_t}{12}\times 2\pi\right) + \beta_4\left(\frac{m_t}{12}\times 2\pi\right) + e_t \tag{31}$$

where N_t is the trend variable, with $N_t = 1$ for January 2010 and m_t is the calendar month index (1-12) for period t. For each federal order we estimated the trend in utilization rates separately for skim milk and butterfat for each class. The estimation period was January 2005 through December 2019. Regression results are presented in Table 2. In all federal orders analyzed, Class I skim milk utilization rate had a statistically significant negative trend coefficient. Between January 2010 and January 2021, predicted Class I skim milk utilization rate declined between 3.4 percentage points (Central FMMO), and 13.7 percentage points (Northeast FMMO).

To isolate the effect of changes in utilization rates on producer price differentials we keep all factors other than utilization rates fixed. Therefore, the Step 1 model has the following assumptions and restrictions:

1) Utilization rates are set equal to those predicted by trend/seasonal models described in equation (31). Time-limited depooling is not allowed. The only source of changes to utilization rates are structural changes in dairy production and consumption.
2) Component tests for each month are held constant at the levels observed in each respective 2010 calendar month.
3) Announced dairy product and milk component prices are held constant at the average levels observed over January 2010 through December 2019, as summarized in Table 3 (component test) and Table 4 (prices).
4) Advanced prices are set equal to the announced prices – constant at average 2010-2019 values.
5) Base Class I skim prices are calculated assuming they are priced using the higher of advanced Class III skim milk pricing factor and advanced Class IV skim milk pricing factor:

$$p_{S,I,A} = \max\left(p_{S,III,A}, p_{S,IV,A}\right) \tag{32}$$

   This was the official pricing method used by USDA from January 2000 through April 2019.
6) Class I location differentials and location adjustments to producers are set at per hundredweight levels predicted by trend/seasonal models described in the equation (31).

The impact of trends in utilization rates is presented in Table 5. Across six FMMOs analyzed, between January 2010 and January 2021, predicted PPDs declined on average -\$0.30/cwt or -32%. In dollars per hundredweight terms, the greatest loss is predicted for the Northeast order, with -\$0.47/cwt reduction in PPD. In percentage terms, the greatest loss is predicted for the Pacific Northwest order, where PPD declined by -48%.

Step 2. Change in Component Tests

Producers have selected genetics and nutrition programs to increase component tests over time as the result of economic incentives. From (27), the impact of increase in the protein test on PPD is given by:

$$\frac{\partial TPPD}{\partial T_{PR}} = p_{NFS,A} \times U_{S,II} \times W_M + p_{PR} \times U_{S,III} \times W_M + p_{NFS} \times U_{S,IV} \times W_M - p_{PR} \times W_M \tag{33}$$

Assuming further that advanced prices are equal to announced prices, and that $p_{PR} > p_{NFS}$:

$$\frac{\partial PPD}{\partial T_{PR}} = \left(p_{NFS} \times U_{S,II} + p_{PR} \times U_{S,III} + p_{NFS} \times U_{S,IV} - p_{PR} \right) < 0 \tag{34}$$

Increases in protein test reduce total producer price differential. The reduction is higher in orders where more milk is utilized in Class I. Since the value of Class I skim milk depends only on pounds of skim milk used, not protein test, increase in the protein test does not increase handler obligation to the pool for Class I skim milk. The negative impact on PPD will also be more pronounced the wider the spread between protein price and nonfat solids price. All protein is paid to producers based on protein price, derived from cheese prices. However, only protein used in Class III milk results in increased sales of dairy products where increased solids increase handler obligations to the pool proportional to the increase in component value of milk. When used in the production of nonfat dry milk powder, skim solids typically do not create as much value as when used in the production of cheese and whey. Handler obligations to the pool are increased by p_{NFS} but component value of milk is increased by p_{PR}. The difference between the increase in component value of milk and handler obligations to the pool reduces the producer price differential. From the pool's perspective, the marginal cost (component value of milk) exceeds marginal revenue (handlers obligations to the pool). The way that pool accounting is operationalized amounts to a transfer of money from low component herds to high component herds, a subsidy that promotes cattle breeding selection and nutrition based on component tests.

To quantify the impact of increases in component tests, the Step 2 model uses the actual component tests rather than component tests observed in 2010. All other restrictions and assumptions are the same as in the Step 1 model. The impact of trends in utilization rates is presented in Table 5. We compare predicted PPDs for January 2021 between models that keep component tests at January 2010 level (Step 1) vs January 2021 level (Step 2). On average predicted PPDs are reduced by -$0.20/cwt or 35%. In dollars per hundredweight terms, the greatest loss is predicted for the Southwest order, with -$0.35/cwt reduction in PPD. In percentage terms, the greatest loss is predicted for the Pacific Northwest order, where PPD declined by -77%. For October 2020, for Pacific Northwest order, combined effect of changes in utilization rates and higher component tests are sufficient to result in a negative PPD. In that order, continued growth in component tests will result in regularly reoccurring negative PPDs for October through January periods when component tests are seasonally the highest.

Step 3. Variability in Announced Milk Component Prices

Under federal orders, skim solids are paid for based on their value in cheese and whey, but only a fraction of skim solids are used in cheese and whey. They are also used in nonfat dry milk powder, in yogurts and fluid milk. When there is a positive spread between market value of skim solids in cheese and whey vs. nonfat dry milk powder, then we pay for components beyond the value they create in the market, and the deficit is manifested as a lower PPD. The extreme illustration of the spread between value of skim solids in cheese and whey vs. nonfat dry milk powder was provided by the COVID-19 pandemic. Due to extensive reduction in away-from-home eating occasions, dairy prices collapsed in April 2020. Federal government intervened through the "Farmers to Families Food Box Program" which increased domestic disappearance of American-style cheese and fluid milk and resulted in record high cheese prices as supply chain struggled to adjust to a shift in demand between cheese types. The onset of the Food Box program coincided with record negative PPDs.

From (27), the impact on PPD from the increase in the protein price, holding other milk component prices constant and assuming that Class III Skim price is the Class I mover in (10), is given by:

$$\frac{\partial TPPD}{\partial p_{PR}} = \left[3.1/\left[100\times\left(1-T_{BF}\right)\right]-T_{PR}\right]\times U_{S,I}\times W_M - U_{S,II}\times T_{PR}\times W_M - U_{S,IV}\times T_{PR}\times W_M \quad (35)$$

For all reasonable values for T_{PR} this expression has a negative sign. In contrast, higher butter prices increase PPDs. If advanced prices are equal to announced monthly prices, then the direct impact on PPD from the increase in the butterfat price is zero. The impact of an increase in the butter price, holding other commodity prices constant, is therefore entirely indirect, through the reduction of the protein price.

To quantify the impact of variability in dairy product prices, the Step 3 model uses the actual announced dairy product and milk component prices, instead of average prices observed over 2010-2019. All other restrictions and assumptions are the same as in the Step 2 model. As an example, the impact of the spread between Class III and Class IV milk prices on predicted PPDs for the Mideast federal order is displayed in Figure 1.

Step 4. Advanced Prices

Advanced prices temper the immediate impact of sudden commodity price crashes or rallies on producer milk checks. When market prices rally, announced prices will be higher than advanced prices, and the PPD will be lower, and vice versa. From (27), the PPD impact from the increase in the announced butterfat price, holding other announced milk component prices and all advanced prices constant, is:

$$\frac{\partial TPPD}{\partial p_{BF}} = -U_{BF,I} \times T_{BF} \times W_M \tag{36}$$

To quantify the impact of advanced pricing, the Step 4 model uses the actual advanced dairy product and milk component prices, instead of keeping them equal to announced monthly prices. The relationship of the spread between announced, monthly average cheese price and advanced two-week average cheese price for the Southwest federal order is displayed in Figure 2.

While depressed or elevated announced prices may impact PPDs for many months, the impact of advanced pricing on PPD is short-term. As soon as commodity prices stabilize at a higher, or lower level, the spread between announced and advances prices reverts to reflecting only seasonality in prices.

Step 5. Class I Pricing Reform of 2018

The base Class I skim milk price formula from (10) which included the higher of Class III or Class IV prices presented hedging challenges for Class I milk buyers (Newton, 2013). In an attempt to address this problem, the Agriculture Improvement Act of 2018 modified the "higher-of" formula to an "average-of" formula given in equation (9). To examine the impact of the Class I pricing reform on PPDs, compare the impacts of the pricing rules:

$$p_{S,I,A,2000-2018} - p_{S,I,A} = \left(\max\left(p_{III,S,A}, p_{IV,S,A}\right) - \min\left(p_{III,S,A}, p_{IV,S,A}\right) - 1.48\right)/2 \tag{37}$$

When the spread between the higher and the lower of the two advanced skim milk pricing factors is lower than \$1.48, then the reformed formula increases the PPD. When the spread is larger than

$1.48, then the "higher-of" formula results in a higher base Class I skim milk price, and thus a higher PPD as well.

To quantify the impact of Class I skim milk pricing reform, the Step 5 model uses the actual formula for base Class I skim milk price for all months since May 2019. Like all previous models, Step 5 model also restricts utilization rates to predicted rates based on trend and seasonal factors. The impact on the PPDs in the Northeast federal order are displayed in Figure 3. When advanced Class III and Class IV skim milk prices are identical, the PPD in Northeast is approximately $0.20/cwt higher than would be under the previous Class I pricing regime. Due to extraordinarily large spreads between Class III and Class IV skim prices during the COVID-19 pandemic, the "average-of" formula resulted in PPDs that were considerably lower than they would have been under the previous price regime.

Step 6. Depooling and Structural Changes

As a final effect, the difference between predicted PPDs under Step 5 model, and the actual PPDs published by market administrators is due solely to depooling and structural changes in utilization rates. This framework does not allow us to separately identify those two factors, but based on monthly variation it is reasonable to assume that almost the entire residual is due to depooling.

Relative Importance of Factors Contributing to Producer Price Differentials

Quantifying the relative importance of six steps described in the previous section can be approached in two ways. First, we can ask what explains the difference between the baseline and actual PPD levels in a particular month and a particular federal order. Alternatively, we can focus on summary statistics that quantify relative importance of these factors to variation around PPD.

We use the Central order PPD for August 2020 as an example to demonstrate how this PPD decomposition approach explains the drivers of PPD. The waterfall chart in Figure 5 illustrates the contribution of each factor to the Central order PPD for August 2020. We define baseline PPD for a particular calendar month as the PPD predicted under the Step 1 Model for that calendar month. In this case, baseline PPD is $0.91/cwt, the predicted PPD for the Central order for August 2010. For comparison, over 2005-2009 period, the average actual Central order PPD for that same calendar month was $0.86/cwt.

The predicted utilization rate for Class I skim milk was 35.8% for August 2010, and 31.5% for August 2020. In August 2010, pool average component tests were 3.44 percent for butterfat and 2.95 percent for protein. In August 2020, average tests were 3.73 percent for butterfat and 3.09 percent for protein. Long-term trends in utilization rates and component tests (Step 2) reduced the predicted PPD by $0.42/cwt.

Over 2010-2019 period, the average spread between Class III and Class IV prices was $0.39/cwt. In August 2020, the spread between Class III and Class IV prices was near the historic high, $7.24/cwt. At the onset of COVID-19 pandemic, both Class III and IV prices sharply declined. However, large-scale USDA intervention through cheese purchases elevated Class III prices up to $19.77/cwt in August 2020, while leaving Class IV prices at a low of $12.53/cwt. The resulting spread of $7.24/cwt was the third largest spread observed up to that month, exceeded only by spreads in June and July 2020. Taking actual announced monthly prices into consideration (Step 3), the predicted PPD was further reduced by $2.33/cwt.

Weekly surveyed cheese prices dropped from $2.71/lb for the week ending on July 18, 2020 to $1.84/cwt for the week ending on August 29, 2020. Consequently, advanced Class III skim milk price for August was $18.08/cwt, while the announced monthly Class III skim price for

August was only $14.58/cwt. Advanced prices for August, published on July 22 before cheese prices dropped, contributed to higher handler obligations to the federal order pool than had the Class I skim milk price been set based on monthly announced prices. Accounting for advanced prices (Step 4), increased the predicted PPD by $1.29/cwt.

In August 2020, the advanced Class IV skim milk price was only $7.12/cwt. The spread between the advanced Class III skim milk price and advanced Class IV skim milk price was $10.96/cwt. The magnitude of this spread was unprecedented, exceeding the average spread between advanced skim milk prices by 5.7 standard deviations. Consequently, the 2019 Class I milk pricing reform (Step 5) reduced the predicted PPD by $1.44/cwt, pushing it down to -$1.99/cwt.

The actual observed PPD at -$3.62/cwt was considerably more negative than predicted by model in the Step 5. Three years earlier, in August 2017, when PPD was positive, Class III receipts of milk and cream totaled 693,753,584 lbs. In contrast, Class III receipts were only 27,017,766 lbs in August 2020. Class III skim milk utilization rate dropped to only 2.91%, down from 47.4% in August 2017. Over this period, there were no news of substantial dairy plant closures or openings, and USDA estimates that cheese production increased in August 2020 compared to prior years. As such, we conclude that the change in utilization rates is not due to sudden structural changes in utilization rates, but the decision of Class III handlers to opt out of the pool for August 2020. Depooling reduced the PPD by $1.63/cwt relative to what would have been the case had the utilization rates remained at their historical trend and seasonal levels.

The clustered bar chart in Figure 6 presents the PPD decomposition analysis for the Central order for annual PPD averages over 2015-2020 period. Long-term trends have had a consistent and increasing negative impact. From 2015 through 2019, the spread between Class III and Class

IV prices had a moderate negative impact, ranging from -$0.31/cwt in 2015 to -$0.02/cwt in 2018. Extreme spreads in 2020 reduced the annual average PPD by -$1.58/cwt. Advanced pricing impacts on PPD are short-term and tend to average close to zero on annual level. Class I pricing reform, implemented in May 2019, increased PPD by $0.02/cwt in 2019 and reduced the PPD by -$0.55/cwt in 2020. Depooling and structural changes to utilization rates account for unexplained drivers of PPD. Presented averages reveal the full magnitude of COVID-19 pandemic on the Central order. At -$1.25/cwt, the depooling impact was substantially more pronounced than in prior years. Despite growth in reported milk production, total receipts of producer cream and milk in the Central order were 19.8% lower in 2020 than in 2018.

Table 6 presents annual average impacts on PPD in 2020 for all analyzed federal orders. In 2020, the spread between Class III and IV milk prices contributed -$1.73/cwt to PPDs. Class I reform reduced PPDs by -$0.46/cwt, while depooling and structural changes contributed -$0.77/cwt.

Since each of five analyzed factors can have either positive or negative impact on PPD in a particular month, their relative importance over longer time intervals is better measured through impact on variability of actual PPDs around base values. To that end we calculate the sum of squared differences between actual and baseline PPDs. We then calculate the sum of squared prediction errors under each model and calculate the ratio of the reduction in the sum of squared errors across consecutive steps to the sum of squared prediction errors against baseline values.

For example, in the Pacific Northwest federal order, the sum of squared differences between actual and baseline PPDs over January 2010 through February 2021 is equal to 337.33. The sum of squared prediction errors for Step 2 – Component Tests is 299.55. And the sum of squared prediction errors for Step 3 – Actual Announced Prices is 30.22. Thus, the percent of variation explained by variability in announced monthly prices is calculated as (299.55 – 30.22) / 337.33, which is equal to 79.8%. Figure 6 displays the relative magnitude of average variation around the baseline PPD values over the period from January 2010 through February 2021 as well as the contribution of each factor to the variation. To focus on the period since the Class I pricing reform, and strongly influenced by the COVID-19 pandemic, Table 7 presents the same data for May 2019 through February 2021.

Policy Analysis

We use the framework presented in previous sections to explore impacts of several FMMO reforms on PPDs. These potential reforms include a) changes in Class I skim milk price formula, b) changes in make allowances, and c) change in the level of standard component tests used for Class III and IV skim milk prices.

Changes in Class I pricing formula

Due to negative impact of the Class I pricing reforms on PPDs in 2020, several alternative Class I pricing formulas are considered. In this section we explore the consequences of the following four Class I pricing alternatives on PPDs:

1. Class I skim milk price is set equal to average of advanced Class III skim milk pricing factor and advanced Class IV skim milk pricing factor, augmented by $0.74/cwt.
2. Class I skim milk price is set equal to average of advanced Class III skim milk pricing factor and advanced Class IV skim milk pricing factor, augmented by $1.00/cwt.
3. Class I skim milk price is set equal to average of advanced Class III skim milk pricing factor and advanced Class IV skim milk pricing factor, augmented by $1.63/cwt.
4. Class I skim milk price is set equal to advanced Class III skim milk pricing factor, augmented by $0.50/cwt.

Changes in make allowances

As demonstrated in the previous section, the largest contributor to negative PPDs in 2020 was the spread between Class III and Class IV milk prices. The proximate causes were the Farmers to Families Food Box program implemented by USDA to counter COVID-19 impacts on food security and faltering dairy markets, and depressed butter prices due reduced foodservice demand. However, a deeper question is why U.S. dairy sector did not have more flexibility to shift production towards cheese types that could be sold in retail or distributed through donation boxes. One reason may be that the cheese and whey make allowances, not updated since 2010, no longer accurately reflect true cheese manufacturing costs. The current cheese make allowance is $0.2003/cwt, the dry whey make allowance is $0.1991, the butter make allowance is $0.1715 and the nonfat dry milk make allowance is $0.1678. Examining the impact of changes in make allowance on commodity prices is beyond the scope of this article. We can, however, examine the impact on milk component prices, given historical commodity prices. For illustration, we modified the cheese make allowance to $0.2350, the butter make allowance to $0.1800, the dry whey make allowance to $0.2050, and the nonfat dry milk make allowance to $0.1800.

Changes in standard milk component tests

Class III and Class IV milk prices use standard component tests: 3.5 pounds of butterfat per hundredweight of milk, and 3.1 pounds of protein and 5.9 of other solids per hundredweight of skim milk. These component tests reflect the average milk solids tests in late 1990s, prior to the last major federal order reform. However, as demonstrated previously, average component tests have since increased considerably. Class I handler obligations to the pool are based on skim milk definition with 3.1 pounds of protein, although such milk may have much higher protein content. This misalignment contributes to negative trends in PPDs over time. In this experiment we modify standard class tests to be 4.0 pounds of butterfat per hundredweight of milk and 3.4 pounds of protein per hundredweight of skim milk. We keep the other solids test at current level (5.9 pounds).

The impacts of these changes on 2015-2020 average PPDs are presented in Tables 8 and 9. Reviewing the Class I pricing proposals, we find that had the "average-of" pricing regime with $1.00/cwt adjustor been in effect from 2015, the average PPD under the $1.00/cwt adjustor would have been nearly the same as under the "higher-of" regime. Proposals with $1.63 adjustor, or based solely on advanced Class III skim milk pricing factors would have resulted in higher PPDs and lower frequency of negative PPDs. Similarly, adjusting make allowances increases average PPD by $0.04/cwt in Upper Midwest, up to $0.16/cwt in Northwest. Increasing butterfat and protein tests in standard Class III and Class IV prices has a material impact on PPDs, with average increase in the Northeast and Southwest orders near to $0.20/cwt.

Summary and Conclusions

We develop a framework to quantify relative contributions of six aspects of milk pricing under Federal Milk Marketing Orders on producer price differentials: 1) long-term trends in utilization of milk in beverage vs. manufactured dairy products, 2) seasonal and long-term trends in butterfat and protein content of milk, 3) variability in dairy product prices, 4) advanced pricing used for beverage milk products, 5) Class I milk pricing reform enacted in the 2018 Farm Bill, and 6) voluntary removal of milk used for manufacturing from market orders, i.e., depooling. We find that long-term trends in utilization and component tests have substantially reduced PPDs over the past decade. There is no reason to think these trends will reverse course at the current time. Class I milk pricing reform of 2018 exacerbated negative PPDs in 2020, but our models suggest the PPDs would have been negative anyway. The greatest contributor to recent negative PPDs is the spread between cheese and milk powder prices, which were further aggravated by ad hoc government intervention programs introduced to counter the impact of COVID-19 pandemic on food security and commodity markets.

A phrase often used to describe the primary goal of FMMO regulations is “orderly marketing,” which is taken to mean well behaved milk distribution, dependable and equitable contractual relationships between beverage milk handlers and milk producers, and reliable relationships for prices and supplies between different markets (Manchester, 1983). Orderly marketing must also include proper incentives to direct milk to dairy products where the milk is adding the most value. That in turn means proper incentives for production capacity utilization to be low enough to allow flexibility in dairy product production in response to changes in demand. One step towards that realignment might be to adjust make allowances to accurately reflect dairy processing costs. Our models show that adjusting make allowances can reduce the spread between the value of skim solids in cheese and dry milk products, and thus increase PPD both directly, and indirectly through incentives to augment aggregate cheesemaking capacity. The ‘average-of’ approach results in a higher PPD when the value of skim solids is sufficiently similar in cheese and milk powder markets, and thus should perform more advantageously to dairy producers if the underlying drivers of wide spreads between Class III and Class IV milk prices are properly addressed.

Beyond adjusting make allowances, further research should explore how product formulas may be altered to provide additional incentives to manufacturers to quickly adjust product mix in response to demand shocks. Finally, a key limitation of our models is that we cannot ascribe how much of the depooling is due to each underlying factor, which is why all our models assume trend-seasonal utilization rates. Future research might focus on developing optimal depooling models. Further on the issue of depooling, it is important to note that historically, equalization in producer prices was driven by large revenue transfers from beverage milk class to manufactured milk classes. With waning of fluid milk sales and growth in domestic and export demand for manufactured products, in a majority of market orders Class I revenue is no longer sufficient to provide even short-term equalization of mailbox prices for producers whose milk is used in powder versus cheese production. Future research might consider market order formulations which avoid persistent problems with depooling and negative and increasingly volatile PPDs happening ever more frequently under the current system. It is almost certain that such reform will need to be much more comprehensive than just adjusting make allowances and/or Class I milk pricing formula.

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Table 1. Factors Affecting Producer Price Differentials

Step	Utilization Rates	Component Tests	Announced Prices	Advanced Prices	Class I Pricing Formula
1. Trends in utilization rates	Linear trend and seasonal model	Constant, 2010 level	Constant, 2010-2019 average	Equal to announced prices	Higher-of regime
2. Structural changes in component tests	Linear trend and seasonal model	Actual	Constant, 2010-2019 Average	Equal to announced prices	Higher-of regime
3. Changes in relative announced prices	Linear trend and seasonal model	Actual	Actual	Equal to announced prices	Higher-of regime
4. Impact of advanced pricing	Linear trend and seasonal model	Actual	Actual	Actual	Higher-of regime
5. Impact of 2019 Class I pricing reform	Linear trend and seasonal model	Actual	Actual	Actual	Actual
6. Depooling and structural changes	Actual	Actual	Actual	Actual	Actual

Table 2. Trend and Seasonal Analysis of Utilization Rates

Utilization Rate	Intercept	Trend	Seasonal (sin)	Seasonal (cos)	Jan 2010 Predicted	Jan 2021 Predicted
Federal Milk Marketing Order #1 - Northeast					%	%
Skim milk, Class I	49.06*	-0.10*	-1.30*	2.59*	44.3	30.6
Skim milk, Class II	19.06*	0.03*	-0.75*	-1.24*	19.7	24.2
Skim milk, Class III	22.44*	0.02*	-0.60*	-0.24	23.3	26.3
Skim milk, Class IV	9.44*	0.05*	2.65*	-1.11*	12.7	19.0
Butterfat, Class I	24.83*	-0.05*	-1.38*	0.99*	22.1	15.9
Butterfat, Class II	40.52*	-0.03*	-1.50*	-2.11*	36.4	33.0
Butterfat, Class III	23.04*	0.04*	-0.27	0.05	25.7	31.6
Butterfat, Class IV	11.61*	0.03*	3.15*	1.06*	15.8	19.5
Federal Milk Marketing Order #30 – Upper Midwest						
Skim milk, Class I	19.59*	-0.07*	0.15	0.78	16.3	7.5
Skim milk, Class II	4.91*	-0.01	-0.20	-0.06	4.4	3.8
Skim milk, Class III	72.77*	0.07*	-0.55	-0.97	75.8	84.9
Skim milk, Class IV	2.72*	0.00	0.60*	0.25	3.4	3.8
Butterfat, Class I	7.60*	-0.02*	-0.07	0.17	6.2	3.0
Butterfat, Class II	11.99*	-0.03*	-0.30	-0.41	9.8	6.2
Butterfat, Class III	72.33*	0.04*	-0.75	-0.77	73.5	78.2
Butterfat, Class IV	8.07*	0.02*	1.12*	1.01*	10.5	12.6
Federal Milk Marketing Order #32 – Central						
Skim milk, Class I	36.39*	-0.03*	-1.85*	2.69*	36.2	32.8
Skim milk, Class II	14.13*	-0.03*	-0.77*	-1.10*	11.2	7.9
Skim milk, Class III	37.71*	0.02	1.42	-1.19	38.6	41.3
Skim milk, Class IV	11.76*	0.03*	1.20*	-0.40	13.9	18.0
Butterfat, Class I	16.58*	0.00	-1.29*	0.65*	16.3	15.7
Butterfat, Class II	25.28*	-0.02*	-1.97*	-1.95*	21.6	19.3
Butterfat, Class III	36.88*	0.03*	0.92	-0.96	38.4	42.4
Butterfat, Class IV	21.25*	-0.01	2.34*	2.26*	23.8	22.6

Table 2. Trend and Seasonal Analysis of Utilization Rates (continued)

Utilization Rate	Intercept	Trend	Seasonal (sin)	Seasonal (cos)	Jan 2010 Predicted	Jan 2021 Predicted
					%	%
Federal Milk Marketing Order #33 – Mideast						
Skim milk, Class I	34.25*	-0.06*	-0.98	1.87*	41.0	34.7
Skim milk, Class II	6.64*	0.00	-0.22	-0.37*	15.8	17.0
Skim milk, Class III	27.31*	0.05*	1.41	-0.58	34.0	28.6
Skim milk, Class IV	31.19*	0.02	0.11	-0.76	9.2	19.8
Butterfat, Class I	16.09*	-0.03*	-1.02*	0.68*	19.0	16.7
Butterfat, Class II	18.07*	-0.01*	-1.12*	-0.78*	26.7	32.0
Butterfat, Class III	29.81*	0.03	1.00	-0.87	33.4	26.0
Butterfat, Class IV	36.03*	0.01	1.14	0.96	20.9	25.3
Federal Milk Marketing Order #124 – Pacific Northwest						
Skim milk, Class I	34.25*	-0.06*	-0.98	1.87*	31.7	23.9
Skim milk, Class II	6.64*	0.00	-0.22	-0.37*	6.1	5.9
Skim milk, Class III	27.31*	0.05*	1.41	-0.58	30.6	37.1
Skim milk, Class IV	31.19*	0.02	0.11	-0.76	31.6	33.7
Butterfat, Class I	16.09*	-0.03*	-1.02*	0.68*	14.6	11.3
Butterfat, Class II	18.07*	-0.01*	-1.12*	-0.78*	16.1	14.4
Butterfat, Class III	29.81*	0.03	1.00	-0.87	31.5	35.6
Butterfat, Class IV	36.03*	0.01	1.14	0.96	37.8	38.7
Federal Milk Marketing Order #126 – Southwest						
Skim milk, Class I	45.18*	-0.06*	-2.47*	2.39*	42.3	34.4
Skim milk, Class II	11.54*	-0.02*	-0.36	-0.81*	9.6	7.2
Skim milk, Class III	30.14*	0.06*	-0.47	-0.05	33.7	42.0
Skim milk, Class IV	13.14*	0.02	3.30*	-1.54	14.4	16.4
Butterfat, Class I	27.69*	-0.05*	-1.95*	0.17	23.7	16.9
Butterfat, Class II	26.45*	0.00	-1.81*	-1.39	24.2	23.9
Butterfat, Class III	30.78*	0.07*	-0.61	-0.11	34.5	43.5
Butterfat, Class IV	15.07*	-0.01	4.37*	1.33	17.5	15.7

Table 3. Average Milk Component Tests

	2008-2009			2020		
Federal Milk Marketing Order	**Butterfat**	**Protein**	**Other Solids**	**Butterfat**	**Protein**	**Other Solids**
	%	%	%	%	%	%
FO #1 – Northeast	3.72	3.06	5.70	3.92	3.11	5.77
FO #30 – Upper Midwest	3.71	3.04	5.72	3.96	3.14	5.77
FO #32 – Central	3.63	3.07	5.73	3.92	3.20	5.79
FO #33 – Mideast	3.70	3.06	5.70	3.88	3.16	5.78
FO #124 – Pacific Northwest	3.69	3.10	5.70	4.07	3.25	5.77
FO #126 – Southwest	3.61	3.06	5.74	4.07	3.28	5.78

Table 4. Dairy Product and Milk Component Prices Summary Statistics

	Minimum	Maximum	Average	Standard Deviation	Coefficient of Variation
	$/lb	$/lb	$/lb		
Dairy Product Prices (2010-2019)					
Butter	1.36	2.85	1.99	0.35	0.18
Cheese	1.36	2.35	1.72	0.23	0.13
Dry Whey	0.23	0.69	0.46	0.14	0.31
Nonfat Dry Milk	0.70	2.09	1.19	0.37	0.31
Milk Component Prices (2010-2019)					
Butterfat	1.44	3.25	2.20	0.42	0.19
Protein	1.14	4.71	2.56	0.81	0.32
Other Solids	0.03	0.50	0.27	0.14	0.53
Nonfat Solids	0.52	1.90	1.01	0.37	0.37

Table 5. Impact of Long-Term Trends on Predicted Producer Price Differentials

Step 1 – Utilization Rates

Federal Milk Marketing Order	Step 1, Jan 2010 Predicted	Step 1, Jan 2021 Predicted	Change	Change
	$/lb	$/lb	$/lb	%
FO #1 – Northeast	1.88	1.41	-0.47	-25
FO #30 – Upper Midwest	0.35	0.23	-0.12	-34
FO #32 – Central	0.71	0.45	-0.26	-37
FO #33 – Mideast	0.92	0.67	-0.25	-27
FO #124 – Pacific Northwest	0.58	0.30	-0.28	-48
FO #126 – Southwest	1.74	1.34	-0.40	-23

Step 2 – Component Tests

Federal Milk Marketing Order	Step 1, Jan 2021 Predicted	Step 2, Jan 2021 Predicted	Change	Change
	$/lb	$/lb	$/lb	%
FO #1 – Northeast	1.41	1.26	-0.15	-11
FO #30 – Upper Midwest	0.23	0.18	-0.05	-22
FO #32 – Central	0.45	0.24	-0.21	-47
FO #33 – Mideast	0.67	0.49	-0.18	-27
FO #124 – Pacific Northwest	0.30	0.07	-0.23	-77
FO #126 – Southwest	1.34	0.99	-0.35	-26

Table 6. PPD Decomposition for 2020

Federal Milk Marketing Order	Baseline PPD	Step 1, Utilization Rates	Step 2, Component Tests	Step 3, Actual Announced Prices	Step 4, Advanced Prices	Step 5, Class I Pricing Reform	Step 6, Depooling and Struct. Changes	Actual PPD
	$/cwt	$/cwt	$/cwt	$/cwt	$/cwt	$/cwt	$/cwt	$/cwt
FO #1 – Northeast	$1.90	-$0.43	-$0.08	-$2.16	$0.16	-$0.50	$0.05	-$1.06
FO #30 – Upper Midwest	$0.36	-$0.11	-$0.05	-$0.54	$0.04	-$0.16	-$1.22	-$1.66
FO #32 – Central	$0.74	-$0.16	-$0.14	-$1.58	$0.15	-$0.55	-$1.25	-$2.90
FO #33 – Mideast	$0.98	-$0.23	-$0.14	-$2.00	$0.16	-$0.56	-$0.53	-$2.31
FO #124 – Pacific Northwest	$0.52	-$0.25	-$0.12	-$2.32	$0.10	-$0.38	-$0.14	-$2.59
FO #126 – Southwest	$1.79	-$0.36	-$0.29	-$1.77	$0.15	-$0.59	-$1.54	-$2.62
Average	$1.05	-$0.26	-$0.14	-$1.73	$0.13	-$0.46	-$0.77	-$2.19

Table 7. Quantifying Importance of Factors Contributing to Variation Around Baseline PPD, May 2019 - February 2021

		% of Variation Explained by the Model					
Federal Milk Marketing Order	**Variation Around Baseline PPD**	**Step 1, Utilization Rates**	**Step 2, Component Tests**	**Step 3, Actual Announced Prices**	**Step 4, Advanced Prices**	**Step 5, Class I Pricing Reform**	**Step 6, Depooling and Struct. Changes**
	$/cwt	%	%	%	%	%	%
FO #1 – Northeast	11.05	15.7	2.4	71.0	8.1	2.6	0.2
FO #30 – Upper Midwest	5.21	5.6	1.8	38.2	10.4	5.8	38.1
FO #32 – Central	16.75	7.2	4.7	54.8	13.7	8.2	11.4
FO #33 – Mideast	14.75	7.0	3.6	66.8	13.8	5.2	3.7
FO #124 – Pacific Northwest	11.30	9.5	4.2	79.1	4.4	2.5	0.3
FO #126 – Southwest	22.67	10.0	7.9	52.0	10.3	8.3	11.5
Average	13.62	9.2	4.1	60.3	10.1	5.4	10.9

Table 8. Average Producer Price Differentials, 2015-2020, under Different Policy Frameworks

Federal Milk Marketing Order	Current Regime (Step 5 Model)	Adjusted Make Allowances	Adjusted Standard Component Tests	Class I: Higher-Of	Class I: Average + $0.74/cwt	Class I: Average + $1.00/cwt	Class I: Average + $1.63/cwt	Class I: Adv Class III Skim + $0.50/cwt
	$/cwt	$/cwt	$/cwt	$/cwt	$/cwt	$/cwt	$/cwt	$/cwt
FO #1 – Northeast	0.86	1.02	1.04	0.94	0.87	0.96	1.15	1.04
FO #30 – Upper Midwest	0.08	0.12	0.13	0.11	0.08	0.11	0.17	0.14
FO #32 – Central	-0.07	0.04	0.11	0.02	-0.06	0.02	0.22	0.12
FO #33 – Mideast	0.10	0.24	0.29	0.19	0.11	0.20	0.40	0.29
FO #124 – Pacific Northwest	-0.42	-0.28	-0.29	-0.36	-0.41	-0.35	-0.21	-0.29
FO #126 – Southwest	0.78	0.89	0.97	0.87	0.79	0.88	1.09	0.98
Average	0.22	0.34	0.38	0.30	0.23	0.30	0.47	0.38

Table 9. Frequency of Negative Producer Price Differentials, 2015-2020, under Different Policy Frameworks

Federal Milk Marketing Order	Current Regime (Step 5 Model)	Adjusted Make Allowances	Adjusted Standard Component Tests	Class I: Higher-Of	Class I: Average + $0.74/cwt	Class I: Average + $1.00/cwt	Class I: Average + $1.63/cwt	Class I: Adv Class III Skim + $0.50/cwt
				% of months				
FO #1 – Northeast	12.5	9.7	9.7	11.1	12.5	11.1	8.3	9.7
FO #30 – Upper Midwest	20.8	19.4	16.7	19.4	20.8	19.4	15.3	16.7
FO #32 – Central	37.5	31.9	23.6	37.5	34.7	31.9	22.2	26.4
FO #33 – Mideast	23.6	22.2	20.8	22.2	27.8	25.0	20.8	20.8
FO #124 – Pacific Northwest	51.4	44.4	44.4	51.4	51.4	50.0	38.9	47.2
FO #126 – Southwest	12.5	9.7	8.3	9.7	12.5	12.5	8.3	8.3
Average	26.4	22.9	20.6	25.2	26.6	25.0	19.0	21.5

Figure 1. Impact of Variability in Announced Prices on Predicted Producer Price Differentials in FO #33 - Mideast

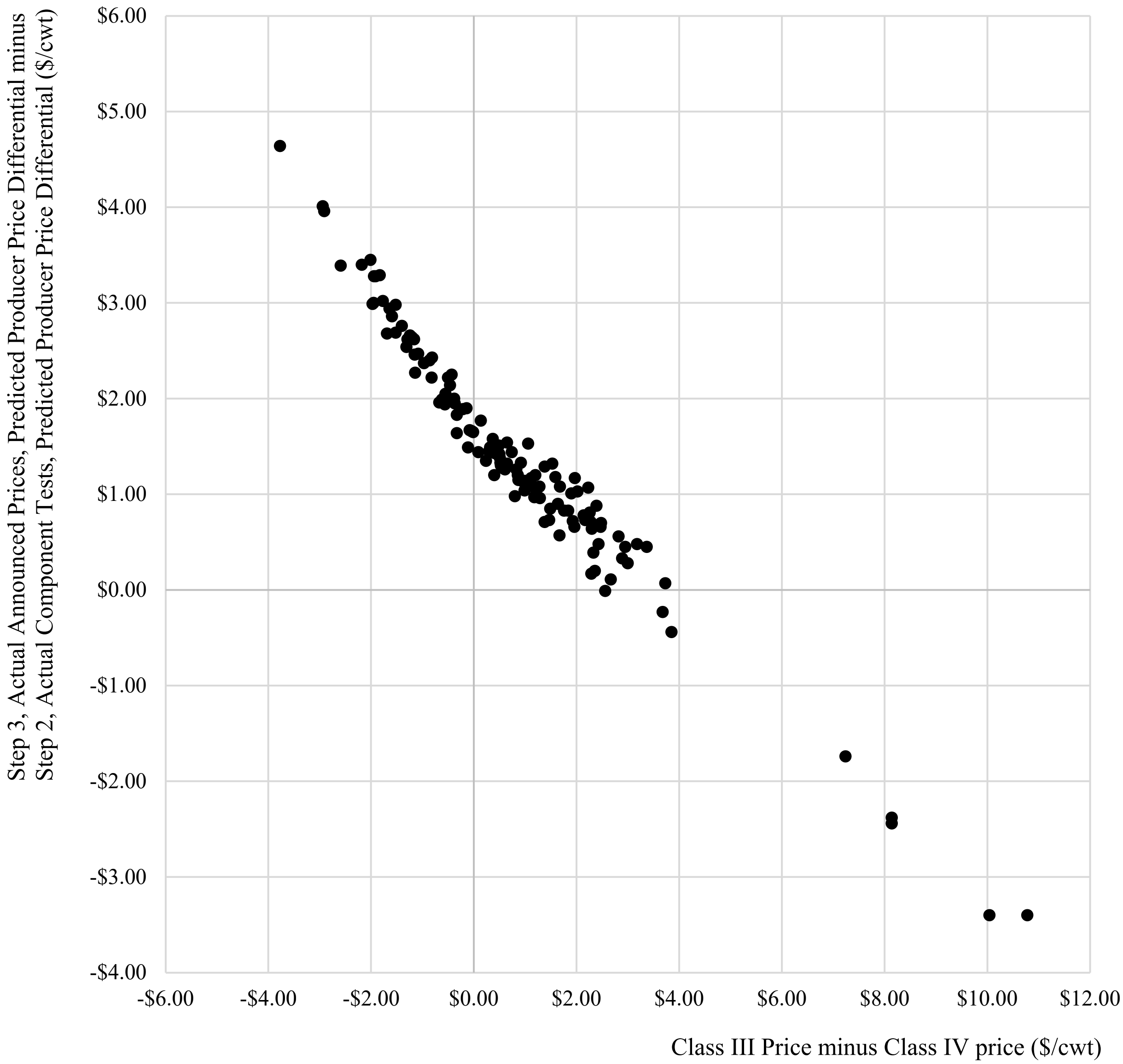

Figure 2. Impact of Cheese Price Rallies and Crashes on Predicted Producer Price Differentials in FO #126 – Southwest

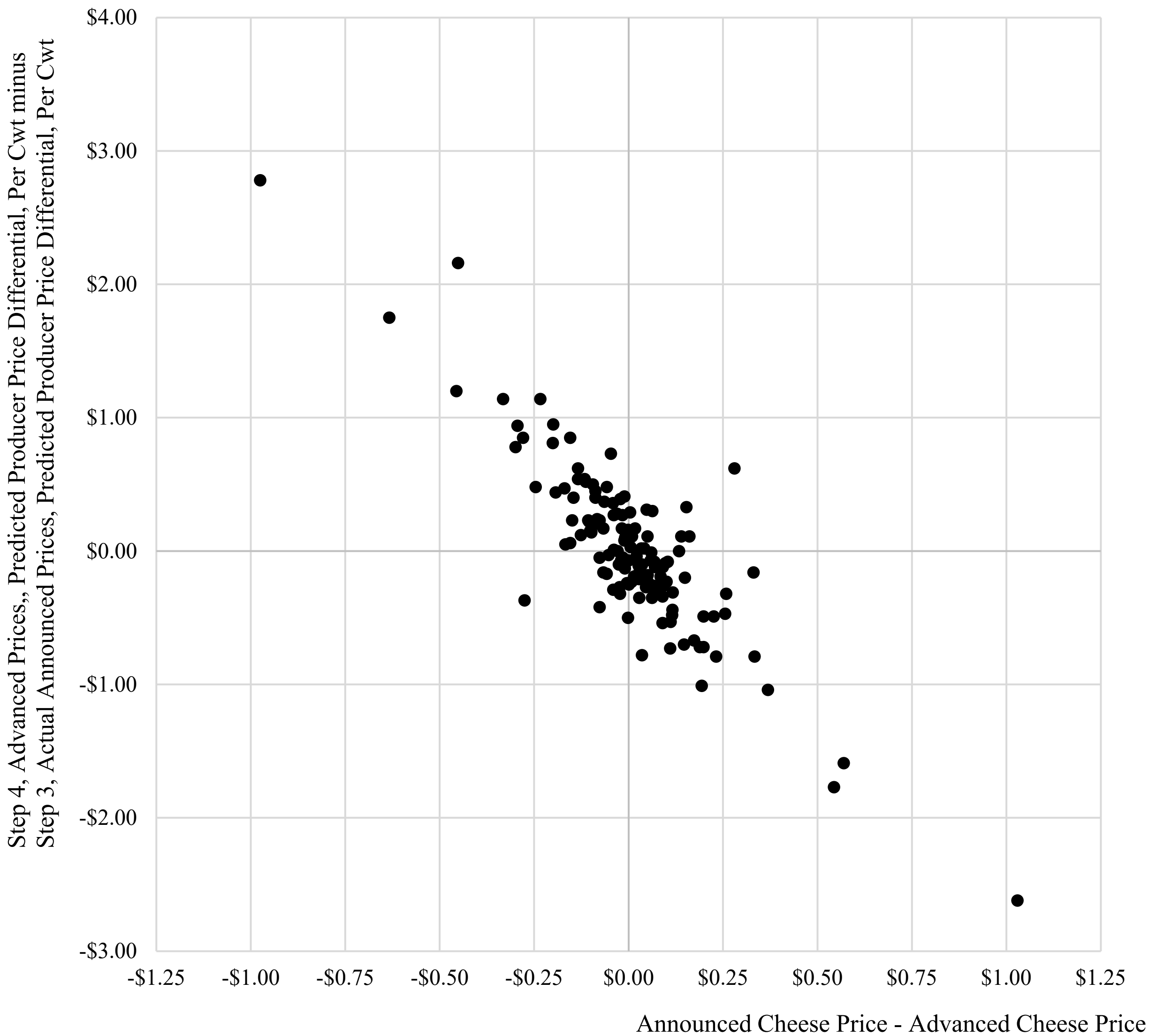

Figure 3. Impact of Class I Pricing Policy Reform on Producer Price Differentials in FO #1 – Northeast, May 2019-Feb 2021

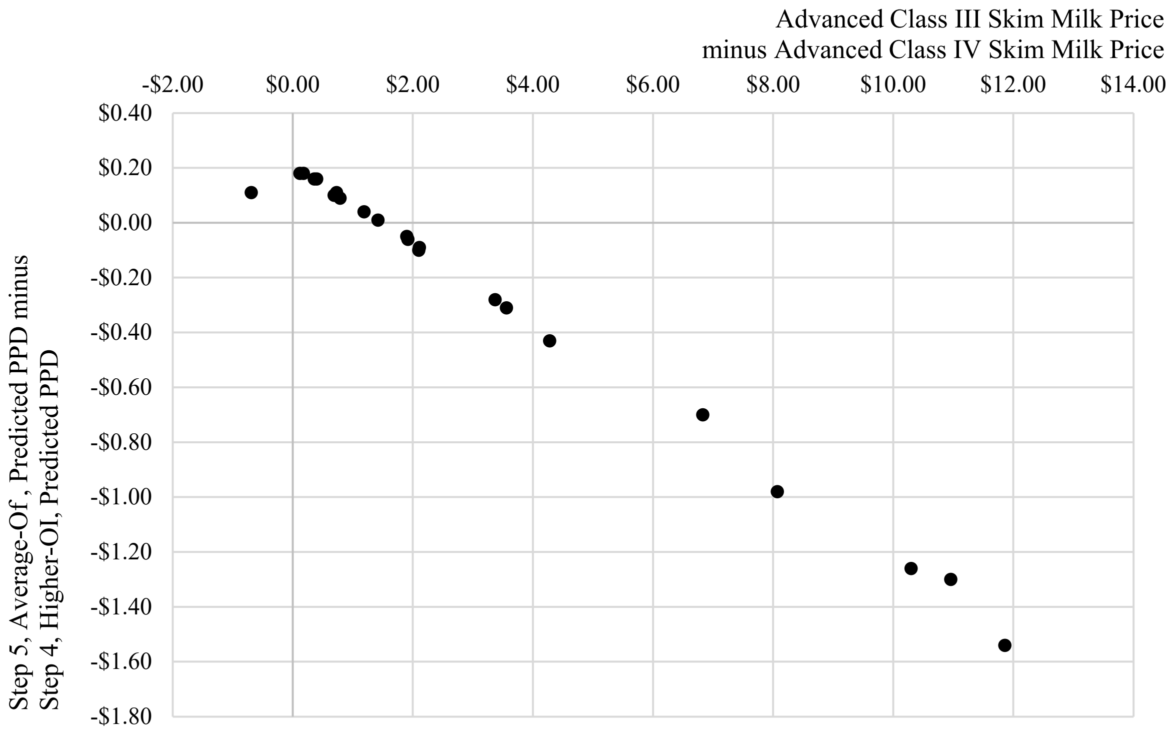

Figure 4. Contributions to Producer Price Differential in FO #32 – Central for August 2020

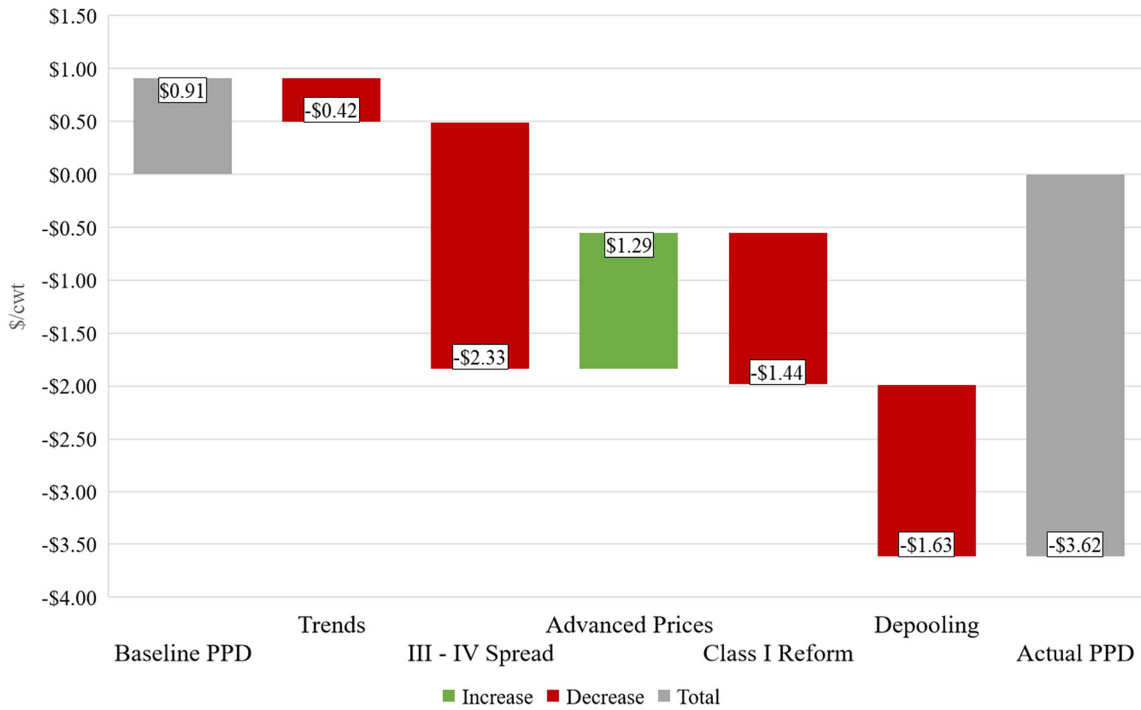

Figure 5. Contributions to Producer Price Differential in FO #32 – Central for 2015-2020

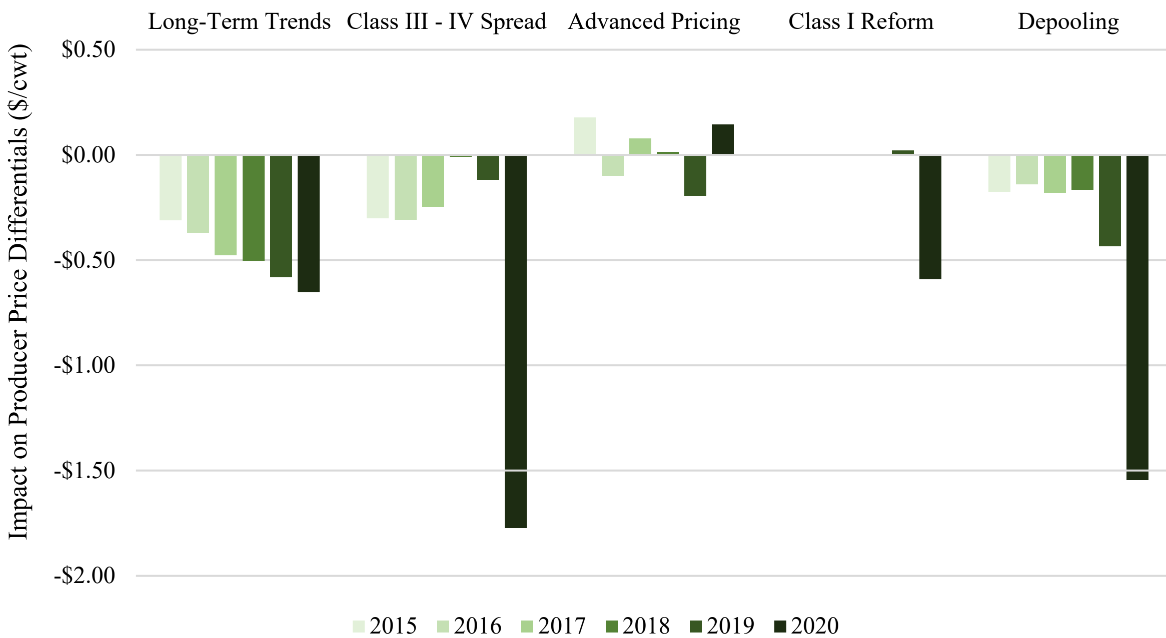

Figure 6. Relative Importance of Factors to Variation Around Baseline PPD, 2010-2021