***Technical Appendix: Opportunity Cost Pricing***

This technical appendix details the derivation of opportunity cost pricing. The assumptions used in this technical appendix are implicit in the derivation of the Van Slyke cheese yield formula and the current Class III protein price, *Technical Appendix: Van Slyke Cheese Yield Formula*.

Opportunity cost (OC) pricing as defined below values protein used in cheese as a function of its value in nonfat dry milk. OC pricing uses the Van Slyke cheese yield formula in combination with standard dairy product component characteristics and commodity prices used currently under FMMOs.

*Derivation of Opportunity Cost Factors*

The first step of the process to derive OC factors is to restate the Class IV nonfat solids price in terms of protein:

$P\_{Pro}^{IV}=P\_{NFS}^{IV}×9/3.1$ (1)

where $P\_{Pro}^{IV}$ is the Class IV protein price in $/lb, $P\_{NFS}^{IV}$ is the FMMO price of nonfat solids in $/lb. Per FMMO standards, 100 pounds of skim milk contains 3.1 pounds of true protein and 5.9 pounds of other solids, such as lactose and minerals, i.e., 9 pounds of nonfat solids. The Class IV protein price is a simple restatement of the total value of nonfat solids to a protein basis. It is this restated price that is used as the basis for calculating a protein price for milk used in cheese and dry whey. The Class IV nonfat solids price is unchanged in its form and as incorporated in a FMMO pool.

The next element in the calculations is an opportunity cost factor used to convert the calculated Class IV protein price to a protein price more appropriate to be used in pricing milk protein used in cheese and dry whey manufacturing. The opportunity cost factor has a numerator representing cheese and dry whey values and a denominator representing nonfat dry milk values. $M\_{Ch}^{nfv}$ measures the total value of cheese produced by a hundredweight of standard component milk, less the total value of butterfat captured in that cheese. The value of the skim fraction of a hundredweight of milk used in manufacturing cheese, $M\_{Ch}^{nfv}$, is determined as:

$M\_{Ch}^{nfv}=\left(C\_{Y}×P\_{Ch}\right)-\left(C\_{F}×C\_{Y}×P\_{BF}\right)$ (2)

where is the cheese yield from equation (1) of the *Technical Appendix: Van Slyke Cheese Yield Formula*, *PCh* is the cheese price and *PBF* is the butterfat price. Consistent with the Van Slyke parametrization in FMMO formulas, the average butterfat content of cheddar cheese is set as $C\_{F}=f\_{r}×\left(F\_{t}-F\_{L}\right)×\left(1-L\right)/C\_{Y}=32.46\%$

where $f\_{r}$. is the butterfat recovery in cheese and set at 0.9; $F\_{t}$ is the milk fat test in standard milk and set at 3.5; $F\_{L}$ captures farm-to-plant milkfat losses beyond $L$; $L$ denotes farm-to-plant milk losses; and $C\_{Y}$ is cheese yield per hundredweight of milk and is set at $9.6373$.

$M\_{W}^{nfv}$ measures the total value of dry whey manufactured from one hundredweight of standard milk, accounting for farm-to-plant losses:

$M\_{W}^{nfv}=$*(((100-*$F\_{L}$*) x (1-L)-*$C\_{Y}$*) x ((*$LW\_{S}$ */(1-3.2%))x*$P\_{W}$*))*$-(LW\_{F}x\left(\left(100-F\_{L}\right)x\left(1-L\right)-C\_{Y}\right)xP\_{BF}$ (3)

where expression $\left(\left(100-F\_{L}\right)×\left(1-L\right)-C\_{Y}\right)$ represents the weight of fluid whey per hundredweight of milk after accounting for farm-to-plant losses and the weight of cheese produced from that milk. $C\_{Y}=9.6373$ is the weight of cheese made; $LW\_{S}=6.8\%$ are whey solids as percent of liquid whey[[1]](#footnote-1); 3.2% is the moisture content of dry whey; $P\_{W}$ is the dry whey price; $LW\_{F}=0.386\%$ is the butterfat content of fluid whey; $P\_{BF}$ is the butterfat price. We calculate $LW\_{F}$ as butterfat not captured in cheese, as percent of total weight of fluid whey, $LW\_{F}=10\%×\left(3.5-F\_{L}\right)×\left(1-L\right)/\left(\left(100-F\_{L}\right)×\left(1-L\right)-C\_{Y}\right)$. The algebraic solution described in equation (3) is a shortcut to account for the value of whey but not get bogged down in how to mirror actual, varied industry practices/standards.

The last part of the opportunity cost cheese protein price factor to be calculated is the denominator, $M\_{NFDM}^{nfv} $, the value of nonfat dry milk produced from a hundredweight of standard milk:

$M\_{N}^{nfv}=$ (0.965 × (9.00 × (1-L) / 93.5%) × $P\_{N}$) (4)

where, 0.965 is the hundredweight of skim milk in 100 pounds of milk at 3.5% butterfat; 9.00 is the pounds of nonfat solids in 100 pounds of skim milk and represents the component test used in current product price formulas; L captures farm-to-plant milk loss, at 0.25%; 93.5% is the minimum solids content of nonfat dry milk; and $P\_{N}$ is the nonfat dry milk price.

Two alternative systems for pricing protein in cheese are considered. Method A proposes summing the total value of cheese and dry whey produced per hundredweight of milk and attributable to nonfat solids and dividing that total by the value of nonfat dry milk produced from a hundredweight of milk. The cheese protein opportunity cost factor, $OCF\_{A}$, is calculated as:

$OCF\_{A}=\left(M\_{Ch}^{nfv}+M\_{W}^{nfv}\right)/M\_{N}^{nfv}$ (5)

The opportunity cost-based Class III cheese protein price per Method A, $P\_{OCP,A}^{III}$ is then calculated as the Class IV protein price multiplied by the cheese protein opportunity cost factor:

$P\_{OCP,A}^{III}=P\_{Pro}^{IV}×OCF\_{A}$ (6)

Under Method A, other solids are no longer valued independently, and the entire value of the components in skim milk is ascribed to protein. The Class III milk price under Opportunity Cost Method A is defined as:

$M\_{OC,A}^{III}=3.5×P\_{BF}+0.965 x \left(3.1×P\_{OCP,A}^{III}\right)$ (7)

where *PBF* is the butterfat price.

The primary advantage of Method A is that cheese and dry whey make allowances are no longer needed. However, a potential shortcoming of this method is the treatment of butterfat in whey. In Method A we assume all solids in liquid whey are valued based on the dry whey price, less the value of butterfat in liquid whey. Based on the standards of identity for dry whey, only a fraction of the butterfat in liquid whey can be included in dry whey. In addition, cheese manufacturers remove whey cream before further processing liquid whey.

To address these concerns, we propose Opportunity Cost Method B. Under this method, the Class III milk price continues to include the direct compensation for other solids, but protein is priced using the opportunity cost approach. Under Method B, the Opportunity Cost Factor is modified to exclude the value of whey products attributable to nonfat solids:

$OCF\_{B}=M\_{Ch}^{nfv}/M\_{NFDM}^{nfv}$ (8)

With $P\_{OCP,B}^{III}=P\_{Pro}^{IV}×OCF\_{B}$, the Class III Milk Price under Opportunity Cost Method B is defined as:

$M\_{OC,B}^{III}=3.5×P\_{BF}+0.965×\left(3.1×P\_{OCP,B}^{III}+5.9×P\_{OS}\right)$ (9)

where *PBF* is the butterfat price and *POS* is the other solids price.

*Rewriting Opportunity Cost Factors in Terms of Commodity Prices*

The respective equations (6) and (8) can be rewritten in terms of the ratio of cheese, butter and dry whey prices to nonfat dry milk prices, respectively. Rewriting the composite factor illustrates the relative effect of each price ratio on the resulting factor and may make it more accessible. Rewritten, the factor for Method A is:

$OCF\_{A}=\left.\left.(1.0401×\left.P\_{Ch}\right.+0.6831×P\_{W}\right.-0.4543×P\_{B}\right.+0.0779)/P\_{N} $ (10)

where *PCh* is the cheese price, *P*W is the dry whey price, *P*B is the butter price and *P*N is the nonfat dry milk price.

Rewritten, the factor for Method B is:

$OCF\_{B}=\left.(1.0401×\left.P\_{Ch}\right.-0.4089×P\_{B}\right.+0.0701)/P\_{N}$ (11)

For both Method A and Method B, the cheese to nonfat dry milk price ratio has a relatively strong weight of plus 1.04. The weights for butter and whey are smaller. The rewritten form of the factor also includes an additional, very small negative effect associated with the inverse of the nonfat dry milk price. It is also worth noting that the simplified equations (10) and (11) are of a form that could be easily incorporated into a FMMO language format.

Equations (10) and (11) are also used to develop a reduced-form formulas for each protein price:

$P\_{OCP,A}^{III}=2.9895×\left.P\_{Ch}\right.-1.3057×P\_{B}+1.9634×P\_{W}+0.2239-0.5016×\frac{P\_{Ch}}{P\_{N}}+0.2191×\frac{P\_{B}}{P\_{N}}-0.3295×\frac{P\_{W}}{P\_{N}}-0.0376×\frac{1}{P\_{N}}$ (12)

$P\_{OCP,B}^{III}=2.9895×\left.P\_{Ch}\right.-1.1753×P\_{B}+0.2015-0.5016×\frac{P\_{Ch}}{P\_{N}}+0.1972×\frac{P\_{B}}{P\_{N}}-0.0338×\frac{1}{P\_{N}}$ (13)

Equations (12) and (13) can be compared with reduced form Class III protein formula under the current FMMO pricing system:

$P\_{Pro}^{III}=3.2222×\left.P\_{Ch}\right.- 1.2752×\left.P\_{B}\right.- 0.4267$ (14)

Where $P\_{Pro}^{III}$ is the current Class III protein price, $P\_{Ch}$ is the cheese price and $P\_{B}$ is the butter price. Equations (12), (13) and (14) are shown in the body of the paper as equations (5), (6), and (7).

1. We assume 5.9 pounds of other solids per hundredweight of skim milk at the farm. Other solids in liquid whey are then calculated as (5.9/100)x(100-*FW*)x(1-*L*) = 5.6793. Butterfat not captured in cheese is (*FW*-*FL*)x(1-*L*)x(1-0.90) = 0.3476 lb. Casein loss is 0.1 lb. Total solids are 6.1269 lbs. Total liquid whey weight is (100-*FL*)x(1-*L*) - *CY* = 90.0977 lbs. Whey solids, expressed in percentage terms, is (6.1269/90.0977)x100% = 6.80%. [↑](#footnote-ref-1)