A User's Guide to Understanding *Basis* and *Basis* Behavior in Multiple Component Federal Order Milk Markets

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What are the general ideas behind a futures contract price and the concept of the *Basis* calculation?

The Class 3 milk futures contract traded at the Chicago Mercantile present opportunities for you to forward price your milk if your milk is pooled in a multiple component market such as Federal Order #33. The use of a Class 3 or Class 4 milk contract allows a producer to forward price the butterfat, protein and other solids components of his milk production in multiple-component pricing federal orders or to forward price butterfat and skim in fat/skim federal order markets. Using the futures instruments to protect against uncertain market prices is a new revenue management tool for the dairy industry. Likewise, the use of a Class 3 or Class 4 contract allows a dairy product manufacturer (buyer of liquid milk) to forward price the butterfat, protein and other solids components of his liquid milk needs to protect against rising prices. The use of futures markets to accurately forward price milk either as an output or as an input necessitates that one must know the relative cash price / futures price relationships that are captured in what is called *basis*. This article will define the general concept of basis as it is used in futures and options markets and how it can be calculated for a milk producer who intends to use Class 3 / 4 futures contracts as a means to hedge against price declines in a multiple component market. The focus in this paper will be on the Class 3 futures contract and to multiple-component Federal Order markets. The use of the other class contract, the Class 4 futures contract, raises additional issues and will be discussed in a sequel to this paper.

Futures Contracts and Basis: General Ideas

The process of using futures contracts or options to protect against falling prices for expected production is called hedging. For dairy producers, hedging involves selling expected milk production via futures contracts that expire sometime in the future. The Class 3 futures contracts are either offset buy purchasing back those same contracts prior to expiration or being cash settled at contract expiration. Options on Class 3 futures contracts are another marketing tool that can be used to protect a producer against falling milk prices. A put option g4es the producer the right but not the obligation to sell a Class 3 futures contract for certain price by a certain date. This price is known as exercise price or the strike price. The date is known as the expiration date. The fee for purchasing a put option at a specified strike price is known as a premium.

Put options are typically used by producers to lock-in a minimum floor on their forward price. This price floor is designated by the strike price the producer selects. For every Class 3 futures contract there is a range of strike prices that are available when purchasing a put option. Typically, a producer will select a strike price closest to the price to where the futures contract is currently trading.

A put option protects the producer against downside price risk. If a producer uses a put option to place a floor (the strike price) on his milk price and the futures price falls below the strike price, then the put option is exercised by selling futures contract at the specified strike price. If the futures price keeps falling the futures contract may be purchased back at a lower price than the strike price. Here, the producer is protected against the futures price falling below the strike price. If the futures price does not fall below the put option strike price then the option expires worthless. A put option example is g4en at the end of this paper.

Typically, the change in value of the futures contract will offset the change in the cash market prices. This assumes the cash market price moves in the same direction as the futures price.

Defining *Basis* – A textbook exposition:

A review of any textbook or trade book written on the topic of futures and options markets will contain an exposition on the topic of basis. What is basis, how is it defined, and why knowledge of basis if important. The textbook authored by John C. Hull provides a useful exposition and is reproduced in this paper as the starting point for our consideration of basis.

The term 'basis' describes the relationship between the cash market and the futures market on any given day. The textbook definition of basis can be defined as the difference between the local cash market price, hereafter referred to as the spot price of the asset and the futures price for a selected future month. A simple model which captures the primary elements of 'basis' and the issues addressed in this paper can be expressed as:

Basis = Spot price of asset to be hedged - Futures price of contract used.

S_1 = spot price at time t_1 S_2 = spot price at time t_2

F_1 = futures price at time t_1 F_2 = futures price at time t_2

b_1 = basis at time t_1 b_2 = basis at time t_2

Effective Short Hedge Price: $F_1 + b_2$

Effective Long Hedge Price: $F_1 + b_2$

The effective revenue to the producer is the initial futures price F_1 plus the basis, b_2 earned at the time the hedge is lifted. For the buyer of milk the effective revenue from the long hedge is exactly the same. For both of the effective revenue prices the initial futures value is know with certainty and it is only the basis which is uncertain. Hull reminds us of the fact that there are at least three occurrences which give rise to uncertainty over the value of the basis or basis risk:

1) The hedger may be uncertain as to the exact date when the commodity will be sold or purchased,
2) The hedge may require that the futures contract be closed out well before its expiration date,
3) The commodity whose price is to be hedge may not be exactly the same as the commodity underlying the futures contract.

These three aspects of the hedge go to the central issue of the existence of basis risk inherent with the use of milk futures contracts and are discussed in this paper. First it is maintained that as an empirical fact dairy producers are always certain as to the exact date of sale and therefore the first item in the above list does not contribute to basis risk in any meaningful way. Second, for most producers, the use of the milk futures contracts will not require that the hedge be closed out before its expiration date. For most milk producers the hedge is maintained and cash settled at expiration. Therefore the second item on the list also does not induce any basis risk. The third item on the list is the one that can be viewed as giving rise to basis risk. The definition of the commodity underlying the futures contract is not at issue but the definition of the *spot price of the asset to be hedged* is opened to debate and alternative definitions. Referring back to the Hull basis model this aspect of basis risk can be expressed as:

Lets $S_2^* =$ Price of the commodity underlying the futures contract at time t_2

by hedging the milk producer ensures that the price that will be paid

for the commodity is:

$S_2 + F_1 - F_2$ which can be expressed as:

$F_1 + (S_2^* - F_2) + (S_2 - S_2^*)$

where

$(S_2^* - F_2) =$ basis when spot commodity

and futures commodity are identical,

$(S_2 - S_2^*) =$ basis arising from the difference between

the spot commodity and the futures commodity.

The central theme of this paper is that for most milk producers using either the Class 3 or Class 4 milk futures contracts $(S_2^* - F_2) = b_2 = 0$ and while $(S_2 - S_2^*) \neq 0$ under the spot asset definition typically used in the current literature this is incorrect and should not be properly considered when considering the hedging strategy. The fundamental misinterpretation of the definition of the underlying asset to be hedged has lead to a great deal of confusion as to whether or not basis risk exists when hedging with the milk contracts and whether or not this risk is sufficient to suggest that these contracts are not useful tools for revenue management by dairy producers.

Why is the knowledge of the Basis important for using futures markets?

The historical knowledge of the basis allows a producer to know, on a given day, what his/her forward cash price will be relative to the futures market. This knowledge is important because the cash market is involved in part of the mechanics of executing a futures hedge. The following is a typical explanation of the relationship between the use of a short hedge, basis and basis risk using milk futures contracts goes along these lines. For example, let's say that we have a producer in July 2000 anticipating the sale of expected milk production in January 2001. The producer anticipates that milk prices will follow the normal seasonal patter and will be lower following December holiday period. The milk producer wants to use the hedge to lock in a better price to cover his/her production costs. The producer finds that the January 2001 contract is currently trading at a good price. The producer sells a January 2001 Class 3 futures contract for $12.29/bu on July 15, 2000. From published data the producer learns that the expected basis for his /her marketing area for the month of January is $1.00 / cwt. This means that based on some available market information the pay price per cwt. received by the milk producer in January averages $1.00 above the Class 3 contact price. In this situation the milk producer expects "lock in" a forward cash spot price of $13.29/cwt. With the initial hedge price and this knowledge of the anticipated January basis the milk producer has the ability to forecast the final revenue price in the future.

February 5, 2001 rolls around and on that day the announced January 2001 Class 3 futures price is $11.29/cwt and the revenue price per cwt. to the producer is $12.79. The basis is $0.50 and not $1.00 / cwt. as anticipated. The producer short hedge position is marked-to-market at $11.29 and the producer receives $12.79 for the sale of the January milk production. The hedge provides the producer with a $1.00/cwt futures gain ($12.29/cwt. -$11.29/bu). At the initiation of the hedge position the milk producer anticipated a final spot market price of $13.29 but received instead a spot price of $12.79. In this scenario, the anticipated basis declined by $.50 /cwt. and therefore the hedge was subject to *basis risk*. This *basis risk* resulted in a lower final price than originally anticipated by the milk producer when placing the hedge. Had there been no basis risk, i.e., had the actual basis equaled the anticipated basis of $1.00 the milk producer would have received the $13.29 as expected. Another explanation, and one that is unique to the milk futures markets is that basis is zero, the anticipation of the $1.00 over the contract terminal price is erroneous, and as the basis is zero basis risk is zero for milk producers using the Class 3 or Class 4 milk futures contracts.

For many futures contracts on agricultural commodities, basis follows a reasonably predictable pattern, and producers learn to recognize deviations from that pattern. The usefulness of a futures market to a producer is captured in the basis patterns. For price protection to be viable in reducing price risk there must be a high correlation between the cash price and the futures price and, therefore, the basis must be fairly stable or predictable from one trading month to the next trading month. If basis is extremely variable then the ability to forecast forward market cash prices becomes difficult. Since forecasted cash prices would be more difficult to forecast then it also becomes more difficult to lock-in a target price.

What is the 'basis' in a multiple component priced Federal Order milk market?

Class 3 milk futures contracts are traded at the Chicago Mercantile Exchange. Before a dairy producer can use futures markets he/she must know how the Class 3 futures prices move with the revenue components of his monthly mailbox price. This involves calculating the basis between the revenue components of the monthly mailbox price and the futures price. In this article I will argue that the basis relative to the Class 3 futures contracts is always zero and as a result the Class 3 contract offers as close to a "perfect" hedge for the milk producer in a multiple component market as is possible.

For the dairy producer, comparing the cash milk price (mailbox price) with the Class 3 futures contract price is not as straightforward as it is in other agricultural commodity markets. This is due to the intervention of the Federal Order Marketing system. First and foremost, for most milk producers there does not exist a daily spot market for milk to which a certain amount of production can be delivered and priced. In multiple-component Federal Order markets the typical milk producer is paid a monthly milk price based on a weighted average of three milk component prices, a return from a classified pricing system called the producer price differential, and other adjustment factors. This fact makes the notion of a contemporaneous basis at the time of the hedge irrelevant. This revenue per cwt. received by the milk producer can be expressed as:

1)	Milk Check Revenue =		[Pounds of Butterfat]	x	[Butterfat Price]
		+	[Pounds of Protein]	x	[Protein Price]
		+	[Pounds of Other Solids]	x	[Other Solids Price]
		+	[Producer Price Differential]		
		+	[Net Adjustment Factors]		

Milk check revenue is a net revenue received by the milk producer for the total volume of milk sold. When expressing the price of milk received as if it where the spot price of milk producers divide this total net revenue by the volume sold in cwt. and this is expressed in terms of price/cwt of milk sold. In the typical approach to explaining the hedging activity this calculated price/cwt is compared to the final settlement price of the Class 3 futures contract for the purpose of defining basis. The Class 3 basis is calculated by taking the calculated price/cwt less the Class 3 futures settlement price.

To gain an understanding of why this approach to defining basis for milk futures is not correct Four items of information published monthly by the Federal Order Administrator Office are needed. These are i) an example of a typical producers milk check, ii) the *F.O#33 Announcement of Producer Prices,* 3) *FO#33 Announcement of Advanced Prices and Pricing Factors,* and 4) *FO#33 Announcement of Class and Component Prices* for a particular month.

To address the question as to the match of the spot market commodity to the commodity underlying the futures contract we first must look at the breakdown of the monthly milk check. The main idea behind these calculations is to determine how much of the milk check can be attributed to Class 3 components. What we are accomplishing at this step is to match the definition of the underlying commodity for the futures contract as closely as possible with the concept of a spot price for milk as received by the milk producer. By matching the Class 3 milk components common to both the futures commodity and the cash commodity we can identify a price series that moves with the Class 3 futures price. In a typical producers milk check revenue is generated by the sale of protein, other solids, and butterfat commodities. As an example to illustrate this matching activity these revenues are $8,715.75, $1,148.06, and $8127.67, respectively, and are given in Table 1.

Table 1. The Total Producer Revenue From Class 3 (@ 3.5% bf) Components

Component	Revenue
Protein	$ 8,715.75
Other Solids	$ 1,148.06
Class 3 Butterfat	$ 8,127.67
Total Revenue	$17,991.48

The total milk production is 1,800.66 cwt. Dividing total revenue by the volume of milk sold we calculate the price/cwt of milk arising from Class 3 revenues which match the definition of the commodity underlying the Class 3 futures contract. From this heuristic example this is:

2) $9.99/cwt = $17,991 / 1800.66 cwt

As long as the milk producer ships at least the standard composition of components as defined for Class 3 milk (3.5% butterfat, 2.99% protein, 5.6% other solids) he/she will be paid a base price of $9.99/cwt before any other additions or subtractions. Notice, that this base price and the Class 3 cash price are identical. This is always correct as the Class 3 futures contract cash settles at this publicly announced price each month. The base price represents the calculated market value of the butterfat, protein and solids. $9.99 represents all the hedgeable components of the farmer's milk check at the standard milk test values.

Since the Class 3 futures contract is cash settled, it must by contract specification settle to the announced Class 3 cash price. This is a very important point to understand when thinking about what the basis is and what it is not basis in multiple component milk markets. The Class 3 futures contract trades until 1 day before the Class 3 cash price is announced. Once the Class 3 price is officially announced all remaining open futures contracts that are set to expire are then priced at the final announced Class 3 price. Thus, theoretically, the basis will be always be zero.   Therefore for a hedge that is placed at an initial time and held to expiration the Class 3 basis is calculated as follows:

3)   Class 3 Basis = Class 3 part of the mailbox price – Class 3 Futures Price

$0.00/cwt = $9.99/cwt - $9.99/cwt

The milk check price per hundredweight is more than the Class 3 price so how can my 'basis' be zero?

The Class 3 cash price quoted by the market administrator assumes that milk produced is at standard component test values (i.e. 3.5% butterfat, 5.6935% other solids, and 2.9915% protein). If a producer has higher (lower) than standard component test values for his milk then his Class 3 milk revenues will be higher (lower) than $9.99/cwt. If we were not aware that "basis" is by definition, zero, this will result in what appears to be a changing basis, i.e. a less negative or more positive basis. For example, Table 2 at the end of this paper shows that in Federal Order #33, for the month of January 2001, the average producer's base component revenues are $10.53/cwt, due to having higher than standard test milk values. The basis would appear to be:

4)   Class 3 Basis = Class 3 part of the mailbox price – Class 3 Futures Price

$0.54/cwt = $10.53/cwt - $9.99/cwt

This is not basis per se but a <u>component production premium differential</u> (cppd) that reflects the additional revenue added to the $9.99/cwt base price because of higher milk test values for protein, butterfat and other solids. Basis is always zero and can be seen as such by recognizing that this additional $0.54 / cwt is an added payment for shipping more than the specified quantity per cwt of butterfat, protein and other solids.

For January 2001, the Class 3 components of the market average milk check comprise 81.25% of the $12.96 mailbox price. The remainder is $2.42. Along with the (cppd) of $0.54 this $2.42 is typically included as part of the basis. If this were correct (and it is not) then these two items would represent the term $(S_2 - S_2^*)$ in the Hull basis model and would be responsible for generating basis risk for these milk contracts. The $2.42 remainder represents a disbursement of economic rent generated by the price discrimination scheme known as Classified Pricing for milk and dairy products. This is officially termed the Producer Price Differential PPD and should not be considered a hedgeable aspect of the spot commodity price as is currently the practice. Variation in this component are due to changes from month to month in reported Class 1 - 4 milk utilization, variation in component prices and to variations in the wholesale price of nonfat dry milk. For Federal Order 33 over the period January 2000 to January 2002 the component production premium averaged a positive $0.36/cwt. Over the period January 2000 – December 2000 the PPD averaged $2.34 and for January 2001 – December 2001 the PPD averaged $1.42. Over the 2000-2001 time period the Class 3 components of the typical milk check averaged 84% of the average mailbox price.

Why is the difference between the milk 'mailbox price' each month and the Class 3 futures settle price for that month not a proper definition of basis?

Many producers have been advised that the correct interpretation and usage of the concept of basis and basis risk is to use their individual mailbox price less the Class 3 futures contract as a basis value for which to make economic decisions. This is *incorrect* for several reasons. As stated earlier, for price protection to be viable in reducing price risk there must be a high correlation between the cash price and the futures price. The cash components of the milk check, butterfat, protein, and other solids comprise exactly the Class 3 cash price by definition. Therefore, they will move exactly with the Class 3 futures contract. *Hence basis is zero, basis risk is zero and the hedge is a perfect hedge.*

The mailbox price by definition is the individual producer's Class 3 price plus the producer price differential (PPD), location adjustments, and other adjustment factors. It is known that the location adjustments, quality premiums, volume premiums are generally offset by hauling charges (usually paid by the producer) and therefore the PPD plus the cppd are the only remaining amounts not covered by the futures contract. Also it makes no sense to attempt to hedge such items as hauling charges, or quality / volume premiums as these are set by negotiation and are fixed contractual amounts expressed on a volume basis. The idea that these somehow belong in the definition of the spot commodity price is without merit. Using the mailbox price as a cash price to create a basis series introduces price components of the milk check - notably the PPD, that is not likely to be highly correlated to the Class 3 price. The PPD part of the milk check is influenced by a Federal Order's class utilizations and the Class I and Class II differential values and the Class 4 skim milk price as calculated from the advanced prices for Grade AA butter and Nonfat Dry Milk. Changes in each of these components will impart changes in the producers milk check but none of these factors can be hedged with the Class 3 futures contract as currently specified. In fact it can be shown that there is a significant negative correlation between the hedgeable Class 3 price and the PPD and therefore there is a natural or built-in hedge taking place each month in the milk market.

An application of hedging results with zero basis and no basis risk

Now that we have the concept of basis firmly in hand, we can take a look at a hedging example in multiple component markets such as the Mideast Market – Federal Order #33. Managing revenue risk by hedging with the Class 3 futures contract does not have to be a complicated affair. In this section, basic hedging strategies are shown in Tables 2 and 3. Tables 2 and 3 present six-month-ahead and three-month-ahead hedge strategies for Class 3 futures contracts, respectively.

Let's say that a farmer wishes to lock the Class 3 part of his milk check six months ahead. Every month the farmer locks in a Class 3 futures contract that expires six months from the time the hedge is initiated. The farmer sells the Class 3 futures contract, now, and receives the final announced Class 3 price six months from now. For example, in Table 2 on July 15, 1999 the farmer sells a Class 3 futures contract for

$12.40/cwt. Since the Class 3 basis is zero, by definition, the farmer expects to lock in $12.40/cwt of the Class 3 cash part of his milk check. When January 2000 rolls around, the producer receives the final announced Class 3 price of $10.09/cwt and sells the milk to the processing plant. When the farmer receives his milk check he sees that the Class 3 revenues of his milk check sum to $10.65/cwt. The difference between $10.65 and $10.09 is the component production premium for producing milk at higher than standard test values. The Class 3 revenues ($10.65/cwt) plus the producer price differential ($1.27/cwt) result in an $11.92/cwt mailbox price. The Class 3 futures contract gain is $2.31/cwt. The mailbox price plus the gain from the hedge transaction results in a final producer price of $14.22/cwt. The use of the futures hedge gives the producer and extra $2.31/cwt!

Table 2 shows the six month-ahead hedging strategies using Class 3 futures contracts. If a farmer is relying only on the cash market to provide for his future revenue generation he takes a risk that the mailbox price may go down. A farmer can use Class 3 futures contracts to lock in his Class 3 cash part of his mailbox price up to six months into the future. From July 1999 to July 2000, a farmer using a six month-ahead hedging strategy every month has an average final ending price of $14.44/cwt. This is better than the average mailbox price of $12.21/cwt Class 3 cash revenue had the farmer not used the futures market. Here, the average gain to using Class 3 futures contracts is $2.23/cwt.

Table 3 shows an alternative three-month-ahead hedging strategy replicated every month from October 2000 to October 2001. Over this period, the farmer on average expects to lock-in $11.20/cwt of Class 3 revenue of his/her monthly milk check. The actual Class 3 milk cash components average $10.15/cwt. The average gain using Class 3 futures contracts is $1.41/cwt. The average final ending price (mailbox + futures price) is $13.62/cwt.

The six-month-ahead hedging strategy resulted in higher final ending price ($14.44/cwt) compared to the three-month-ahead hedging strategy ($13.62/cwt). The producer who uses a shorter hedge time horizon, 3 months, on average receives 82 cents less than the producer who used a longer hedge time horizon. These results may not be due to the length of the hedge time horizon but the fact that milk market prices have been declining in the past two years. The milk markets prices have been shifting downward due to excess supply or production. Each marketing year must be closely analyzed to see how production and demand factors have impacted price and to assess price trends. Note, how in this hedge example basis did not enter into the calculation nor does the producer have to worry about basis variability.

Table 2. Six Month Forward Pricing Hedges Using Class 3 Futures Contracts ($/cwt)									
Month Hedged	Contract Month	Class 3 Futures Beginning	Class 3 Futures Ending	Component Revenues at Market Test	Producer Price Differential PPD	Component Premium cppd	Gain From Futures	Ending Mailbox Price	Mailbox Price Plus Futures
July 15, 99	Jan 00	12.40	10.09	10.65	1.27	0.56	2.31	11.92	14.22
Aug 16, 99	Feb 00	12.47	9.58	10.10	1.62	0.52	2.89	11.71	14.60
Sept 15, 99	Mar 00	11.92	9.57	9.97	1.84	0.40	2.35	11.80	14.15
Oct 15, 99	Apr 00	11.60	9.45	9.79	2.01	0.34	2.15	11.80	13.95
Nov 15, 99	May 00	11.62	9.41	9.62	2.59	0.21	2.21	12.20	14.41
Dec 15, 99	June 00	11.80	9.51	9.60	2.72	0.09	2.29	12.32	14.61
Jan 14, 00	July 00	12.43	10.70	10.67	2.13	-0.03	1.73	12.80	14.53
Feb 15, 00	Aug 00	12.45	10.17	10.19	2.36	0.02	2.28	12.55	14.83
Mar 15, 00	Sept 00	12.44	10.79	11.01	1.60	0.22	1.65	12.60	14.25
Apr 14, 00	Oct 00	12.46	10.05	10.49	1.70	0.44	2.41	12.19	14.60
May 15, 00	Nov 00	12.00	8.60	9.19	2.59	0.59	3.40	11.77	15.17
June 15, 00	Dec 00	11.80	9.40	10.15	1.96	0.75	2.40	12.10	14.50
July 14, 00	Jan 01	10.95	9.99	10.53	2.43	0.54	0.96	12.96	13.92
Averages →		12.03	9.79	10.15	2.06	0.36	2.23	12.21	14.44
Std Deviations→		0.47	0.59	0.52	0.45	0.24	0.58	0.41	0.35

Table 3. Three Month Forward Pricing Hedges Using Class 3 Futures Contracts ($/cwt)									
Month Hedged	Contract Month	Class 3 Futures Beginning	Class 3 Futures Ending	Component Revenues at Market Test	Producer Price Differential PPD	Component Premium cppd	Gain From Futures	Ending Mailbox Price	Mailbox Price Plus Futures
Oct 15, 99	Jan 00	11.65	10.09	10.65	1.27	0.56	1.56	11.92	13.48
Nov 15, 99	Feb 00	11.40	9.58	10.10	1.62	0.52	1.82	11.71	13.53
Dec 15, 99	Mar 00	10.60	9.57	9.97	1.84	0.40	1.03	11.80	12.83
Jan 14, 00	Apr 00	10.81	9.45	9.79	2.01	0.34	1.36	11.80	13.16
Feb 15, 00	May 00	10.29	9.41	9.62	2.59	0.21	0.88	12.20	13.08
Mar 15, 00	June 00	10.95	9.51	9.60	2.72	0.09	1.44	12.32	13.76
Apr 14, 00	July 00	11.50	10.70	10.67	2.13	-0.03	0.80	12.80	13.60
May 15, 00	Aug 00	12.10	10.17	10.19	2.36	0.02	1.93	12.55	14.48
June 15, 00	Sept 00	12.70	10.79	11.01	1.60	0.22	1.91	12.60	14.51
July 14, 00	Oct 00	12.20	10.05	10.49	1.70	0.44	2.15	12.19	14.34
Aug 15, 00	Nov 00	11.05	8.60	9.19	2.59	0.59	2.45	11.77	14.22
Sept 15, 00	Dec 00	10.37	9.40	10.15	1.96	0.75	0.97	12.10	13.07
Oct 16, 00	Jan 01	10.00	9.99	10.53	2.43	0.54	0.01	12.96	12.97
Averages →		11.20	9.79	10.15	2.06	0.36	1.41	12.21	13.62
Std Deviations→		0.81	0.59	0.52	0.45	0.24	0.66	0.41	0.60