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Dairy Policy and Price Volatility

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Abstract

The US dairy industry is shaped by a patchwork of regulations accumulated over a long history of intervention to achieve various, sometimes conflicting, policy goals. Price supports have long been a central feature of dairy markets, but were largely withdrawn beginning in 1988. Since that time, there has been a dramatic increase in the variability of farm milk and milk product prices. The origins and desirability of volatility has been the subject of much debate; unfortunately models in existence to date have shed little light on the question due to their adoption of essentially non-dynamic methods. This article introduces a dynamic, behavioral dairy model to investigate variability and possible countermeasures.

The model suggests a number of factors that may contribute to price volatility, in addition to the usual explanation of supply-chain amplification of random supply and demand shocks. The behavioral response of industry participants to price and inventory signals, the use of long-term contracting, speculative hoarding, coupled long-term cycles of processing capacity and herd size each contribute their own component of volatility. Some well-intentioned regulatory and industry policies attenuate the price signals directing milk supply to demand, exacerbating volatility, whereas price supports and the availability of trade provide some damping.

Introduction

The US dairy industry, like many of its counterparts throughout the developed world, has a long history of government involvement. The principal stated objectives of government policy are to increase dairy producer income and ensure "orderly marketing" of a bulky and perishable product. To do so, the US government established programs to buy manufactured dairy products, regulated minimum prices paid by buyers of milk (with different prices for milk used in different products, termed "classes") and severely restricted imports of most dairy products. These policies were reasonably successful in slowing the rate of structural change (e.g., farm size and numbers; Pagel et al., 2002), and also provided a good deal of price stability. However, when the program to support farm milk prices through the purchase of dairy products

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became quite costly in the mid 1980s (expenditures of roughly $2 billion per year), the US Congress substantially lowered the target farm price. By the late 1980s, price support was minimal and market conditions determined most dairy prices. As support became less important, there was a dramatic increase in the variability of farm milk and dairy product prices (Figure 1). This variability has been a topic of discussion among farmers, dairy companies and policy makers since that time.

Identifying the sources and nature of volatility is a prerequisite to the development of intelligent policy. Several explanations are possible. Volatility could be merely a reflection of driving noise and seasonality from the supply and demand sides of the system (weather influencing milk production, for example). Disturbances could be amplified by classical supply-chain features akin to the Beer Game dynamics, and exacerbated by misperceptions of feedback or misguided policies. It is also possible – perhaps even likely – that the system generates oscillations endogenously, with entrainment to seasonality. Volatility might even be optimal in the sense that it reflects real costs like the cost of holding inventory between seasonal supply and production peaks. Unfortunately existing models have little to say about the topic, as they generally address policy issues from the static or equilibrium perspective needed to manage detailed dairy regulations. Where models are dynamic, they operate with annual increments, precluding investigation at the weekly to monthly scales on which volatility is observed.

An obvious basic issue with price variation is that someone must assume the risks associated with price changes. Thus, increases in the variability of milk prices have led to additional challenges for farm business planning, debt repayment, and in some cases, solvency of farm businesses. Price volatility may have increased the rate of structural change in the farm sector, if more volatile prices have made expansions more risky for small- and medium-scale dairy farms. Farms in the process of expansion (those with higher debt loads) or with higher production costs may be most in jeopardy from unexpected price swings. Dairy processing companies also face new challenges in managing inventories and dealing with price risk. More volatile prices can imply highly variable profit margins in the short-run, and the possibility that some customers will reformulate their product lines to reduce their use of dairy ingredients (that is, to lessen their own risk exposure). However, price variation also helps some companies to maintain margins by allowing them to increase sales prices in response to higher input costs over time.

To address the farm-level impacts of price volatility, the principal policy response in recent years has been to establish programs to educate individual dairy producers to better manage risk. This includes programs to teach farmers how to use futures and options and reductions in regulatory barriers to forward contracting for milk. The US Department of Agriculture (USDA) established a new entity, the Risk Management Agency, to coordinate efforts to educate US farmers and industry decision makers, and has spent roughly $10 million per year to educate farmers in risk management strategies since 1998. Despite this considerable expenditure, risk management tools are used by a limited number of dairy farmers, probably due to their complexity, costs, limited coverage of relevant commodities, and the fact that locking in a price may result in missing out on a high price period. The limited participation of farmers and dairy processing companies has meant that the futures markets themselves often do not operate efficiently, further compromising their usefulness as a risk reduction strategy.

When Congress approved the package of agricultural legislation[2] in 2002 it mandated that USDA conduct three studies reviewing US dairy policy. Although price volatility was not among the issues Congress required USDA to examine, the agency administering the studies considered price variation to be an important element of the review, and provided financial support for this research. With that background in mind, this paper has three objectives:

1) to review the pattern variability in milk and dairy product prices since 1980
2) to discuss the sources of price volatility
3) to examine how selected dairy policy instruments influence monthly price variation using a newly developed dynamic model of the aggregated US dairy industry.

Basic Concepts and Underlying Issues

Before reviewing the volatility of milk and dairy product prices during the past two decades, it is helpful to distinguish between three characteristics of prices that are often used interchangeably in discussions about price volatility by dairy industry analysts. The first of these is the price *level*, or the average price during some period of time. Often it is extended periods of low prices rather than price movements themselves that cause concern among dairy producers. The second is *how much variation* there is in prices relative to this average level during some period of time. A higher degree of price variation in a given year can create additional management

[2] This legislation is commonly referred to as the "Farm Bill" although it includes other policy elements such as nutritional assistance programs.

challenges for milk producers and milk buyers, as noted above. However, a third characteristic concerns *how predictable* (or unpredictable) the variation in prices is. For example, milk prices varied over the year during the first half of the 1980s, but in a fairly regular seasonal pattern with a peak in the late fall or winter and a low point during the spring flush season (Figure 1). When prices have a relatively predictable seasonal pattern, the impacts of price variation will be less because producers and milk buyers can anticipate their needs and more readily make appropriate management decisions.

An important related issue is whether the key concern is variation in prices or variation in incomes, cash flow, or net margins. These latter depend on both the price and the quantity of a product sold and the cost and amount of inputs used. For a dairy producer, variability in the milk price does not fully describe the variability in net farm income, because milk production and expenses like feed costs will also vary. Thus, these factors also need to be considered when understanding how variation in milk prices affects farm bottom lines. For dairy processors and manufacturers, variation in both milk prices and product prices and quantities sold will affect margins. Thus, looking only at individual milk or dairy product price series will not always provide a reasonable picture of the outcome that is presumably of greatest importance, income rather than prices.

The Nature of Price Volatility Since 1980

How volatile have milk and dairy product prices been for the last 20 years? A simplistic way to measure volatility is to examine the standard deviation of a price compared either to its average (if the price is not increasing or decreasing much on average, this is the coefficient of variation, CV) or to its trend (if the price is increasing or decreasing over time). The advantage of a CV is that is it allows comparison of the variation for different prices by a common standard. To make this comparison, it is also necessary to select a time period by which to measure the CV. Dairy product prices vary daily, whereas farm milk prices are monthly under federal regulations. The current dynamic dairy policy models use annual data, although variation is lower for annual prices than for monthly prices. Changes in farm milk price variability—especially in the late 1990s—can be seen for both monthly data and annual average prices. However, the increased variability and decreased predictability of monthly prices seems to receive greater attention in the industry, so the focus here will be on monthly price variation.

As noted earlier, the degree of variation in prices has been larger since the late 1980s than previously. The standard deviation of monthly farm milk prices for 1988 to 2002 was about double its value during 1980-87 (Table 1). Because the average level of prices differed only modestly for these two time periods, the coefficient of variation roughly doubled as well. The variation in class prices was also higher for 1988 to 2002 than for the first seven years of the 1980s. The standard deviations and CVs for minimum regulated milk prices paid by milk buyers increased a bit more than farm milk prices.

Variation in product prices has also increased since 1988. For wholesale cheese and nonfat dry milk (NFDM) prices, the increases in the CVs are similar to those for farm milk prices. The variation in retail fluid milk prices increased, but remained lower than for other prices. The variability of the butter price increased markedly, and was nearly eight times larger during 1988-2002 than it was during 1980-87. In particular, butter price volatility has increased markedly since CCC stocks of butter were depleted in 1995. The variability in the butter price obviously has contributed to the variability in class prices and farm milk prices, given that butterfat values enter into the calculations for these other prices.

Based on these observations, it is clear that the average level of farm milk prices has not changed a great deal since the 1980s, but that price volatility is significantly higher now than it used to be for a broad range of milk and product prices. Moreover, the predictability of dairy prices appears to have decreased at the same time that price variability has increased. Although it is probably too early to tell whether this is a lasting trend, the amplitude and period of variation in farm milk prices may also have changed as of the late 1990s, leading to longer periods of low milk prices interspersed with a high-price year. Of particular concern to dairy farmers is the possibility that the length of low price spells (such as 1999-2000 or 2002-2003) may be increasing compared to a few years ago. This rest of this paper will focus on price variability rather than on the level or predictability[3] of milk and dairy product prices, though variability and predictability are intertwined by the behavior of agents in the system.

Sources of Volatility

Why has the volatility of dairy product prices increased in recent years? The principal exogenous influence on dairy prices is short-term variation in milk production due to changes in

[3] Note that assessing the "predictability" of prices is not straightforward in any case.

temperature and rainfall (which also influence feed supplies and indirectly affect milk produced per cow). Random shocks to input costs (either milk or other inputs like electricity) can also influence the supply of manufactured dairy products. In addition, both milk production and dairy product demand have strong seasonal components. Milk production peaks in the late spring, whereas demand for most dairy products, especially cheese and butter, is highest in the late fall (the holiday season). Seasonality in milk production and random shocks to milk per cow due to weather can be viewed as sources of variation in milk supplies, propagating through to milk prices. Other changes, such as longer-term shifts in demand are of less interest for understanding price volatility, as these changes presumably occur too slowly to influence weekly or monthly cycles.

Another key influence is the impact of policy. One policy change that has been mentioned is the reduction in support price levels in the late 1980s. When support prices were lowered, government inventories ceased to function as a buffer against seasonal demand and supply imbalances, increasing the importance of private inventory holdings. The characteristics of minimum price regulation have also been cited as increasing price variability. These include the use of fixed manufacturing cost allowances in product-based pricing formulae that presumably lessen the incentives to allocate milk to its "highest value" use, the use of the maximum of two possible base prices (rather than a minimum or some weighted average) to set a minimum price for fluid milk, the use of product-price formulas rather than actual pay prices for manufacturing milk to set manufacturing milk prices, the number of classes of milk used for manufactured dairy products, and value-pooling provisions that blunt product-specific price signals and that provide incentives to move milk. The fact that many of these reforms have taken place only recently, whereas price volatility increased more than 10 years prior to them, suggests that these issues are not a key underlying source of price variation, although these changes may amplify natural tendencies toward price variability. Trade policy can also have an impact on price volatility. As trade restrictions are lowered, it becomes easier for imported products to enter the country in response to higher US prices, especially for manufactured dairy products[4]. This should tend to lessen price variability, all else being equal, but because it takes time to manufacture and ship products to the US, the effects may be small unless high prices are maintained for some period of time.

[4] The US commitments under the Uruguay Round Agreement on Agriculture in 1995 converted fixed quotas to tariff rate quotas (TRQs) which allow access at low (in-quota) and higher (over-quota) tariff rates. When US prices are high, it is often feasible to import some products (like butter) even after paying the higher tariffs.

Another category of effects concerns industry operating practices, such as inventory management, production planning, and the nature of supply contracts between milk buyers and sellers and between processors or manufacturers and their customers (retailers, wholesalers, or other food processing firms). The importance of these effects has been relatively little explored, in part because of the level of institutional and proprietary detail needed to examine them adequately. It is worth noting, however, that at the time price volatility increased in the late 1980s, many industry analysts expected that a learning process within the industry would reduce the volatility within a couple of years. The fact that this did not occur suggests that either the incentives to an individual company for learning how to lower overall price variation (that is, at the industry-level rather than only for their purchases or sales) were smaller than expected, or that the complexity in doing so was larger than imagined.

Viewing the dairy industry from a systems perspective provides an alternative framework to examine issues of price volatility. It has been common for dairy industry representatives to ask the question “Why has price variability increased since the late 1980s?” In contrast, it may make more sense from a systems perspective to ask “Why can’t the industry mitigate (dampen) the effects of supply shocks now like it did in the early 1980s?” One obvious place that industry has noted is the reduced role of government inventories of manufactured products, but this raises other questions about the incentives to hold commercial stocks of these products (Pratt and Stephenson, 1998). To understand the sources of price variability in the dairy system and the influences of policy, a dynamic systems model can be helpful.

The Dynamic Dairy Systems Model

The dynamic dairy systems model builds upon the basic commodity model structures in Meadows (1970) and Sterman (2001). The key modifications include:

- Integration of a raw material supply sector (i.e., farm milk production) with seasonality of supply;
- Multiple products are made from the raw material. This includes both perishable and storable products, with different seasonal patterns of demand. Because there are multiple uses for the raw material, an allocation mechanism for milk is necessary. The allocation mechanism differs by milk use, but is based on what are termed market “premiums” (payments above the minimum regulated price);

- Specification of minimum prices for the raw material by use category ("class" under the federal price regulations);
- Government offers to purchase manufactured products at specified prices to support farm milk prices. An agency of the government thus becomes a holder of inventories. Dairy processing firms can purchase government inventories at the selling price plus 10%, providing a mechanism to move government inventories to commercial inventories;
- International trade policy is represented by allowing a limited quantity of storable manufactured dairy products imports to enter the US, and additional imports to enter (with a delay) when US market prices are high;
- Speculative behavior by dairy product purchasers ("buy now to beat a price increase") and storable dairy product manufacturers ("if price increases, avoid a stockout at all costs by holding more inventories").

More specifically, the model includes representations of farm milk supply, allocation of farm milk to processing activities (six products in four regulated classes, processing and storage of manufactured products and final or wholesale product demands. Farm milk supply is determined by cow numbers and milk per cow, both of which change in response to explicit expectations about future milk prices. The demand for final products is at the retail level for fluid milk and soft products, and at the wholesale level for cheese, butter, NFDM, and dry whey. Demand adjusts to price changes, but with larger effects in the long-run. Demand for each of the products is seasonal.

A key distinction between our model and many other dairy industry models is the level of detail concerning inventories of storable dairy products. The total commercial inventories of a manufactured product are assumed to play a role in price setting. As inventory coverage (inventories divided by commercial sales) falls below a desired level market prices increase. When inventories become too large relative to a desired level, market prices tend to fall until variable costs are reached. Prices, of course, provide signals to change production, milk supply and product consumption. When inventories are tight, wholesale cheese prices will increase, which will decrease quantity demanded, a little at first and more in the long term. Simultaneously, cheese production will increase (constrained by capacity), and over-minimum price premiums for milk used in cheese will rise to attract more milk to cheese plants. In the longer term, sustained price changes affect expected margins earned on the manufacture of the product, and thus investment in processing capacity. All of these responses will tend to move inventories back to their desired level, though they may be obstructed by raw milk pricing and allocation rules or speculative (hoarding) behavior. The exact nature of the transient behavior depends on a complex interplay of adjustment times, expectation formation, and other factors.

Four types of government policies are explicitly included in the model structure (Figure 3). The price support program is represented by the opportunity of dairy manufacturers to sell product to the government, and for the government to hold inventories of these products. When prices fall below the purchase price less any additional costs incurred for processing to meet government product specifications, sales will be made to the government. If prices rise to 10% above the purchase price, dairy manufacturers can "buy back" products held in government inventories. The government is assumed to dispose of a portion of its inventories through domestic disposal programs or as concessional exports (any potential demand-depressing effects these may have are neglected). Minimum price regulation is represented by the product pricing formulas that became effective in January 2000. Because the current version of the model is aggregated at the national level, no separate pricing formulae are included for California (which has its own separate system of minimum prices). In 2002, Congress passed legislation making payments to dairy producers for a certain amount of milk per farm when prices fell below a specified level. Payments under this program included in the average price received by dairy producers, using assumptions about the total amount of eligible milk. Finally, imports are restricted by Tariff Rate Quotas (TRQs), and therefore amounts in excess of quotas will enter the country only when US and world market price relationship allow profitable over-quota shipments.

The allocation of milk among different classes is a key determinant of model outcomes. Classes I and II (fluid and soft products) are allocated all the milk that they require to meet the demand for final products. The remaining milk production is allocated between class III (cheese and whey) and class IV (butter and powder) based on their "indicated" demand for milk, that is, the amount of milk that plants in that product category would want to process to meet demands given current prices and inventory holdings. If the sum of Class I and II demands and the indicated demands for Class III and IV are less than current milk production, this "surplus milk" is allocated to Class III and IV based on a proportion that changes with the level of over-market premiums that cheese plants are willing to pay. A shortage of milk (demands greater than current production) is treated similarly. If the indicated demand for milk to make cheese is greater than the amount currently shipped to class III, the premiums that class III handlers are

[5] Thus, these effects are considered as "balancing" feedback loops.

willing to pay will rise over time and the amount of milk used in class IV will decrease, and premiums for milk will also increase for Class I and II handlers. Although the way in which milk allocation and premiums are specified in the model is a simplification of reality, it represents the delayed and incomplete nature of milk allocation changes in response to class and product price movements.

The Impact of Selected Dairy Policies on Price Volatility

To assess the impacts of dairy policy on price volatility, we use the dynamic dairy systems model in the following way. Model parameters are specified to result in a pattern of prices roughly characteristic of dairy market conditions since 1996. This serves as the starting point for analysis of how the US dairy system responds over time to various policy alternatives. The same basic market conditions will be assumed for analysis of five policy scenarios:

1) A **Base Case** in which the purchase prices are below equilibrium market-clearing levels for cheese and butter, and at the market clearing level for NFDM. There is no payments program. The “maximum price“ provisions are in effect, so that minimum prices for fluid milk are determined by the higher of Class III and IV prices. Trade in manufacturing products is based on the current system of within-quota and over-quota imports. Within-quota imports are assumed to be completely filled, and over-quota imports enter the US only when product prices are sufficiently high to allow over-quota tariffs to be paid (and with a shipment delay of 2 months).
2) A **MILC (Milk Income Loss Contracts)** scenario which incorporates the payments to dairy producers under the 2002 farm legislation. This increases the average price paid to producers and increases milk supplies, which in turn lowers dairy product prices (and increases the extent of the payment). Thus, MILC represents a positive feedback loop leading to further reductions in milk prices and further increases in payments;
3) A **Restricted Imports** scenario in which imports of manufactured dairy products are limited to the “within quota” amount, regardless of US market prices. This will have the effect of limiting imports of manufactured dairy products when US market prices are high. In effect, it weakens or eliminates a balancing feedback loop that will tend to mitigate price variability;
4) A **Weighted Average** scenario in which a utilization-weighted average of Class III and IV skim prices determines the Class I price. This has the effect of lessening the impact of a

positive feedback loop between manufactured dairy product prices and farm milk prices, particularly for the fluid milk price;

5) An **Increase Support Price** scenario in which the purchase prices of cheese, butter and NFDM are increased to correspond to a $1.00/100 lbs (hundredweight or cwt)[6] increase in the support price compared to current levels. This has the effect of weakening a balancing loop between product prices and farm milk supplies, but also results in additional government-held inventories that should stabilize manufactured product prices.

The behavior over time of farm milk and dairy product prices will be compared for each of these policy scenarios to understand how they influence the magnitude and timing of price variation in the system. The purpose of this analysis is not (yet) to suggest specific policy interventions to reduce price volatility, but to gain a rough perspective on the degree to which each of these policy instruments affects price variation and to further our thinking about the dynamic stability of the US dairy system. Changes in the mean and standard deviation of farm milk prices, class prices and product prices compared to the base case suggest the impact of the policies listed above.

Before discussing the results of the policy scenarios, it is helpful to note that one essential source of price variability in the dairy industry—as noted earlier—is seasonality. More specifically, the key is how the seasonality of milk production (mis)aligns with the demand for dairy products. Our model makes assumptions about the nature of seasonality of the milk supply and product demands, which have a range of 4% for fluid milk supply to roughly 60% for NFDM. (We also assume no unexpected shocks to milk supply or dairy product demand, shocks that do in fact have an important influence on price variability.) If there were no seasonality, quite obviously, dairy price variation would be very much less than it is now. However, it is not just the presence of seasonality that results in price variation, but also the manner in which industry participants respond to seasonality (in part influenced by the nature of the products, such as their storability). Thus, seasonality continues to be an important consideration in understanding price variability, but it is not the only relevant factor.

[6] The standard unit of farm milk pricing is a "hundredweight" or 100 lbs of milk, abbreviated "cwt". The price of milk and milk products is on the order of 10 to 100 $/cwt.

The treatment of seasonality is, for now, static in the sense that agents are presumed to know the true underlying seasonal components of supply and demand. For supply, this is likely a good approximation of reality. For demand, it is less clear that this is so. It is possible that expectations of seasonality interact with pricing and inventory holding behavior to accentuate seasonal cycles, analogous to the endogenously generated seasonal cycles in Industrial Dynamics (Forrester, 1961). In a future refinement of the model it would be useful – but also very complicated – to develop a behavioral description of agents' detection and response to seasonal cycles.

<u>MILC</u>

Compared to the base case, the MILC scenario results in lower all milk, class, and product prices, and smaller price variation at all market levels (Table 2). Total farm receipts per cwt increase by some $0.70/cwt due to direct payments of $.89/cwt. Due to the cushioning effect of the direct payments, farm receipts per cwt are made much less variable than in the base case, and in comparison to the all-milk price. Reduction in the variability of product prices is relatively modest.

<u>Restricted Imports</u>

Under the restricted imports case, no imports over the TRQ amounts are allowed even when product prices in US markets are high. Thus, additional imports cannot dampen a price spike, and we might therefore expect that both average prices and price variability will increase. The standard deviation of farm, class and product prices increase substantially under this scenario, with the exception of NDM prices. The standard deviation of farm receipts per cwt is more than double that in the MILC scenario. It is worth noting that the all-milk price under this scenario is not always higher than the price in the base case (Figure 4). The inability to bring in additional imports in response to a product price increase results in a much higher all-milk price in the short-run (months 12-18 of the simulation). However, as dairy producers respond to this much higher price, they increase milk production to such a degree that eventually, the all-milk price falls below lower the base case (months 20-26). Moreover, the increase in milk production capacity tends to have a dampening effect on subsequent price peaks even though additional imports are still not allowed. (That is, after month 30, the price peaks in the base case and restricted imports case have roughly the same height, although the peak persists longer in the restricted imports case.)

Weighted Average

The impact of the use of the weighted average of Class III and IV skim prices to set the fluid milk minimum price is to slightly decrease the variability of farm milk prices, largely due to a marked decrease the variability of the Class I price. There is essentially no change in the variability of other class prices or product prices. The average Class I price declines by roughly $0.40/cwt, and therefore the average all-milk price declines by $0.09/cwt.

Increased Support

Increasing the support price by $1.00/cwt will obviously increase average farm milk and product prices if the higher purchase prices result in government purchases and inventory holdings. By providing a price floor at a higher level we might also expect that price variation will be dampened, in a manner similar to that observed during the 1980s. Increased support reduces the variability of farm milk prices, class prices, and product prices, but does not completely eliminate price variation or price cycles (Table 2). The overall effects of the increase on price variation are qualitatively similar to those under the MILC.

The base scenario suggests a fairly regular seasonal pattern of price peaks and troughs, and although this has been observed in the actual farm and class price series, more recently this pattern has been less evident. Rather there are higher price peaks and longer periods of flat prices (witness the period from mid 1999 to mid-2001, or the period since mid-2001). This suggests the possibility of a change in the period of price movements, which is distinct from the measure of variation such as the standard deviation. Our dynamic model provides a clue as to what might lie behind this changing pattern of price peaks and troughs. As dairy producers become more sophisticated managers (and as farm sizes increase) it is likely that the ability of producers to expand in response to periods of high prices has increased over time. As the responsiveness of expansions to price signals increases, this appears to generate a pattern of price behavior that includes both higher peaks and a disruption of the seasonal pricing patterns observed in the 1990s (Figure 3). Higher price peaks are surrounded by longer stretches of flat prices, with manufacturing product prices at DPSP levels. Overall price variation increases markedly at all levels. Thus, if producer responsiveness to high prices has increased, we might expect future price variation to be higher than in the past—at least, in the absence of new policies or alternative decision making rules in the industry.

The disruption of seasonal patterns is particularly interesting as it suggests that phenomena on longer time scales (such as changes in herd size) may be participating in, influencing, or obscuring volatility on shorter time scales (e.g. due to inventory fluctuations). Indeed, early dynamic commodity models (Meadows, 1970) concentrated entirely on oscillations with periods related to capital lifetimes and animal gestation and maturation times. For dairy commodities, these time scales are on the order of two years, and may become entrained by the 12-month seasonal cycle to produce every-other-year oscillatory behavior and other complex outcomes to simple shocks. Additional dynamic modeling work would seem helpful to better understand this and other potential changes in industry price patterns.

Concluding Comments

The dynamic dairy systems model suggests that a number of factors are potentially important influences on price volatility. One source is supply and demand shocks (weather, consumer spending). Another is the behavioral response of various segments of the industry to price signals and inventory holdings (whether government of commercial), which may result in over- or under-use of contracts, too much or too little speculative inventory holding (hoarding versus limited liquidity), cycles of processing capacity, and cycles in cow numbers. Note that some of these behavior-related sources are polar opposites. Finally, government minimum price regulation attenuates signals to the industry, resulting in the potential for greater price variability, but the price support program (when actively purchasing dairy products) and trade agreements tend to have price-stabilizing effects. Further empirical and structural development of our model will allow us to better understand the roles of each of these factors, and to suggest policies or programs to reduce price variability.

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Figure 1. US Average Farm Milk Price, Regulated Minimum Price for Manufacturing Milk, and Government Target Price, 1980-2002

Table 1. Measures of Variability in Farm Milk and Dairy Product Prices, 1980 to 2002

Price	Average			Standard Deviation			Coefficient of Variation[1]		
	1980-1987	1988-2002	Change	1980-1987	1988-2002	Change	1980-1987	1988-2002	% Change
Farm Milk Prices, $/cwt									
US All-Milk (Mean farm price)	13.14	13.39	0.24	0.65	1.42	0.77	0.05	0.11	115.1
Order 2 Blend (Weighted average regulated farm price)	12.77	13.08	0.31	0.72	1.40	0.68	0.06	0.11	89.4
Support Price (Government target price for manufacturing milk)	12.09	10.00	-2.09	0.71	0.21	-0.51	0.06	0.02	-65.2
Classified Prices, $/cwt									
Class I Mover[2] (Fluid milk)	11.97	12.22	0.26	0.60	1.51	0.91	0.05	0.12	146.3
Class II (Soft products)	12.10	12.57	0.47	0.61	1.56	0.95	0.05	0.12	146.1
Class III (Cheese and whey)	11.96	11.97	0.00	0.60	1.65	1.05	0.05	0.14	174.2
Class IV[3] (Butter and NFDM)		12.43	12.43		1.90	1.90		0.15	
Product Prices									
Wholesale Cheese, ¢/lb	125.9	127.5	1.6	6.4	15.7	9.2	0.05	0.12	140.9
Wholesale Butter, ¢/lb	144.6	105.0	-39.6	5.8	32.7	26.9	0.04	0.31	671.5
Wholesale NFDM, ¢/lb	88.0	104.6	16.6	5.9	13.6	7.7	0.07	0.13	93.6
Retail Fluid ¢/ ½gallon[4]	61.0	62.3	1.3	2.2	4.8	2.5	0.04	0.08	108.9

[1] Equals standard deviation divided by average price.

[2] Equals Order 2 blend price less Class I differential.

[3] January 1995 to December 2002 only.

[4] Through December 1997 only due to limited data availability.

Figure 3. Aggregated CLD for the US Dairy Industry, Showing Key Policies

Table 2. Measures of Variability in Farm Milk and Dairy Product Prices, Five Policy Scenarios[1]

Price	Average					Standard Deviation				
	Base	MILC	Restrict Imports	Weighted Average	Increase Support	Base	MILC	Restrict Imports	Weighted Average	Increase Support
Farm Milk Prices, $/cwt										
US All-Milk Price	12.28	12.08	12.63	12.19	12.71	1.01	0.87	1.26	0.97	0.86
Blend Price	11.75	11.56	12.10	11.66	12.19	0.98	0.84	1.24	0.93	0.82
Farm Receipts/cwt[2]	12.28	12.97	12.63	12.19	12.71	1.01	0.60	1.26	0.97	0.86
Classified Prices, $/cwt										
Class I	13.85	13.66	14.23	13.45	14.26	1.22	1.06	1.43	1.00	0.99
Class II	11.19	11.04	11.50	11.24	11.83	1.46	1.29	1.60	1.48	1.32
Class III	10.84	10.65	11.17	10.87	11.18	0.93	0.83	1.25	0.94	0.73
Class IV	10.52	10.36	10.83	10.87	11.15	1.48	1.30	1.62	1.49	1.32
Product Prices, ¢/lb										
Wholesale Cheese	121.51	120.07	125.49	121.75	125.23	9.41	8.41	12.70	9.56	7.42
Wholesale Butter	113.35	112.35	119.84	113.51	116.02	13.58	12.85	18.31	13.71	11.98
Wholesale NDM	86.51	85.12	86.89	86.93	92.60	11.71	9.65	10.92	11.84	9.85

[1] Average and standard deviation over 60-month simulation horizon.

[2] Equals all-milk price plus direct payments under MILC.

Figure 3. Weighted Average Farm Milk Price Under Five Policy Scenarios

Figure 4. Minimum Regulated Class Prices and Farm Milk Price, Greater Expansion Responsiveness