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Changing Structure, Financial Risks, and Government Policy for the U.S. Dairy Industry

James M. MacDonald
Jerry Cessna
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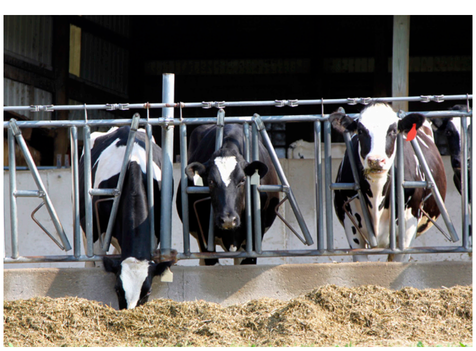

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Changing Structure, Financial Risks, and Government Policy for the U.S. Dairy Industry

James M. MacDonald, Jerry Cessna, and Roberto Mosheim

Abstract

Congress reorganized dairy policy in the Agricultural Act of 2014 when it eliminated three programs and created the Dairy Margin Protection Program. The new program aims to provide farmers with financial protection against risks from increasing volatility in milk and feed prices. These developments occurred amid ongoing structural change toward larger dairy farms, as well as ongoing change in dairy product demand, away from fluid milk, and toward manufactured products sold in domestic and export markets. This report focuses on the interrelated topics of structural change in dairy production, changes in dairy product markets, growing price volatility, and dairy policy. It details the major developments in each, traces the linkages among them, and identifies the challenges that structural change, evolving product markets, and price volatility pose for policy.

Keywords: farm structure; Margin Protection Program; dairy policy; dairy trade; ARMS; dairy farm finances; milk prices

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Errata

On May 17, the following corrections were made to ERR-205, *Changing Structure, Financial Risks, and Government Policy for the U.S. Dairy Industry*. Three cells in Table 3 were updated as follows: “Western States, 3,000-3,999 head in 1992" (19), “Traditional States, 1,000-1,999 head in 1997" (54), and “Other States, 1,000-1,999 head in 2002" (56). On page 10, the State in which Shamrock Farms is located was corrected. In addition, Appendix table A-2 was updated to reflect return-on-equity calculations for the full rather than a restricted sample of dairy farms.

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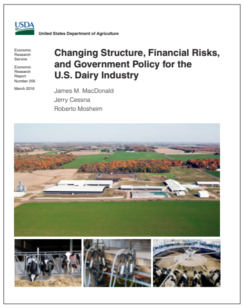

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Changing Structure, Financial Risks, and Government Policy for the U.S. Dairy Industry

James M. MacDonald, Jerry Cessna, and Roberto Mosheim

What Is the Issue?

Congress reorganized dairy policy in the Agricultural Act of 2014. A new program, the Dairy Margin Protection Program (MPP-Dairy), aims to provide farmers with financial protection against adverse movements in milk and feed prices. MPP-Dairy was initiated in response to increasing volatility in milk and feed prices, particularly in 2009 when falling milk prices combined with still-high feed prices to impose unprecedented financial stress on the dairy industry. In contrast to prior dairy policy, MPP-Dairy targets fluctuations in the difference between milk and feed prices (the margin), relies on a combination of Government support and producer premiums for financing, and offers protection against margin risks for all enrolled dairy operations.

The structure of dairy farming has changed dramatically in the last two decades, with cows and production shifting to much larger operations. Structural change has likely affected dairy industry competitiveness in world markets; it also results in a wide range of costs and of financial outcomes, which complicates the design and application of dairy policy. U.S. dairy products are also changing. Beginning in the 1970s, milk use has shifted from beverage products toward cheese and other dairy products used in foodservice and food manufacturing. International trade in dairy products—concentrated in nonfat dry milk, whey products, cheese, and butter—now has greater prominence. Shifts in the dairy product mix alter the geography of milk production as well as the price risks facing dairy farmers.

What Did the Study Find?

Structural change, in the form of production shifting to larger farms, has reduced industry-average production costs and contributed to an expansion of dairy product exports. However, increased international exposure creates new sources of price risks for U.S. farmers, and dairy policy has been redesigned in response to price risks and changing structure.

- Milk production continues to shift to larger farms. In 1987, after decades of consolidation, half of all dairy cows were on farms with 80 or fewer cows. By 2012, that midpoint herd size was 900 cows.
- Costs are a driving force behind structural change. The largest farms earn substantially higher net returns per hundredweight of milk produced, and they have strong incentives to expand. Average milk costs of production fall sharply as herd sizes increase, and the largest farms—those with 2,000 or more head—realize costs, per hundredweight of production, that are 16 percent below farms with 1,000-1,999 head and 24 percent below farms with 500-999 head.
- Changes in the size structure of dairy farms reduced national-average milk production costs by nearly 19 percent between 1998 and 2012. In turn, lower milk production costs reduced milk prices compared with what they would have been without structural change.

- The United States has become a major exporter of dairy products, including nonfat dry milk, skim milk powder, cheese, butter, and whey. Total U.S. dairy exports were $7.2 billion in 2014, up from $1.0 billion in 2003. Expanded exports follow from growing international demand for dairy products (particularly from Asia and Latin America), improvements in U.S. dairy productivity, and changes in dairy and trade policies.
- Dairy farmers face substantial financial risks arising from wide fluctuations in milk and feed prices. Farm milk prices have been more volatile since 1995, and the volatility of feed prices increased sharply after 2005. Specific features of dairy markets make them prone to price volatility. Milk supply varies little in response to price changes. Moreover, dairy product demand also responds only weakly to price changes. Consequently, shifts in the demand for dairy products require substantial changes in price in order to reset the supply-demand balance for farm milk.
- The dairy industry faced a severe financial setback in 2009 when milk prices fell sharply, due to declines in domestic and international demand, and feed prices remained high. The margin between milk and feed prices—which must cover all other dairy costs such as labor, utilities, equipment, and structures—fell to unprecedented lows in 2009. Dairy farmers lost $10 billion in equity—about $150,000 per farm on average—and took on over $4 billion in new debt, largely to finance rather than expand operations.

MPP-Dairy is designed to protect producers against adverse movements in milk-feed margins. Enrollees may receive catastrophic coverage, for a $100 enrollment fee, providing payments when national-average margins fall below $4 (the average monthly margin was $8.30 in 2004-2013). Expanded coverage, which provides payments when national-average margins fall between $4 and $8, may be purchased for premiums.

- Almost 25,000 farms—55 percent of licensed dairy operations, accounting for about 80 percent of 2014 U.S. milk production—enrolled in the program for 2015 coverage. Forty-five percent of enrollees—representing more than half of the historic milk production of enrolled farms—chose catastrophic coverage for a $100 administrative fee, while 42 percent of enrollees chose to pay premiums for coverage of $6.00 and $6.50 margins.
- MPP-Dairy provides farmers with the opportunity for greater financial protection, under a variety of scenarios, than the programs that it replaced. However, because farmers can change their coverage annually in anticipation of expected price changes, and thereby minimize the premiums that they pay, the program also carries the risk of substantial increases in Government costs.
- A crucial issue for MPP-Dairy concerns its effects on milk production. If the program leads to increases in milk production, it can lead to lower average milk prices. And if projected indemnities cause farmers to reduce production less than they might have in response to lower milk-feed margins, it can prolong periods of low margins.
- Finally, while farmers can adjust coverage each year, these adjustments relate only to the share of a farm's production history and the margin that the farm has chosen to cover; under current rules, farmers cannot adjust production histories to account for large changes in herd size. Much of the industry's structural change has been accomplished via such changes.

How Was the Study Conducted?

The study relies on farm-level records drawn from two U.S. Department of Agriculture (USDA) sources—the Census of Agriculture and the annual Agricultural Resource Management Survey (ARMS)—to summarize and analyze structural change in the industry and to assess the impacts of the 2009 margin crash on dairy farms. It uses data from USDA's National Agricultural Statistics Service, Agricultural Marketing Service, and Economic Research Service for summaries and analyses of trends in milk and feed prices, dairy product prices and consumption, and international trade in dairy products.

Data provided by USDA's Farm Service Agency, which administers MPP-Dairy, indicate initial enrollment in the program. Finally, we applied an updated Quarterly Dairy Forecasting model, developed for earlier analyses at the Economic Research Service, to assess industry supply responses to price movements and to evaluate the sources of the margin crash in 2009.

Changing Structure, Financial Risks, and Government Policy for the U.S. Dairy Industry

Introduction

Congress reorganized dairy policy in the Agricultural Act of 2014 (popularly known as the 2014 Farm Bill). It created a new program, the Dairy Margin Protection Program, aimed at providing farmers with financial protection against adverse movements in milk and feed prices. The Dairy Product Price Support Program, the Dairy Export Incentive Program, and the Milk Income Loss Contract Program expired after they were not renewed in the Act.

The new program was initiated in response to wide fluctuations in milk and feed prices, and in particular to events in 2009, when falling milk prices combined with still-high feed prices to exert unprecedented financial stress on the industry. Dairy policy has long been concerned with milk pricing and with financial risks facing dairy farmers, and the 2014 initiatives adjusted risk-management policies in light of ongoing changes—particularly in farm structure and in dairy products—that affect industry performance and influence dairy policy.

Milk production has been shifting to much larger farms for decades. Production costs at the largest farms are considerably lower, on average, than costs at smaller farms. These structural changes have led to lower average production costs in the industry and lower product prices. However, structural change complicates policy; with dairy production now covering a wide range of herd sizes, production costs, and indebtedness, policy tools affect different farms in different ways.

Dairy products are also changing. Exports account for a growing share of dairy production, as dairy policy and improved productivity (in part caused by structural change) have made U.S. dairy product prices more competitive. Exports provide a source of increased demand for U.S. dairy products, but also heighten risk arising from sudden changes in global dairy production, global demand, and exchange rates. Beginning in the 1970s, domestic milk use shifted from beverage products to cheese and other dairy products used in foodservice and food manufacturing. Since fluid milk processing concentrates near population centers, changes in the dairy product mix alter the geographic landscape of milk production, favoring more remote locations. Changes in the dairy product mix may also alter dairy price relationships, and hence may affect dairy price volatility.

Dairy farmers face two kinds of price risks. Most of their gross income comes from milk sales, and farm-level milk prices can fluctuate sharply from month to month. Feed accounts for a high share of total costs, and feed prices also fluctuate sharply. Milk and feed prices have shown increased volatility in the 2000s, partly due to market developments and partly due to policy. That increase in volatility—particularly the margin crash of 2009 when milk and feed prices converged to create large economic losses in the industry—played a driving role in the 2014 policy change.

This report focuses on the four interrelated issues of structural change, changes in product markets, price risks, and dairy policy. It details changes and causes of change in each, traces the linkages among them, and identifies how structural change, evolving product markets, and volatility affect the design and impacts of dairy policy.

Dairy policies and price risks

Dairy policy has long been concerned with price volatility and the attendant financial risks for dairy farmers, but specific programs have followed different strategies, reflecting specific contemporary dairy issues as well as developments in broader farm policy. The instruments of policy have shifted over time from market intervention, to set floors on milk prices, to direct payments aimed at ameliorating the effects of low milk prices, and most recently, to subsidized insurance programs aimed at the margins between milk and feed prices. The target audience has also shifted, from all producers under market intervention programs, to a concentration on smaller producers under direct payments, and back toward all producers under insurance programs.

Dairy policies change over time, but several key issues are always present. Producers respond to the incentives in dairy programs, and those responses affect milk production, taxpayer burden, milk price volatility, and farm financial performance. In turn, taxpayer burden has played an important role in program design and in program changes. International dairy markets and trade agreements constrain dairy programs and affect program design.

Dairy price supports, a form of market intervention, were introduced in the Agricultural Act of 1949 (1949 Act) and served as a major dairy policy tool through the 1990s. Under the program, the Commodity Credit Corporation (CCC) of the U.S. Department of Agriculture purchased cheese, butter, and nonfat dry milk. Purchase prices of these dairy products were set through formulas that attempted to equate the product prices to the support price for farm milk.[1] As CCC purchases removed products, product prices in commercial markets would move in response to CCC prices. Changes in product prices should directly affect prices received by farmers for farm milk, and the administrative pricing system encompassed by Federal Milk Marketing Orders directly links minimum farm milk prices to dairy product prices (see box, "Federal Milk Marketing Orders").

During the 1970s, CCC support prices were raised and tied to an index of general farm input prices; as input prices rose with general inflation, support prices followed to reach the equivalent of $13.10 per hundredweight (hereafter cwt) of farm milk in 1980. However, actual dairy production costs rose less rapidly than input price inflation because of continued productivity growth in the industry, so support prices in the early 1980s were high enough to create profits and induce increased milk production, which USDA was obligated to purchase in order to maintain the support price.

High support prices effectively reduced price fluctuations, but at considerable cost to taxpayers: the CCC spent $2.97 billion in outlays on dairy programs in 1983, one-sixth of total cash receipts to the dairy sector. While the CCC did recover some expenses through later sales of the stored products, CCC dairy receipts never exceeded 15 percent of outlays in the 1980s, and were usually much lower, as products were donated or sold into low-value uses.

The taxpayer burden and oversupply of milk resulting from high support prices in the 1980s led to important changes in dairy programs. Congress gradually reduced support prices in successive farm bills in the 1980s and 1990s, eventually reaching $9.90 per cwt in 2002. In 1983, Congress

[1]The products would be stored and sold when prices recovered, or distributed to domestic or foreign users outside of normal market channels. Legislation passed in 2008 shifted the program focus to specified dairy product prices instead of farm milk prices. Dairy Product Price Supports (DPPS) expired with the 2014 Farm Bill, but the original 1949 enabling legislation for milk price supports is still in force and could become law if the MPP-Dairy program were to expire.

Federal Milk Marketing Orders

Federal milk marketing orders (FMMOs) establish rules under which first buyers of milk (called *handlers* in Federal order provisions) purchase milk from dairy farmers. There are currently 10 regional FMMOs, and they regulate over 60 percent of all milk produced in the United States. Most of the milk without price regulation by FMMOs is regulated by similar State programs, with the largest being California.

FMMOs are created and amended through a hearing process overseen by the U.S. Secretary of Agriculture. This process enables the dairy industry to submit proposals and evidence to support the establishment of and amendments to an FMMO. Decisions concerning FMMOs must be approved by dairy farmers, or their cooperatives, through a referendum process.[1]

FMMOs set minimum prices that handlers pay dairy farmers or their cooperatives. Minimum prices are set monthly and are based on formulas that include market-determined monthly dairy product prices as reported to USDA's Agricultural Marketing Service, combined with other fixed factors reflecting estimated processing costs, yield factors, and location factors. FMMO minimum milk prices move directly with dairy product prices: minimum milk prices rise if dairy product prices rise, and they fall if product prices fall.

The FMMO system features two main elements: classified pricing and pooling. Handlers are required to pay minimum prices based on the end use, or *class*, of the milk. There are currently four classes of milk:[2]

- Class I: milk products intended to be used as fluid or beverage milk;
- Class II: fluid cream and other cream products, cottage cheese, yogurt, and frozen desserts;
- Class III: hard cheeses and cream cheese; and
- Class IV: butter and milk products in dried form.

Class I milk prices usually exceed prices for other classes because they include Class I differentials, adjustments to account for the higher costs to dairy farmers or their cooperatives associated with marketing milk for fluid beverage use. Class I differentials vary by location, and they generally increase incrementally from milk-surplus regions to milk-deficit regions.

Minimum milk payments are coordinated through a *pooling* system. While handlers pay minimum prices based upon the class of the milk, the minimum paid to dairy farmers or their cooperatives is a weighted-average *blend price* that accounts for class utilization in the marketwide pool, ensuring that farmers receive the same minimum prices regardless of the actual use made of the farmer's milk. The minimum blend price for each dairy farmer also accounts for differences in milk content: four orders are based upon butterfat and skim milk, while six employ pricing based upon butterfat, protein, and other milk solids. Four of the latter six also include an adjustment for somatic cell count (SCC).[3] Handlers usually offer farmers prices above FMMO minimums, with premiums for quality, volume, market demand, or other factors.

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[1]In cases where changes do not directly affect milk prices, USDA may elect to use informal rulemaking—a shorter process that does not involve a hearing. The legal authority for FMMOs is found in 7 U.S.C. 601-674, and 7253, while regulations are detailed in 7 CFR Parts 1000-1135.

[2]The list in this report is abbreviated to include only major dairy products.

[3]The SCC is an indicator of milk quality. Somatic cells are present in all milk. The majority of somatic cells are white blood cells, which increase in response to udder infections. Milk quality increases as SCCs decrease. According to the U.S. Pasteurized Milk Ordinance, milk for fluid use is allowed to contain no more than 750,000 somatic cells per milliliter.

Continued—

Federal Milk Marketing Orders—continued

FMMOs were first implemented in the 1930s to provide stability to markets that had been decidedly unstable for several decades and that voluntary actions had been unable to address (Paggi and Nicholson, 2013). Specifically, the high transportation costs, perishability, and fluctuations in production associated with fluid milk marketing led to wide fluctuations in milk prices and in fluid milk availability as well as excessive investment in milk collection and processing capacity. Moreover, there was concern with what would now be termed monopsony power held by local processors over dairy producers. Efforts to promote cooperatives to address these issues had seen limited success during the 1920s.

Marketing orders sought to address those problems and ensure orderly flows of milk to fluid markets by sharing higher fluid milk values with farmers whose milk was used for manufacturing but which served as a reserve for the fluid market. Market orientation was balanced with equal treatment of producers by tying minimum prices to be paid for farm milk in each market's shared pool to dairy product prices and the costs of supplying local fluid markets.

Over time, FMMO coverage and pricing formulas have been adjusted to account for changes in technology and milk markets, and there is continuing discussion regarding their design and effects. Cropp and Jesse (2004) point to the role of location in setting Class I differentials, which they call "one of the most contentious aspects" of FMMOs. They also point to the use of fixed values for milk yields and manufacturing costs in pricing formulas, and question whether these can reflect a quickly changing reality.

A March 2011 report from the Dairy Industry Advisory Committee, appointed by the U.S. Secretary of Agriculture in the wake of the industry's 2009 financial squeeze, acknowledged that "FMMOs have many functions in the dairy industry" and touched on several issues (U.S. Department of Agriculture, 2011):

- FMMOs play a valuable role in oversight of compliance issues such as accuracy of weights, milk component testing, contract enforcement, data gathering, and publication of statistics vital to market transparency.

- Some of the original justifications for classified pricing and pooling should be reexamined. According to the report, "Developments in milk transportation and storability, long-term declines in per capita beverage milk consumption and increases in cheese consumption, establishment of extremely large farmer-owned cooperatives, development of protein filtration technology, the increasing use of dairy products for ingredient usage in other foods, the emerging product preferences of both domestic and global dairy consumers, and a host of other factors necessitate a strategic look at the future role of FMMOs, especially in its role in price setting and pooling."

- Chicago Mercantile Exchange (CME) prices for cheese and butter have a large influence on minimum milk prices, even though they are not directly used in formulas. Because these spot markets trade relatively little volume, these markets sometimes exhibit large and unexpected price swings, though neither the CME nor the Commodity Futures Trading Commission, which oversees the CME, has found evidence of manipulation as a significant problem. In addition to CME spot prices, dairy manufacturers use a variety of other sources to set their sales prices, including USDA's Dairy Market News, CME futures markets, and even the same USDA weekly mandatory survey, which is used to set the regulated prices.

For more information about the Federal order system, see Paggi and Nicholson (2013), Jesse and Cropp (2004), and USDA Agricultural Marketing Service: http://www.ams.usda.gov/rules-regulations/moa/dairy.

established the Milk Diversion Program to reduce milk production.[2] The program was applied to milk sold during the 15-month period from January 1984 through March 1985; 38,000 milk producers enrolled and were paid about $955 million. Milk production fell by 3.0 percent during 1984, after rising by 3.0 percent in 1983; however, production growth accelerated after the program's end, rising by 5.7 percent in 1985.

Congress again attempted to reduce dairy production when it introduced a Dairy Termination Program, known as the dairy herd buyout, in the 1985 Farm Bill. Producers could offer bids to sell their milking herds for slaughter or export during one of three liquidation periods in 1986 and 1987. If the bid was accepted, the producers committed to stay out of dairy production for 5 years. CCC outlays for the termination program came to $1.5 billion over 1986-89. USDA accepted bids from nearly 14,000 producers, with 1.55 million cows, or 14 percent of the 1985 national inventory.

However, milk production was reduced by considerably less than the number of animals in the buyout would suggest. The national inventory of milk cows fell by about 1 million head from 1985 to 1990, as some of the termination program's herd reduction was offset by new herd entry and herd expansion. As important, the cows that were removed under the program had lower milk production than remaining and entering cows. Overall production growth did fall during the buyout, but modestly, to 0.8 percent annual growth in 1986-90, compared to 1.3 percent in 1982-86 and 1.0 percent in 1990-94.

High support prices also affected international markets by discouraging U.S. exports of dairy products and encouraging imports. Congress introduced the Dairy Export Incentive Program (DEIP) in 1985 to support exports. Under the program, USDA paid cash bonuses to U.S. dairy product exporters to meet prevailing world prices for targeted dairy products and destinations. The payments allowed exporters to buy dairy products at relatively high domestic prices and then sell export products at lower world prices.[3] During the 1980s, the United States also maintained quotas on dairy product imports attracted by high U.S. domestic prices; they were later adjusted to tariff-rate quotas, which placed high tariffs on imports over a certain target (quota) level.

The programs described so far are all based on intervening in dairy markets to affect prices or production. Congress took a different approach in the 2002 Farm Bill, when it introduced the Milk Income Loss Contract (MILC) Program. The program provided countercyclical payments to farmers when a specified price (the Federal Class I price in Boston) fell below a target price set in legislation. When that happened, farmers received a payment equal to 45 percent of the difference between the prices, hence dampening the impact of price swings on revenues.[4]

A key element of the MILC program was a cap on eligible production. In the original legislation, countercyclical payments could only be provided on the first 2.4 million pounds of production on a farm; the 2008 Farm Bill raised the cap to 2.985 million pounds. At an annual production of 20,000 pounds per cow, the 2008 cap was equivalent to annual production from 149 cows. Consequently, a farm with a milking herd of 500 cows would receive the same total payments as an otherwise iden-

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[2]Participating farmers were eligible for payments of $10 per cwt for reductions in milk marketings of 5 to 30 percent below a specified base. The program was financed through assessments on milk marketings.

[3]The DEIP was primarily used to match export subsidies provided by the European Union.

[4]The next farm bill, in 2008, adjusted MILC to also account for feed price movements: when a specified NASS measure of dairy feed prices rose above a target level, the target milk price was raised by 45 percent of the difference between the target and market (NASS) feed prices.

tical farm with 150 head, but the payments would be spread over more production, and the larger farm would receive less support per pound. With production shifting to larger dairy farms, the MILC program targeted support to smaller, usually higher cost farms that were under considerable financial stress.

The MILC program generated outlays of $1.8 billion in 2003, the first year of operation, and outlays exceeded $200 million in 2004, 2006, 2009, and 2012 (outlays rose in years of low milk prices). The program addressed an outcome of price risks—income volatility—not by supporting product prices but by providing direct payments to farmers when prices fell.[5] However, to the extent that MILC kept some inefficient producers in business, it would have delayed supply adjustments to falling prices and kept prices lower than they would have been without the program. The supply impact was mitigated by the limited and declining coverage of the program: the cap meant that MILC provided no expansion incentives to midsize and large farms, and it covered a declining share of total milk production.

The Dairy Margin Protection Program (MPP-Dairy) of 2014 represents another important shift in policy, as it replaced MILC, DEIP, and DPPS. It is a voluntary risk management program that offers protection to dairy producers when the difference between national average milk and feed prices (the margin) falls below a certain dollar amount (with premiums staggered) selected by the producer. The program is elective in that producers choose whether or not to participate and can choose the level of coverage they wish to purchase. There are no caps on either covered production or annual payments in MPP-Dairy. Initial signup occurred in late 2014, with the program set to cover margins in 2015.[6] MPP-Dairy mirrors a broader shift in U.S. agricultural policy from direct payments toward subsidized insurance programs aimed at financial risks.[7]

Experience with previous dairy policies indicates that producers react to the incentives in programs: they alter production in the short run, and they may alter investment in the long run, when policies generate profits on expanded production. In turn, producer response affects market production, prices, efficiency, and taxpayer burden. Each of these issues—producer response and consequent market impacts, taxpayer burden, the target audience for policy—will arise again in future evaluations of MPP-Dairy.

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[5]In this regard, the MILC program followed the broader trends in commodity programs set in the 1996 and 2002 Farm Bills, with an emphasis on countercyclical payments tied to the gap between target prices and market prices.

[6]Congress also introduced the Dairy Product Donation Program in the 2014 legislation; under the program, USDA purchases certain dairy products when the national-average margin between milk and feed prices falls below $4 per cwt. Products are donated directly to organizations involved in domestic feeding programs. While the program functions much like earlier price support programs, USDA is not permitted to store products for later disposal and the trigger for purchases is set at a low margin.

[7]USDA's Risk Management Agency introduced an insurance program for dairy in 2008—livestock gross margin insurance (LGM-Dairy)—which protects against loss of gross margin (market value of milk minus feed costs) on milk produced from dairy cows. A producer can insure up to 24 million pounds of milk a year, for periods up to 11 months following enrollment, with contract renewals available. LGM-Dairy provides a margin guarantee, and therefore insures against short-term declines in margins, but it does not insure against continuing low margins. For that reason, LGM-Dairy is most valuable to farms when margins are high and likely to fall in the near future. The amount of money appropriated for premium subsidies for livestock gross margin insurance, including dairy, has been limited, which also limits enrollment in periods of high demand. Farms cannot enroll in both MPP-Dairy and LGM-Dairy.

The Changing Structure of Dairy Farming

Structural change encompasses changes in farm size, farm ownership and organization, the location of production, and farming practices. Two decades ago, most milk came from farms with fewer than 150 cows, on which a farm family handled milking, herd management, and crop production for feed. Today, most milk comes from farms with more than 900 cows; while most of these farms are owned and operated by a family, most of the labor is provided by hired workers and many farms purchase most or all of their feed.

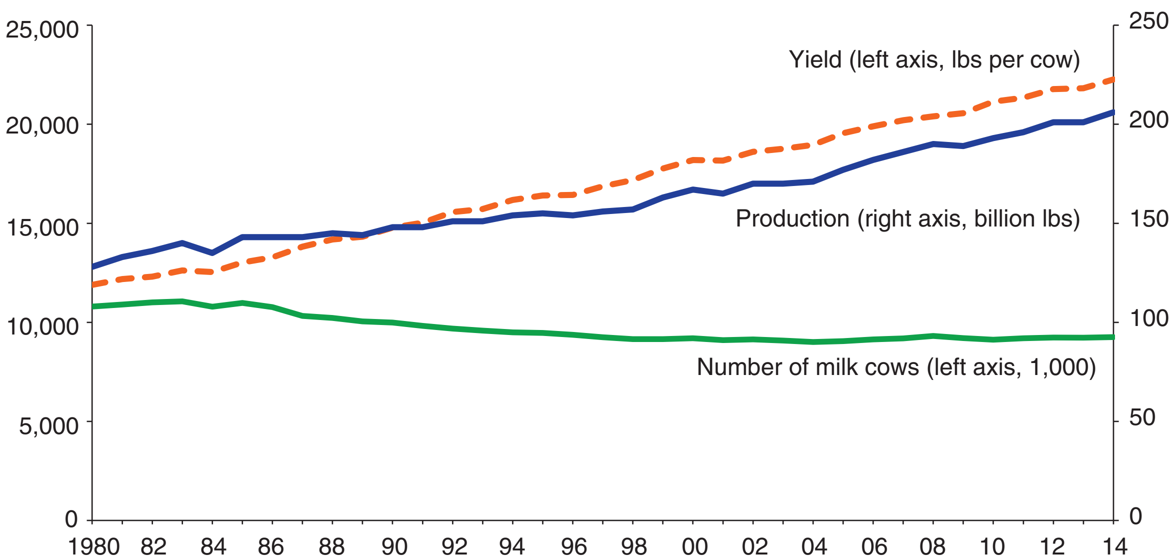
The shift occurred against a backdrop of steady increases in U.S. milk production. Between 1985 and 1998, the total number of milk cows in the United States declined by about 17 percent and has since remained in a range of 9.1-9.3 million cows (fig. 1). However, total milk production continued to grow steadily, driven by persistent increases in annual milk production per cow (yield), which reached 22,258 pounds in 2014, compared to 11,891 pounds in 1980.

How has farm structure changed?

The mean farm size—the average number of milk cows per farm with cows—nearly tripled between 1987 and 2012, from 50 to 144 cows (fig. 2). However, that increase does not capture the magnitude or nature of the industry's transformation. While the United States still has many herds of 50 to 100 cows, most cows and production have moved to much larger herds, many with well over 1,000 head.

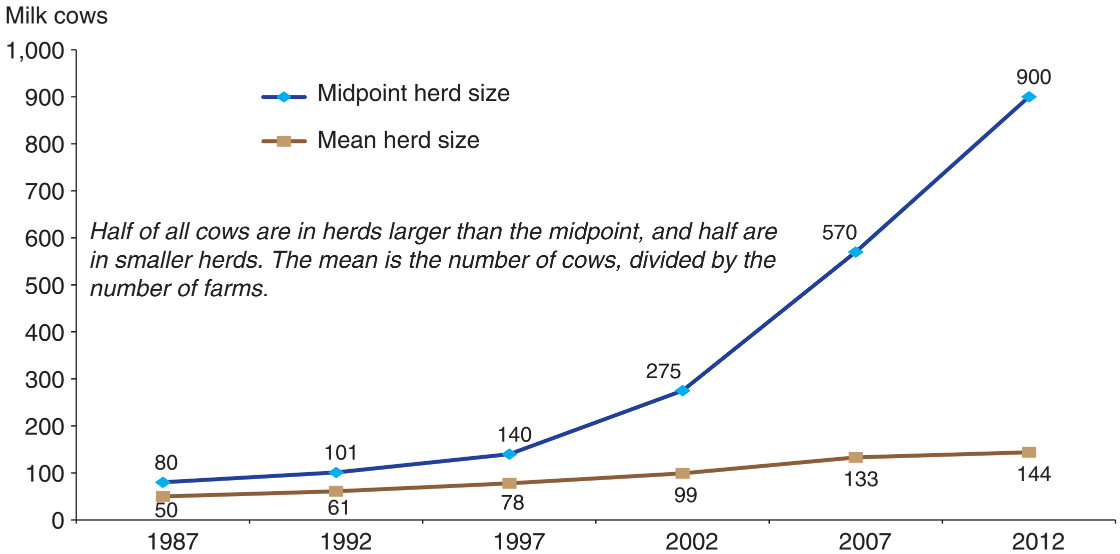
The midpoint herd size, a useful measure of that consolidation, splits the national inventory of cows such that half of all cows are in larger herds and half are in smaller (Lund and Price, 1998). The midpoint was 80 cows in 1987, compared to a mean of 50, indicating that most cows were on modestly sized farms near the mean size (figure 2). But the midpoint increased more than tenfold over the next 25 years, far more than the mean, to 900 cows in 2012. That shift shows no sign of

Figure 1
U.S. milk production, milk per cow, and cows, 1980-2014



Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, Quick Stats.

Figure 2
Changes in herd size, 1987-2012



Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, Census of Agriculture. Means are from published census estimates; midpoints are ERS estimates from unpublished census records.

slowing—indeed the rate of increase accelerated after 1997. While most dairy farms were still fairly small in 2012, most cows were on much larger farms.

Table 1 provides detail behind those shifts. In 1992, 135,000 small farms (less than 100 cows) held nearly half of all milk cows; 20 years later, 50,000 small dairy farms accounted for 17 percent of all cows. It's important to emphasize that most U.S. dairy farms are still fairly small; those with fewer than 100 cows still accounted for 78 percent of all farms with milk cows in 2012 (although about 15,000 of them did not sell milk commercially, but instead kept cows for home consumption only). Only 1,807 farms had at least 1,000 cows in 2012, but their number more than tripled from 1992. And by 2012, those large farms accounted for nearly half of all cows, up from 9.9 percent in 1992.[8]

Dairy farm structure follows a distinct regional pattern, with larger farms concentrated in the West, but the shift to larger farms occurred across the country (table 2).[9] In 1992, farms with less than 100 cows accounted for most milk cows in each of the 9 major dairy States located in the Northeast, eastern Corn Belt, and Upper Midwest. Small farms made up a smaller proportion in the 8 major dairy States in the West and Southwest, but large farms with at least 500 cows accounted for most cows in only 3 of those States—Arizona, California, and New Mexico. In the next 20 years, the small-farm share fell by over 20 percentage points in each of the nine Eastern States and eroded sharply in the four Western States where small farms were prominent in 1992. Cows shifted to farms in the 500+ category in every State, and the shifts were quite striking in the Eastern Corn Belt, Iowa, New York, Texas, and Vermont. In 2012, small farms accounted for

[8]Larger farms have higher yields of milk per cow, on average, than smaller farms, and by 2011 farms with at least 1,000 milk cows accounted more than half of production.

[9]Table 2 reports data for 17 major dairy States. The largest size class reported for States in the census of agriculture is farms with 500 or more cows because some States have very few farms of that size. Farms in Western States are more likely to purchase all of their feed, while focusing their labor and capital on milk production and larger herds. It is easier for newer farms, more common in Western States, to build to large scales than it is for older farms to add capacity.

Table 1
Changing size structure of U.S. dairy production, 1992-2012

Head per farm	1992	1997	2002	2007	2012
	Number of farms with dairy cows				
<50	93,118	63,657	48,260	34,338	34,332
50-99	41,813	33,477	25,465	18,986	15,351
100-199	14,062	12,602	10,816	8,975	7,359
200-499	4,652	4,881	4,546	4,307	3,712
500-999	1,130	1,379	1,646	1,702	1,537
>999	564	878	1,256	1,582	1,807
Total	155,339	116,874	91,989	69,890	64,098
	Share (%) of inventory				
<50	20.4	14.5	9.8	7.2	6.3
50-99	29.0	24.5	19.1	13.8	11.1
100-199	19.0	18.0	15.4	12.8	10.6
200-499	13.7	15.3	14.7	13.8	12.0
500-999	8.0	10.2	12.2	12.5	11.3
>999	9.9	17.5	28.8	39.9	48.7
Total	100.0	100.0	100.0	100.0	100.0

Source: USDA, National Agricultural Statistics Service, Census of Agriculture.

most cows in only one major dairy State—Pennsylvania—while holding over 30 percent only in Ohio, Minnesota, and Wisconsin.

Production has not simply shifted to larger farms: instead, the largest farms have become much larger over time. In 1992, a farm was considered to be very large if it had between 1,000 and 2,000 head, and most of those were in the West; a large dairy farm in traditional Northeastern or Midwestern dairy States might have had 500 to 1,000 cows. But that pattern has changed as well. While there were just 15 farms with at least 1,000 head in traditional dairy States in 1992, there were 472 in 2012 (table 3). Moreover, while there were 104 U.S. dairy farms with 2,000 or more cows in 1992 (compared to 450 with 1,000-1,999), there were 815 by 2012. Western dairy States had 5 dairy farms with at least 5,000 head in 1992, and 128 in 2012. Traditional States had no dairy farms with 3,000 or more cows in 1992, but 67 by 2012.

Table 2
Herd size distribution, by State and region, 1992 and 2012

	Herd size			
	<100 cows		>499 cows	
Region or State	1992	2012	1992	2012
	Percent of State or region inventory			
Northeast	64.0	37.7	3.7	30.5
NY	55.8	28.1	5.6	44.2
PA	75.6	52.8	1.3	12.7
VT	55.8	21.1	4.3	38.9
E. Corn Belt	62.6	24.6	2.0	46.0
IN	70.5	28.2	<1	50.6
MI	51.9	13.6	3.9	54.7
OH	70.3	37.8	0.9	30.7
Upper Midwest	81.1	31.8	0.4	32.3
IA	80.5	23.4	<1	39.5
MN	84.1	35.0	<1	28.5
WI	80.0	32.0	0.6	32.5
Southwest	11.3	1.3	46.1	93.1
AZ	0.7	0.3	85.0	99.0
NM	2.1	0.4	85.6	98.7
TX	16.2	2.3	26.3	86.4
West	5.6	0.9	59.2	91.3
CA	1.3	0.3	72.4	94.2
CO	6.9	1.6	38.1	90.8
ID	22.2	1.9	36.2	90.7
OR	18.2	3.4	22.2	72.2
WA	10.0	1.6	31.3	82.0
17 Major States	50.0	17.6	20.4	63.3
United States	49.4	17.4	18.4	60.0

Source: USDA, National Agricultural Statistics Service, Census of Agriculture.

Across the country, dairy farms much larger than any seen in earlier decades began to emerge.[10] Several farms now have milking herds of well over 10,000 head, along with thousands of replacement heifers. Oregon's Threemile Canyon Farms has a milking herd of 32,000 cows and 39,000 acres of cropland. In Indiana, Fair Oaks Farms milks over 30,000 cows, while Arizona's Shamrock Farms milks over 10,000.[11] However, dairy farming remains dominated by family-run businesses. Family farms account for over 90 percent of farms and production, even in the largest size classes, in the Agricultural Resource Management Survey and in census of agriculture data (see box, "Family Farms").

[10]These developments are not restricted to the United States. There has been a gradual shift to larger dairy operations in Europe, and a number of very large farms have begun operations in Denmark and in the United Kingdom (Henley, 2014).

[11]See www.threemilecanyonfarms.com, www.fofarms.com, and www.shamrockfarms.net/.

Table 3
Large dairy farms, by size and region, 1992-2012

Region and herd size	1992	1997	2002	2007	2012
			Number of dairy farms		
Western States					
1,000-1,999	401	545	606	607	595
2,000-2,999	60	132	197	237	267
3,000-3,999	19	40	94	137	153
4,000-4,999	8	16	40	68	57
5,000+	5	12	39	89	128
	493	**745**	**976**	**1,138**	**1,200**
Traditional States					
1,000-1,999	12	54	135	229	330
2,000-2,999	3	7	27	57	75
3,000-3,999	0	1	12	20	37
4,000+	0	0	4	19	30
	15	**62**	**178**	**325**	**472**
Other States					
1,000-1,999	37	50	56	68	67
2,000-2,999	10	7	25	24	33
3,000-3,999	5	8	9	10	16
4,000-4,999	1	3	4	4	5
5,000+	3	3	8	13	14
	56	**71**	**102**	**119**	**135**
All States	564	878	1,256	1,582	1,807

Source: ERS calculations from unpublished census of agriculture records. Western States are AZ, CA, CO, ID, MT, NV, NM, OR, TX, UT, WA, and WY. Traditional States are CT, DE, IA, IL, IN, MA, MD, ME, MI, MN, MO, NH, NJ, NY, PA, OH, RI, VT, and WI.

Family Farms

The ERS family farm definition focuses on the principal operator—the person who makes day-to-day operating and management decisions for the farm—and defines a family farm as one whose principal operator, and people related to the principal operator, own more than 50 percent of the farm business. The definition focuses on operation and control of the enterprise: owning more than half of the business provides control for the family that operates the business. Family farms do not have to be sole proprietorships: half of farms with at least 1,000 cows are organized as partnerships, and about 30 percent organize as limited liability companies (LLCs).

Some very large dairy farms are owned by a single family that owns multiple farms and relies on hired managers to operate the farms. ERS would not classify them as family farms unless the hired managers were also part of the family that owns the farms. Some other large farms are operated by a farmer who has an ownership interest, but who also relies on investors for financial support. If the outside investors own more than half of the equity in the business, ERS would not class this type of business as a family farm. While still not common, these types of arrangements are likely to become more important in the future if farms milking 10,000 or more cows become more prominent, because the amount of capital needed for such operations exceeds what most families, even if affluent, could afford to sink into a highly specialized and risky endeavor.

Costs and the shift to larger farms

Costs are a driving force behind structural change: on average, larger farms realize lower costs and higher returns. Table 4 reports estimates of the average cost of production for milk by herd size for 2010, the year covered by the most recent Agricultural Resource Management Survey (ARMS) cost-of-production (COP) dataset (see box. "A Note of ARMS Datasets Used in this Report").[12]

ERS COP estimates aim to be comprehensive, accounting for all resources used in milk production, not just cash expenses. In particular, the ERS COP accounts include cash expenses, such as purchased feed and hired labor, but also include estimates of the costs of homegrown feed and the unpaid labor provided by the farm operator and family members. Homegrown feed is priced at the value it would bring if sold instead of used on the farm.[13] Hours of unpaid labor are priced at the average earnings obtained by farm operators when they work off the farm.[14] Finally, ERS generates estimates of the annualized costs of capital recovery for the dairy enterprise—funds the farm would have to retain to replace capital as it wears out.

A Note on ARMS Datasets Used in This Report

Our analysis relies heavily on data drawn from an annual large-scale survey of U.S. farms, the Agricultural Resource Management Survey (ARMS). The ARMS, which is jointly administered by the National Agricultural Statistics Service (NASS) and the Economic Research Service (ERS), links measures of farm financial performance to farm production and production practices and to farm household resources and finances.

We create two dairy farm datasets from ARMS (more details are in appendix A). The ***Dairy COP*** (cost of production) dataset is based on a version of the ARMS questionnaire that is designed specifically for dairy farms. It gathers extensive information on production practices, resource use, revenues, and expenses associated with the dairy enterprise of a farm. The most recent dairy version covered 2010; earlier versions covered 2000 and 2005, and the next will cover 2016.

The ***Dairy whole-farm finance*** dataset provides annual whole-farm financial data. ERS uses ARMS data to develop financial accounts—income statements and balance sheets—for each farm in ARMS and for the farm sector as a whole. We draw on dairy farm records to evaluate temporal changes in the sector's financial condition over 2005-14 and to assess how different sizes of farms fared during the 2009 dairy margin crash.

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[12]ERS reports baseline and subsequent annual estimates at http://www.ers.usda.gov/data-products/milk-cost-of-production-estimates.aspx. Table 4 differs from the 2010 estimates reported there because it excludes organic production and reports separate estimates for farms with 1,000-1999 head and 2,000 or more head.

[13]Because ERS estimates the value of feed provided to the dairy enterprise by the farm, the COP accounts do not separately account for the resources, including cropland, used in feed production. We do account for the modest amount of land used in milk production.

[14]Specifically, ERS obtains detailed data on off-farm earnings of all farmers from questionnaire version 1 of ARMS Phase III, which covers all types of farms. ERS analysts relate farmers' off-farm earnings to attributes such as age, education, ethnicity, location, and marital status. That analysis is then used to generate a predicted off-farm wage for dairy farmers (an estimate of that they could have earned, if they worked off the farm), based on their own attributes.

Table 4
2010 Costs of production, by herd size, 2010

Item	<50	50-99	100-199	200-499	500-999	1,000-1,999	>1,999
	Herd size (milk cows)						
Mean herd size	33	68	135	313	701	1,393	3,757
Output per cow	15,614	17,255	18,966	19,754	22,296	24,135	22,430
	Dollars per hundredweight sold						
Operating costs							
Feed							
Purchased feed	4.96	4.60	4.94	5.97	6.31	6.41	7.11
Homegrown feed	7.15	6.71	5.98	4.87	3.37	2.80	1.47
Grazed feed	0.43	0.19	0.12	0.10	0.01	0.01	0.01
Total feed costs	12.54	11.50	11.04	10.93	9.70	9.22	8.59
Other operating costs	4.01	3.85	3.33	3.52	3.06	2.50	1.93
Total operating costs	16.55	15.35	14.37	14.45	12.76	11.72	10.52
Allocated overhead							
Hired labor	0.52	0.80	1.21	1.79	1.84	1.49	1.39
Unpaid labor	13.22	6.79	3.42	1.40	0.49	0.22	0.11
Capital recovery	7.44	6.08	4.26	3.45	2.41	2.32	1.36
Other overhead	1.38	1.22	0.99	0.91	0.59	0.62	0.42
Total allocated overhead	22.56	14.89	9.88	7.55	5.33	4.65	3.28
Total costs	**39.11**	**30.24**	**24.25**	**22.00**	**18.09**	**16.37**	**13.80**
Gross VOP	19.06	18.99	18.52	18.39	18.03	16.74	16.61
Net returns	**-20.05**	**-11.25**	**-5.72**	**-3.61**	**-0.05**	**0.36**	**2.82**

Gross VOP is gross value of production.
Source: ERS Milk Cost of Production estimates, based on USDA 2010 Agricultural Resource Management Survey, version 4. Organic farms are excluded.

The estimates are reported for seven herd size classes. The average total cost of production, across all milk sold, was estimated to be $18.18 per cwt in 2010, but costs fall sharply as herd size increases, from $39.11 per cwt in the smallest class to $13.80 in the largest. Average cost in the largest class (2,000 or more cows) was 16 percent lower than in the next largest size class (1,000-1,999 cows) and 24 percent below that for herds with 500-999 cows—large differences that provide strong incentives to grow.

ERS also estimates the gross value of production associated with the dairy enterprise, and net returns are the difference between gross value and total costs.[15] Smaller farms realize higher gross values per cwt primarily because milk prices are higher in regions where small farms are concentrated.

[15]The gross value consists of the value of milk sold, plus the value of products produced jointly with milk, such as sales of dairy cattle (arising from milk cows culled from the herd for slaughter, heifers sold to other farms for milk production, and calves sold for beef production), cooperative patronage dividends, and the fertilizer value of manure produced by the cows.

In 2010, farms in the largest size class (at least 2,000 cows) earned net returns of $2.82 per cwt sold, after accounting for all costs. For a farm with 2,500 milk cows and a milk yield of 224 cwt per cow, this amounts to an economic profit of almost $1.6 million. During the same year, the average net return in the next largest class (1,000-1,999 head) was 36 cents per cwt, while net returns were negative in all smaller farm classes (table 4). Dairy farms in the smallest size classes generated substantial economic losses, on average.

Decomposing dairy enterprise costs: farm labor, milk yields, and technology

The detail in the COP accounts allows us to identify some major sources of large farm cost advantages. One clearly lies in allocated overhead—labor and capital recovery (table 4). Larger operations rely more on hired labor than do smaller farms, and large-farm hired labor expenses are higher, per 100 pounds of milk produced, but not much higher. In contrast, capital recovery and unpaid labor costs—per cwt of production—are much lower at larger operations.

The implicit wage (table 5) of unpaid labor ranges from $19.36 per hour, for operators of the smallest farms, to $24.36 for operators in the largest size class.[16] Recall that this estimate is based on the hourly earnings of farm operators who work off the farm, linked to their personal characteristics and locations. Farmers in larger size classes tend to have higher levels of education and to be younger than farmers in the smaller classes, and these differences in characteristics drive differences in estimates of what they could earn off the farm. Larger farms do not realize lower labor costs because they pay less; in fact, their hourly wage rates (hired and implicit family wages) are higher than small farm wages (table 5).

Table 5
Labor on dairy farms, by herd size, 2010

	Herd size (milk cows)						
Item	<50	50-99	100-199	200-499	500-999	1,000-1,999	>1,999
	Mean values across farms						
Production (cwt)	5,287	11,913	25,817	62,664	158,984	341,464	844,463
Labor hours (all)	4,218	5,184	7,013	16,136	22,637	39,892	80,934
Cwt/hour (all)	1.3	2.3	3.7	3.9	7.0	8.6	10.4
Unpaid hours							
Principal operator	2,466	2,807	2,994	2,885	2,823	2,606	2,771
All	3,821	4,076	4,121	3,907	3,306	3,149	4,038
Implicit wage ($/hr)	19.36	20.36	21.16	22.32	23.48	23.99	24.68
Paid hours	397	1,108	2,892	12,229	19,331	36,743	76,896
Percent paid	9.4	21.4	41.2	75.8	85.4	92.1	95.0
Paid wage ($/hr)	10.41	10.06	11.67	11.55	11.16	11.96	12.01

Source: USDA, 2010 Agricultural Resource Management Survey, version 4. Organic farms excluded.

[16] ARMS respondents report hours of work on the dairy enterprise, for hired labor and for unpaid labor, where the latter is reported separately for operators, spouses, and other unpaid labor. Respondents also provide wage rates for hired labor, while ERS estimates implicit hourly wages for unpaid labor, based on what farmers earn when they work off the farm.

Instead, larger farms realize lower labor costs because labor productivity (output of milk per hour of labor) is much higher, with the largest farms realizing 10 cwt per hour of labor, compared to 2-4 cwt per hour on farms with herds of 50-500 head (table 5). In turn, large farms operate differently than small dairy farms, as their size allows them to apply practices and technologies in ways that allow them to realize higher milk yields and labor productivity.

Average milk yields are higher among farms with at least 500 cows than at smaller farms (table 6). Average yields vary with milking frequency, among other factors, and farms with at least 500 cows are much more likely to milk three times a day, while smaller farms typically milk twice a day (table 6). In the ARMS COP dataset, farms that milk three times a day realized average yields of 233 cwt per cow in 2010, compared to 172 cwt on farms that milked twice a day.[17]

Milking frequency affects labor use and capital equipment. Farms that use hired labor for milking crews are able to offer their workers more hours if they are milking three times a day, an opportunity that is attractive to many hired workers, and the farms can then make more intensive use of their milking equipment (thereby reducing capital cost per cwt of milk). As a result, larger herds allow farm operators to reach a threshold where they can offer enough milking hours to hire milking crews, and incremental additions to those crews allow them to increase milking frequency, thereby raising milk yields and reducing labor and capital costs per cwt of milk. Higher milking frequencies do come at a cost, as larger farms also replace their cows at a higher rate than smaller farms (table 6). Higher mortality and cull rates indicate that larger farms wear out their livestock capital more rapidly, and this imposes a higher cost on larger farms.

Larger farms use different sets of production practices and technologies. Almost all farms purchase some feed, and almost all small farms grow at least some feed, but about 20 percent of large farms purchase all of their feed (table 7). In 2010, operations that purchased all feed accounted for 13

Table 6
Milk yields and herd turnover by herd size, 2010

	Herd size (number of cows)						
	<50	50-99	100-199	200-499	500-999	1,000-1,999	>1,999
	Cwt per cow						
Milk yield	156	175	192	199	226	245	228
Milking frequency	*Percent of farms*						
Twice a day	97	97	91	68	37	41	47
Three a day	2	3	9	31	61	57	53
	Percent of herd						
Mortality rate	6.5	6.1	6.1	6.8	6.1	6.6	6.9
Cull rate	21.4	20.4	21.6	22.0	25.6	26.3	26.5
	Months						
Average herd age	54	53	50	50	49	49	49

Notes: The mortality rate is the number of milk cows that died, divided by the farm's average milk cow herd size during the year, while the cull rate is the number of milk cows that were sold, divided by the average herd size.

Source: USDA, 2010 Agricultural Resource Management Survey, version 4. Organic farms excluded.

[17]Milk yields also vary with climate, with lower yields in very hot climates. Some of the largest dairy farms are located in States, such as Arizona and Florida, that face considerable heat stress on the cows and higher costs of milk production.

Table 7
Technology use and practices, by herd size, 2010

	Herd size (number of cows)						
	<50	50-99	100-199	200-499	500-999	1,000-1,999	>1,999
	Percent of farms using practice						
Practices							
Artificial insemination	75	86	82	80	93	94	99
Routine vet service	43	71	83	89	93	96	96
Nutritionist service	59	76	85	87	92	92	95
All feed purchased	2	2	1	5	8	20	21
Most feed purchased	36	36	41	54	80	78	95
Heifers off-farm	1	5	5	10	26	30	31
Forward contract inputs	7	18	31	49	64	68	69
Negotiate for inputs	17	36	44	63	85	80	93
Computers							
For feed delivery	1	5	14	16	40	44	69
For milking	1	4	7	24	31	30	33

Notes: Most feed is purchased if more than 50 percent of the farm's feed cost is for purchased feed. "Heifers off-farm" means that replacement heifers are raised off the farm (usually by a contract heifer operation).

Source: USDA, 2010 Agricultural Resource Management Survey, version 4. Organic farms excluded.

percent of U.S. milk production, and purchased feed accounted for 60 percent of aggregate feed costs. As production has shifted to larger operations, the market for purchased feed has expanded, and changes in feed price have had a more immediate impact on farm finances.

Farms heavily reliant on purchased feed will be attuned to feed prices and to acquisition strategies. Larger operations were considerably more likely to use forward contracts for the purchase of inputs to ensure supplies, lock in prices perceived as favorable, and manage input price risks (table 7). They were also much more likely to negotiate directly with input dealers over prices and terms of delivery.

Larger farms are more likely to raise some or all of their heifers off the farm; to use professional veterinarian and nutritionist services on a routine basis; and to use computerized feed delivery and milking systems. The cost of professional services and computerized systems increases with herd size, but less than proportionately, so that the cost per cwt falls as herd size gets larger. Professional services and computerized systems add value by helping to reduce labor and feed costs per cwt of production, and thereby provide further advantages to larger operations.[18]

Variation in financial performance and farm survival

The size-cost relationship in dairy farming is large and persistent. Analyses of COP data for earlier baseline years (2000 and 2005) found substantial cost advantages to size (Mosheim and Lovell, 2009; Mayen et al., 2010; Key and Sneeringer, 2014).

These are mean values of costs and net returns, averaged for each size class. Actual values can differ; some large farms incur economic losses, while some smaller farms generate economic profits. In 2010, 82 percent of farms with at least 2,000 milk cows generated positive net returns (so that

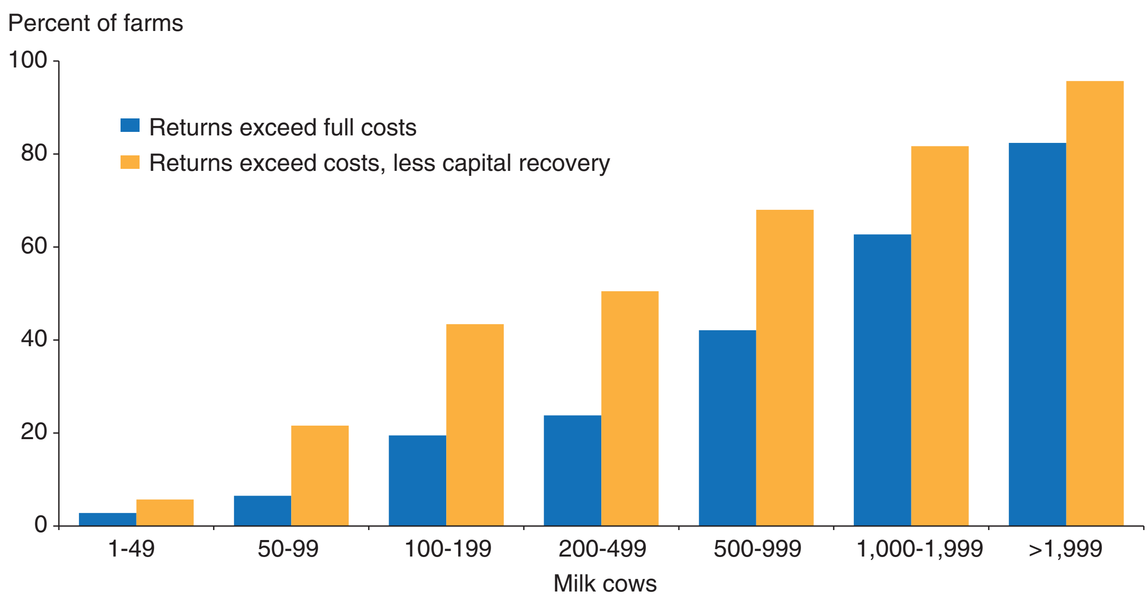
[18]Reports from USDA's National Animal Health Monitoring Survey (NAHMS) provide further detail on dairy cattle health and herd management practices. See, for example, USDA (2007).

nearly 18 percent generated losses). Just over 60 percent of farms with 1,000-1,999 head generated positive returns (fig. 3). Among farms in midsize classes, returns were mostly negative, on average, but 20 percent of farms with 100-199 head and 25 percent of farms with 200-499 head realized positive economic returns.

Why do farms continue to operate if they persistently fail to cover total costs? A farm may operate economically as long as gross returns cover some, but not all, costs. Specifically, total costs include an annualized value of capital recovery costs for structures, equipment, vehicles, land, and animals. As long as gross returns cover cash expenses and provide a return to the farm family's labor, a farmer may be better off operating the farm than shutting down, and many farms that do not cover total costs nevertheless cover all costs except for capital recovery costs (fig. 3).[19] Such farms can be operated for a long time, until cash expenses—including those associated with maintaining aging structures and equipment—exceed gross returns. Other farms may not cover noncapital costs, and they will generate net incomes that are less than what the family could earn working off the farm. Some may accept those earnings and persist, but many will eventually leave dairy production. In either case, adjustment is likely to be gradual, and occur over years.

Herd size is far from the only factor that affects farm financial performance—there were profitable farms in all size categories in 2010. Some smaller dairy farms have found profitable niches through value-added activities like artisanal cheese production, agro-tourism, or the breeding and sale of high-quality calves. Some are also adopting innovations, like robotic milking machines, that can reduce the labor required for milking by operators on small and midsize farms. But the cost advantages of size remain substantial, and production is likely to continue to shift to very

Figure 3
Incidence of profits among dairy farms, 2010



Source: USDA, Economic Research Service milk cost of production estimates, based on 2010 Agricultural Resource Management Survey, version 4.

[19]For example, while only 20 percent of farms with 100-199 cows covered all economic costs in 2010, 43 percent covered all costs except for capital recovery (figure 3).

large dairy farms as operators of unprofitable—often small and midsize—farms retire or leave dairy farming for other occupations.

How structural change affects costs and prices

If average costs are lower in larger herd size classes, shifts of production to larger classes should lower average industry costs. To see how significant this might be, consider recent changes in the size distribution of production. We use these data to estimate the effect of changes in the size distribution—to larger and lower cost farms—on average milk costs of production for the industry.

In 2010, the average total cost of production ranged from $39.11 per cwt in the smallest size class to $13.80 in the largest (table 8). The industrywide average total cost of production was $19.85, when averaged across classes with weights reflecting the 2010 distribution of production. However, suppose that average costs within each size class remained the same, but that production was more concentrated in smaller size classes—specifically, suppose that the size distribution was that of 1998 (the earliest year in which NASS published estimates of production by size class). In that case, the industry average total cost of production would have been $24.00. Production has continued to shift to larger farms after 2010: with the 2012 size distribution, the estimated industry average COP would fall still further, to $19.52 per cwt. By this calculation, industry-average costs in 2012 were 18.7 percent lower than they would have been without the structural change that occurred over the previous 14 years. This is a substantial impact.

Over time, as farms expand and realize lower costs, they also expand industry production. Increases in production reduce real (inflation-adjusted) product prices, and ultimately reduce farm milk prices. In short, shifts in industry structure that reduce average industry costs will place downward pressure on real prices for farm milk. With lower farm milk prices, higher cost producers will come under increased financial pressure, and some will close, continuing the process of structural change. With lower real product prices, buyers find more uses for U.S. milk products, either in domestic or foreign markets, and those new markets become important considerations for producers. Thus farm costs, prices, and markets are linked.

Table 8
Effects of structural change on industry average cost by herd size, 2010

Herd size (milk cows)	Average cost, 2010	Shares of production (%)		
		1998	2010	2012
<50	$39.11	10.5	4.6	4.2
50-99	$30.24	20.9	10.4	9.5
100-199	$24.25	17.9	11.3	10.7
200-499	$22.00	16.9	12.7	12.6
500-999	$18.09	12.6	13.0	12.4
1,000-1,999	$16.37	11.9	15.5	15.9
>1,999	$13.80	9.3	32.5	34.7
Industry average cost		**$24.00**	**$19.85**	**$19.52**

Sources: Average costs by size class: ERS estimates derived from USDA, 2010 Agricultural Resource Management Survey, version 4. Production shares: USDA National Agricultural Statistics Service, *Milk Production*, February 2000 (1998 data), and *Farms, Land in Farms, and Livestock Operations* (2010 and 2012 data).

Changes in Domestic and International Dairy Product Markets

Farm milk is used in many products, from fairly standardized goods like fluid milk, butter, or milk powders, to highly differentiated consumer products like specialty cheeses and fermented drinks, and ingredients like milk protein concentrates used in food and beverage products (Blayney et al., 2006). Some—such as milk, yogurt, and ice cream—are consumed directly and others indirectly in products such as pizza, baked goods, and snacks.

Changes in consumer preferences, some spurred by product innovations, have led to changes in the mix of dairy products consumed domestically. However, the United States has also become a substantial commercial exporter of dairy products, following improved international competitiveness of the U.S. industry, growing global demand for dairy products, and changes in trade and dairy policies.

Domestic dairy consumption

Fifty years ago, nearly half of U.S. milk production was consumed as fluid (beverage) milk. U.S. consumers have shifted away from fluid milk to dairy products like cheeses and yogurt, and to bakery and snack products that use milk. When they do drink fluid milk, they tend to consume different products than 30 and 40 years ago.

Fluid milk consumption, on a per capita basis, has been gradually declining for many years, and by 2014 was about 35 percent lower than it had been in 1975 (fig. 4).[20] Continuing U.S. population growth—about 1 percent per year—combined with per capita declines in consumption kept total fluid milk consumption steady at 53-55 billion pounds from 1975 until 2010; however, total fluid consumption has fallen steadily since then, to 51 billion pounds in 2014 (fig. 5).

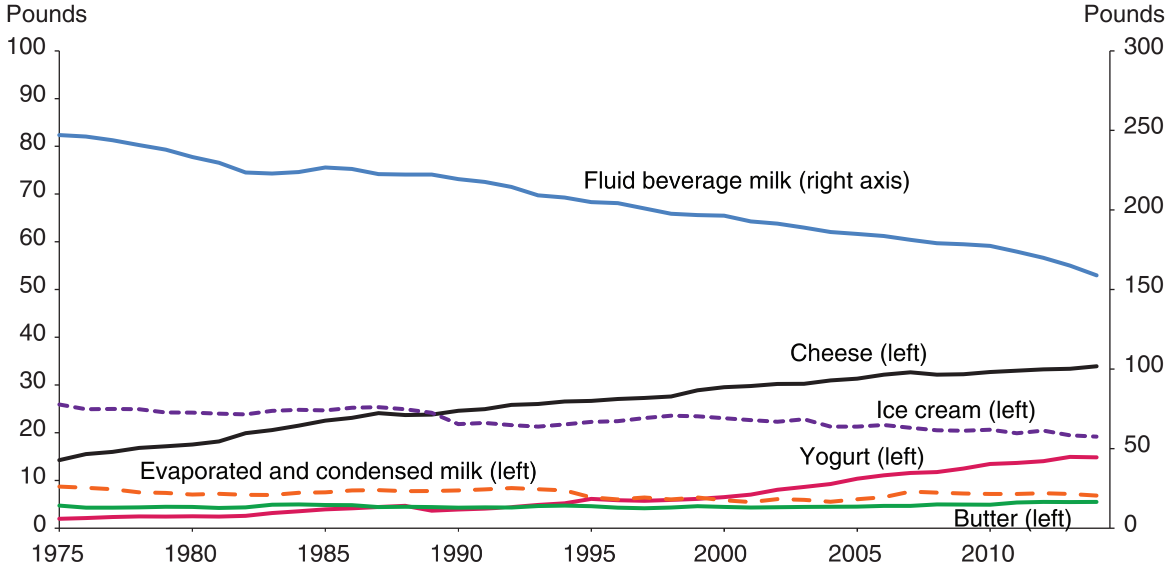
Today's consumers are more likely to seek out lower fat fluid milk products. In 1975, whole milk accounted for 68 percent of all total fluid milk consumed, but whole milk consumption fell by 2.5 percent per year over 1975-2014, while consumption of 2-percent, 1-percent, and skim milk expanded (figure 5). Consumption of flavored whole milks has declined over time, but consumption of all flavored milks, including low-fat products, more than doubled between 1975 and 2014, when it amounted to 9 percent of total fluid consumption.

Many innovative new fluid products—like low-lactose, high protein, and organic milk, for which we have more limited data—have been introduced. Organic accounted for 5 percent of retail fluid milk sales by volume in 2014, according to statistics from USDA's Agricultural Marketing Service (AMS), up from 2 percent in 2006.

In contrast to the decline in per capita fluid milk consumption, per capita consumption of manufactured dairy products has grown since 1975 (figure 4). Per capita cheese consumption has more than doubled, yogurt increased more than sevenfold, and butter consumption has also grown as consumers and processors have shifted away from trans-fat oils.

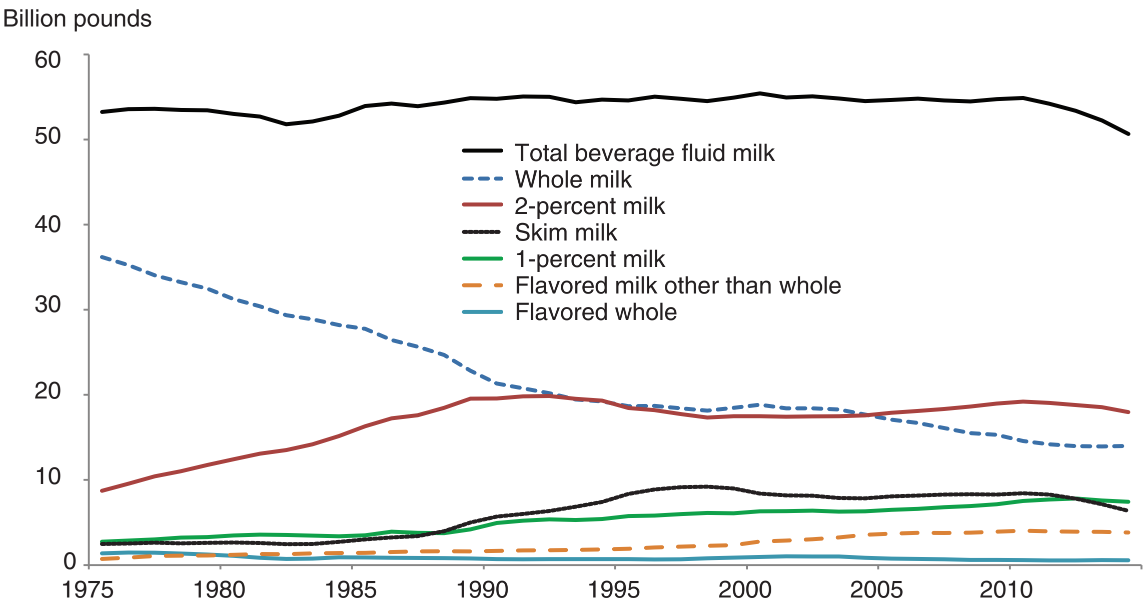
[20]Fluid milk is primarily water, while moisture is removed from manufactured products; hence, the weights of fluid milk and manufactured dairy products are not directly comparable in terms of farm milk requirements and are reported on different axes in figure 4.

Figure 4
Annual U.S. per capita consumption of dairy products



Source: USDA, Economic Research Service calculations based on data from USDA, Agricultural Marketing Service and selected State Departments of Agriculture.

Figure 5
Total U.S. fluid milk consumption, 1975-2014



Source: USDA, Economic Research Service calculations based on data from USDA, Agricultural Marketing Service and selected State Departments of Agriculture.

U.S. exports of dairy products

International dairy trade occurs primarily in manufactured products—butter, cheese, dry whey products, and dry milk powders—which can be stored and shipped long distances at modest transportation costs. The United States has not historically been a major dairy exporter, and before 2003, U.S. exports were often subsidized. However, the pattern has changed: the total value of U.S. dairy exports rose from $1.0 billion in 2003 to $7.2 billion in 2014. The growth reflects a rapid expansion of U.S. commercial exports, while subsidized exports declined and then disappeared as the DEIP was eliminated in 2014.[21]

The United States has become a leading exporter of nonfat dry milk (NDM) and skim milk powder (SMP). U.S. commercial exports of NDM and SMP combined were negligible until 2004, when they expanded to 262 million pounds; thereafter, NDM and SMP exports continued to grow rapidly—by 18.7 percent per year—peaking at 1,224 million pounds before declining to 1,182 million pounds in 2014.

U.S. butter exports grew significantly over the same period. While butter export volumes fluctuate widely from year to year, they averaged 101 million pounds annually over 2006-2013, compared to 1 million pounds per year in 1997-2003. Commercial exports of cheese have also grown considerably, reaching 812 million pounds in 2014, up from 51 million pounds in 1995. Growth has accelerated, from 9.6 percent annual growth in 1995-2005 to 25 percent annually over 2005-14.

Export volumes are quite sensitive to prices, and U.S. commercial dairy exports have boomed as U.S. dairy prices became more competitive with international prices. Consider the relationship between prices and annual U.S. exports of NDM and SMP (fig. 6). New Zealand and Australia—collectively, Oceania—have historically been the low-cost global producers of dairy products, and they are major exporters. U.S. domestic prices for NDM remained above Oceania SMP export prices, often by 40-60 percent, until 2003. U.S. commercial exports were negligible during that time, and most U.S. exports were subsidized. After U.S. and Oceania prices converged in 2003, U.S. commercial exports expanded during 2004-2013 when U.S. domestic prices were generally 10-20 percent below Oceania export prices. In 2014, as U.S. domestic prices rose above the Oceania price, U.S. commercial exports declined from the previous year but remained high.[22]

The inference—that trade is sensitive to relative prices—is supported by estimates derived from a Quarterly Dairy Forecasting model developed by ERS (see appendix B). In table 9, we report estimated price elasticities for U.S. dairy exports and imports from that model. Trade volumes respond to changes in relative prices: increases in U.S. prices—relative to international prices—are associated with increased dairy product imports and reduced exports.

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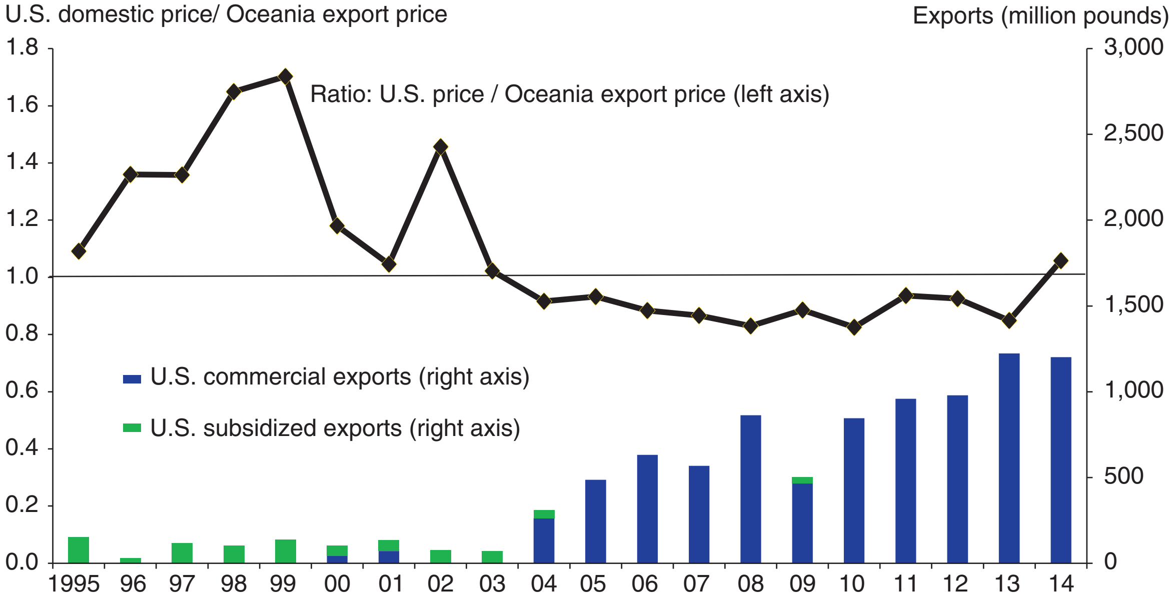
[21]Commercial exports exclude U.S. Government donations to foreign countries, as well as exports subsidized via DEIP.

[22]We use domestic prices for the U.S. and export prices for Oceania because those are the best available price series. Although the U.S. nonfat dry milk prices and foreign export prices for skim milk powder are comparable, there are some significant differences in how they are collected and reported. The products are slightly different since the U.S. price is for nonfat dry milk but the foreign export prices are for skim milk powder. The U.S. price is reported through a mandatory program, while foreign prices are reported voluntarily. While the U.S. price is a domestic price reported f.o.b. plant or storage facility, the foreign export prices are free-on-board port of the exporting country. The U.S. domestic prices are weighted-average prices from a comprehensive survey, including only prices for products shipped within 30 days of the contract, and recorded at the time of shipment and transfer of title. The foreign export prices in our figures are the midpoints of reported price ranges (not averages), including products under forward contract, and are recorded at the time of contract.

Figure 6
U.S. skim milk powder exports and the U.S./Oceania price ratio



Source: USDA, Agricultural Marketing Service, U.S. Bureau of the Census, U.S. Foreign Agricultural Service.

Table 9
U.S. dairy export and import price elasticities

Product	Prices used	Price elasticities: Short-run	Price elasticities: Long-run
Fat basis m.e., exports	Butter	-0.40	-1.31
Fat basis m.e., imports	Butter	+0.15	+0.23
Skim-solids basis m.e, exports	Nonfat dry milk	-0.16	-1.96
Skim-solids basis m.e, imports	Nonfat dry milk	+0.52	+3.68

Note: Elasticities are the percent change in the quantity of exports or imports associated with a 1-percent increase in price. Thus, U.S. fat exports are estimated to fall by 0.4 percent, in the short run, for each 1-percent increase in the U.S. price, while U.S. fat imports are estimated to rise by 0.15 percent. m.e. = milk equivalent.

Source: Mosheim (2012), updated (see appendix B).

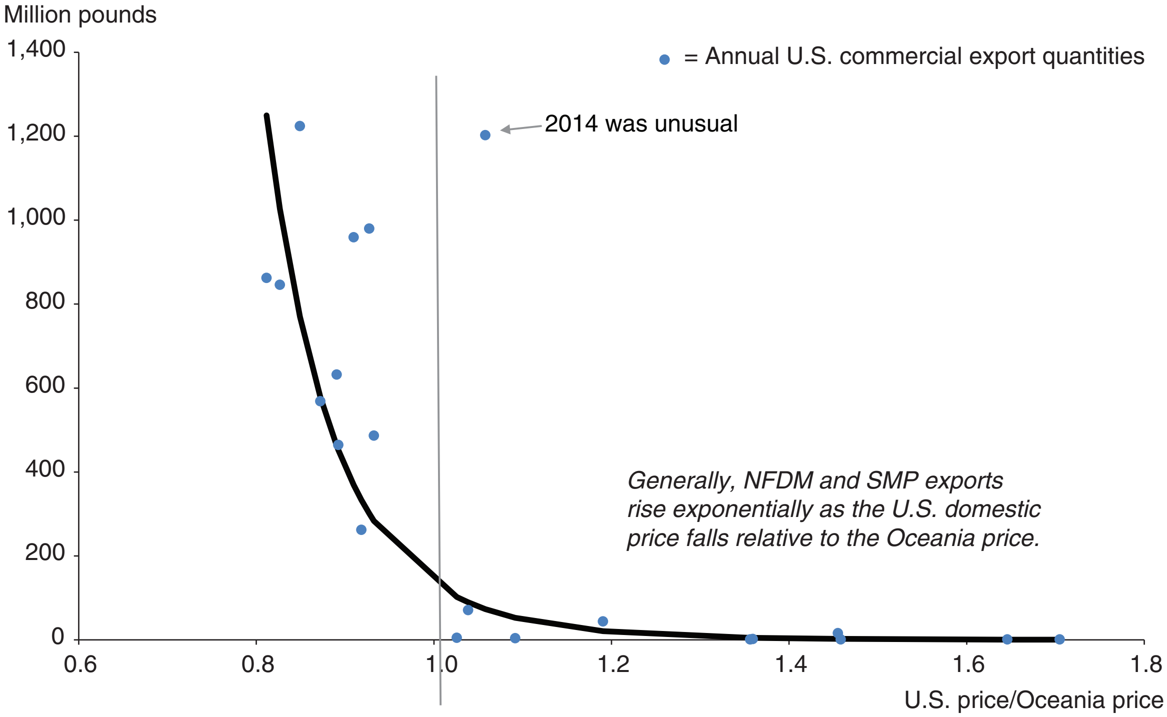
The effects are modest in the short run—in the quarter after that in which the price increases are realized.[23] However, the full response to a price change often plays out over an extended period of time, as it takes time to renegotiate contracts and assemble and ship products. Over the long run, trade flows are more responsive to relative prices. The model estimates indicate that U.S. exports, measured on a milk-fat basis, increase by 1.31 percent for every 1-percent decline in U.S. prices relative to competitor country prices, while exports measured on a skim solids basis increase by 1.96 percent.

The relationship between relative prices and commercial exports can be complex: see figure 7, which displays a scatter-plot of annual data covering 1995-2014, comparing relative U.S./Oceania prices to

[23]For example, exports of dairy fats (such as butter) fall by 0.40 percent for a 1-percent increase in relative prices, while imports rise by 0.15 percent Most of the longrun response occurs over 4 quarters.

Figure 7

Commercial nonfat dry mik (NDM) and skim milk powder (SMP) exports rise sharply as U.S. prices fall to and below Oceania prices



Source: U.S. Census Bureau, USDA, Agricultural Marketing Service, USDA, Agricultural Statistics Service, and USDA, Economic Research Service.

U.S. commercial export volumes of SMP and NDM. U.S. commercial exports are much higher when U.S. domestic prices fall below Oceania export prices (that is, when the relative price is less than 1). However, the relationship is not linear; a curve that is fit to the data points traces out an exponential relationship. When U.S. prices have been high, at 1.4 to 1.7 times the Oceania price, U.S. exports have generally been quite low, and declines in U.S. prices generate increases in exports that, while large in percentage terms, constitute modest volumes. However, once U.S. and Oceania prices are close to one another, U.S. export volumes rise sharply in response to U.S. price declines.[24]

Based on historical data, U.S. commercial exports in 2014 were unusual in that they remained high even though the U.S. domestic price was slightly higher than the Oceania export price. Since proprietary transactional data are not available to us, it is difficult to determine exactly why the relationship between prices and the export quantity changed in 2014. There are at least two possible factors. U.S. exports were forward contracted in 2013 when the U.S. domestic price was low relative to the Oceania export price. Exports under contract were then delivered in subsequent months of 2014. Alternatively, when exports were expanding during 2003-14, U.S. exporters established favorable

[24]The fitted curve is an exponential function in which the longrun price elasticity of U.S. exports with respect to relative U.S/Oceania prices, when those prices start from equality, is about -9.0 (note that this elasticity measures responsiveness to relative prices, whereas the ERS model noted in the text measured responsiveness to U.S. prices alone). Thus, this simple scatter-plot of annual data suggests that exports might be highly sensitive to relative price changes when prices have converged close to one another.

relationships with foreign importers, which allowed them to continue doing business with foreign importers even after U.S. prices rose.

Figures 6 and 7 focus on NDM and SMP trade. U.S. commercial dairy export volumes generally follow similar patterns with respect to U.S., Oceania, and European prices. Export volumes have expanded and are quite sensitive to changes in relative prices once those prices are in proximity to one another.

Production costs, foreign demand growth, and expanding commercial exports

Product prices matter for dairy exports and imports. In turn, prices have in part been driven by developments in dairy production costs. Continued productivity growth in U.S. dairy farming reduced the real (inflation-adjusted) costs of milk production and exerted downward pressure on real costs and prices for dairy products. Some of the sector's productivity growth reflected steady improvements in milk yields, equipment, and practices for all farms, but some reflected shifts of production to larger, lower cost operations. In recent years, Oceania dairy producers have faced rising production and land costs, especially through the effects of drought on feed costs and milk production. Each force helped drive convergence in prices and expanded U.S. exports.

Increased dairy product demand in developing countries, particularly in Mexico and China, has also played a major role in the expansion of U.S. dairy exports; those to Mexico rose from $259 million in 2003 to $1.65 billion in 2014, while dairy exports to China reached $693 million in 2014, 18 times greater than the value in 2003.

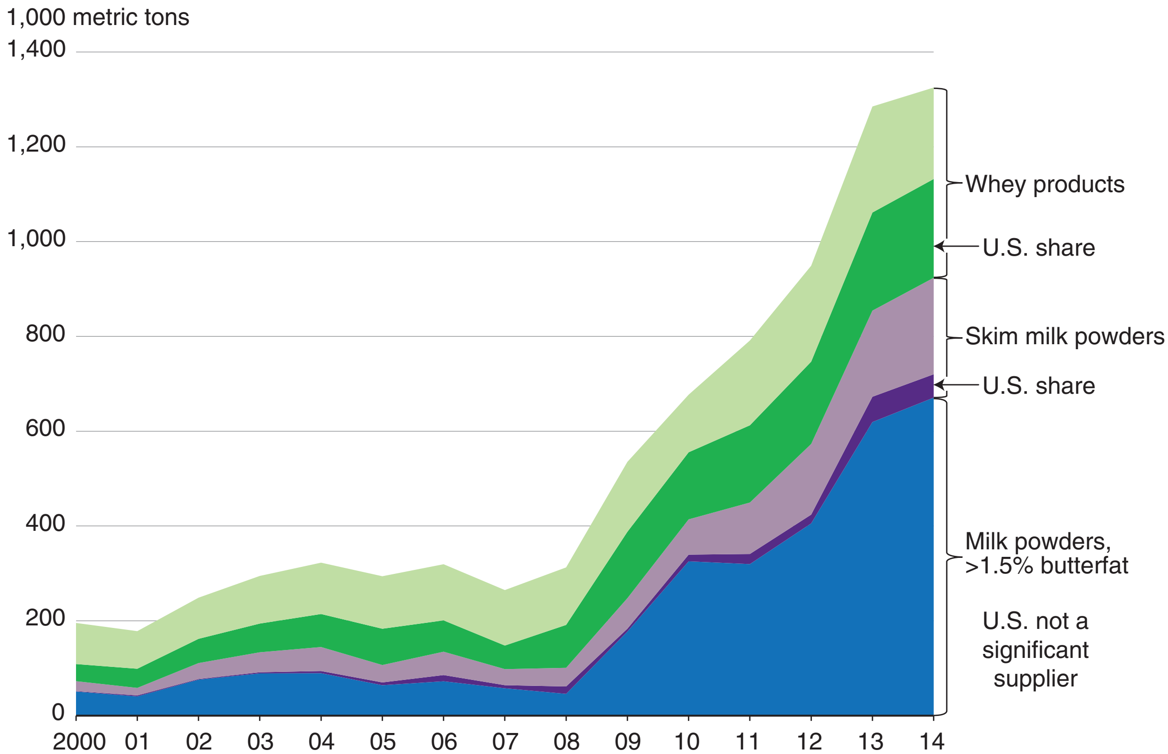
Increasing demand in China for imported dairy products has become a major driver in global markets. The largest increase in Chinese imports has been milk powders with greater than 1.5-percent butterfat, which includes whole milk powder. New Zealand has been the primary supplier of whole milk powder to China, while the United States has been a significant supplier of skim milk powders and whey products (figure 8). In 2014, the United States supplied about 19 percent of China's imports of skim milk powder and about 52 percent of its imports of whey products. Most milk powders are further processed for infant formulas, ultra-high temperature (UHT) milk, yogurt, milk-based beverages, and food processing. About half of the imported whey products are used for animal feed, with the rest mainly used for processed foods and infant formula (U.S. Department of Agriculture, 2013).

U.S. NDM exports to Mexico increased eightfold from 2003 to 2014, while cheese exports increased ninefold over the same period. NDM is mainly used by processors who reconstitute it and sell it as pasteurized or UHT milk or for the preparation of other dairy products, such as yogurt or probiotic beverages. Higher income consumer demand has also increased demand for aged cheese, while lower income consumers have maintained demand for fresh cheese.

The North American Free Trade Agreement (NAFTA), implemented at the beginning of 1994, played a key role in increased exports to Mexico.[25] Restrictions on some U.S. exports to Mexico were eliminated immediately upon NAFTA's implementation while others were phased out over periods of 4, 9, or 14 years. For dairy products, the last tariffs to be eliminated, at the beginning of 2008, were for NDM.

[25]NAFTA's trade liberalization provisions exempted dairy trade with Canada.

Figure 8
China imports of milk powders and whey products



Source: Global Trade Atlas.

Dairy policies and dairy trade

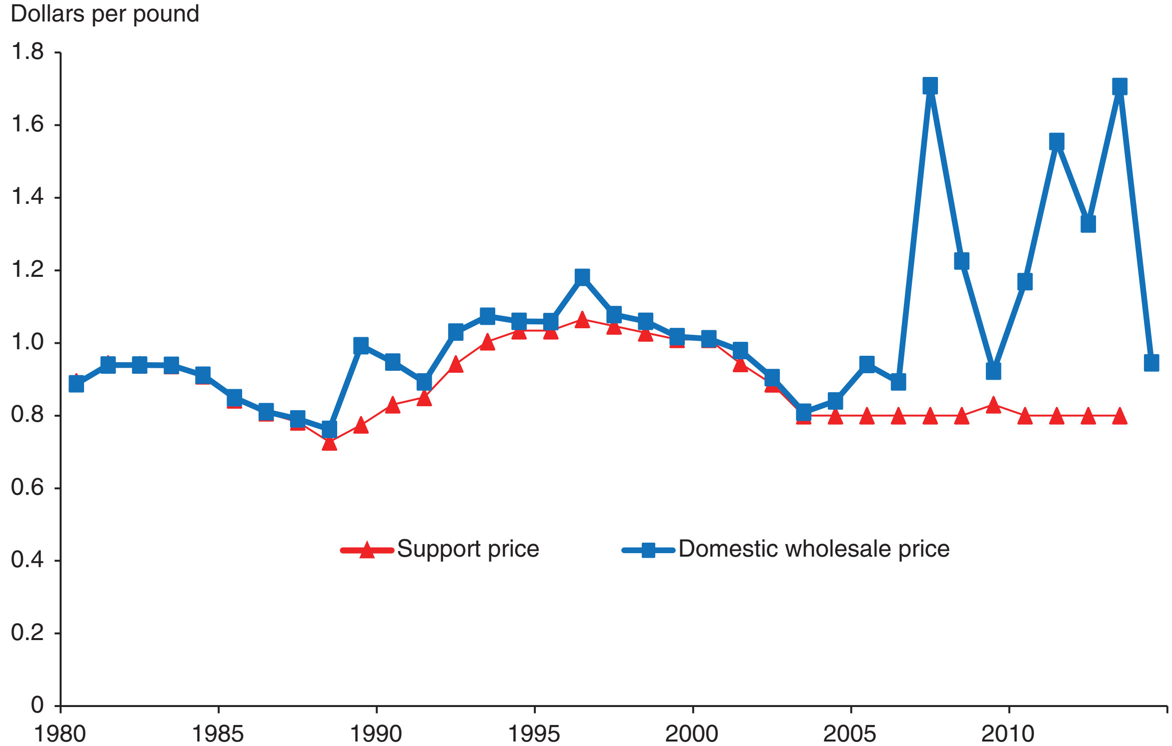
At the 1994 conclusion of the Uruguay round of Multilateral Trade Negotiations, countries who agreed to participate in the World Trade Organization (WTO) also agreed to constrain trade-distorting policies. Because many countries provided significant domestic support to their dairy sectors while also imposing restrictive trade policies, the agreements placed pressure on countries to initiate a series of policy adjustments, extending over years. In particular, gradual changes in U.S. and European Union (EU) dairy policies have helped drive the expansion of U.S. exports and the convergence of global dairy product prices.

To the extent that U.S. price support programs were effective in setting a price floor for dairy products, they could also make U.S. commercial exports less competitive.[26] As price supports became less relevant, commercial exports became more competitive.

Consider the experience with NDM. During the 1980s, U.S. market prices coincided with and were held up by milk support prices (figure 9). After USDA outlays on the program increased sharply in the early 1980s, support prices were reduced in subsequent farm bills and began to lose relevance. From 1988 through 2003, support prices set a floor below which market prices could not fall, but market prices were almost always well above the floor set by support prices. After 2003, market

[26] Noncommercial exports could be made from CCC stocks, sometimes at prices below global prices, and the Government could subsidize export sales by private firms through the DEIP.

Figure 9
U.S. support and wholesale prices for nonfat dry milk



Source: USDA, National Agricultural Statistics Service; USDA, Farm Service Agency; and USDA, Agricultural Marketing Service.

prices, while fluctuating widely, were mostly independent of support prices, and NDM domestic market prices more closely aligned with foreign export prices (figure 6). Support price purchases fell substantially, with the last purchases being made in 2009. The commercial export market became the destination for products that previously would have been purchased by the CCC or subsidized through the DEIP.

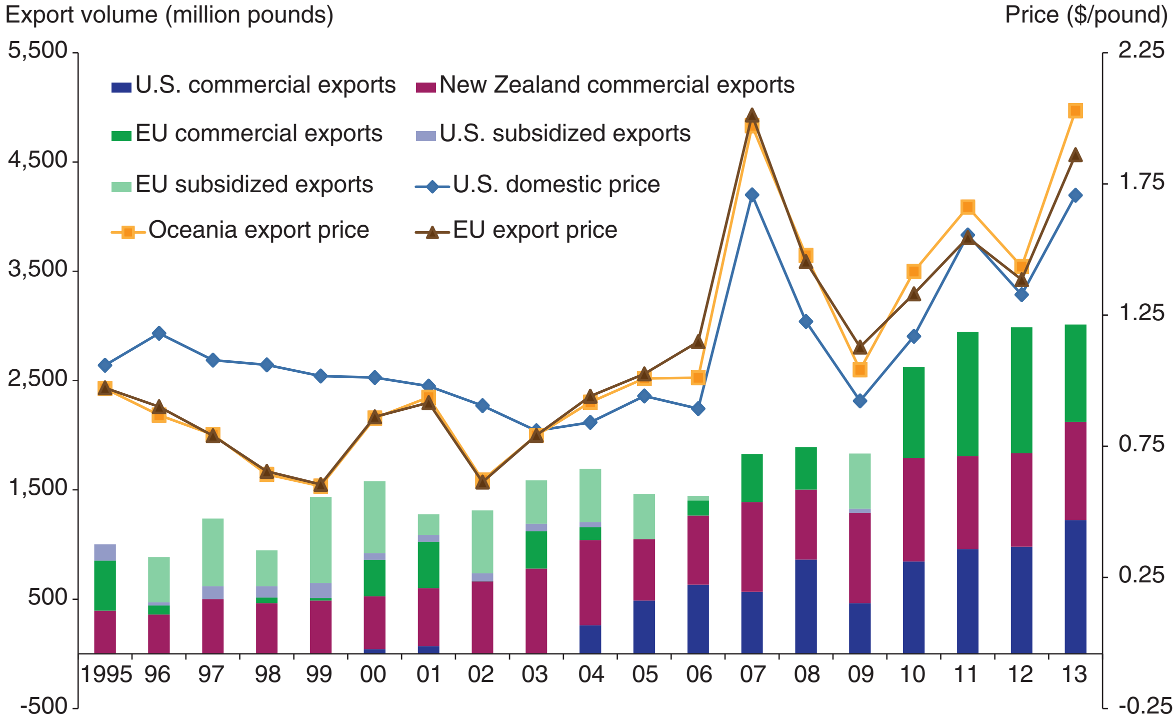
Changes in EU dairy policies have had major effects on world dairy markets. Among other programs, the EU supported its dairy market through an intervention program (similar to the U.S. price-support program) and an export restitution program (similar to the U.S. DEIP program). Traditionally, EU dairy export subsidies had a strong influence on world prices.

These subsidies allowed exports at prices substantially below EU domestic market prices, and EU export prices were the prevailing world prices prior to the mid-2000s. In 2003, EU reform of its Common Agricultural Policy (CAP) altered the landscape for dairy trade by reducing dairy export subsidies. Figure 10 illustrates SMP prices, commercial exports, and export subsidies as an example. From 1996 through 2005, EU-subsidized exports generally exceeded EU commercial exports. After that, U.S., Oceania, and EU prices converged and have generally moved together, and EU and U.S. commercial exports have grown sharply as the EU and the United States curtailed price supports and export subsidies.

Policy also affects U.S. imports, which have grown in value in recent years, but more slowly than U.S. exports—from $2.0 billion in 2003 to $3.5 billion in 2014. Over that time, the United States

Figure 10

Export subsidy reductions for nonfat dry milk and skim milk powder contributed to growth in commercial exports and price convergence



Sources: USDA, Foreign Agricultural Service, USDA, Farm Service Agency, USDA, National Agricultural Statistics Service, and U.S. Census Bureau.

has gone from being a net importer to a net exporter of dairy products. U.S. imports are constrained by tariff-rate quotas (TRQs), two-tiered tariffs with a tariff rate that varies with import volume. A lower (in-quota) tariff is charged on imports within the specified quota volume, while a higher (over-quota) tariff is charged on imports in excess of the quota.[27] The in-quota TRQ volumes were gradually raised from 1995 through 2000, contributing to expanded trade, but relatively high over-quota tariffs remain in place for many dairy commodities.

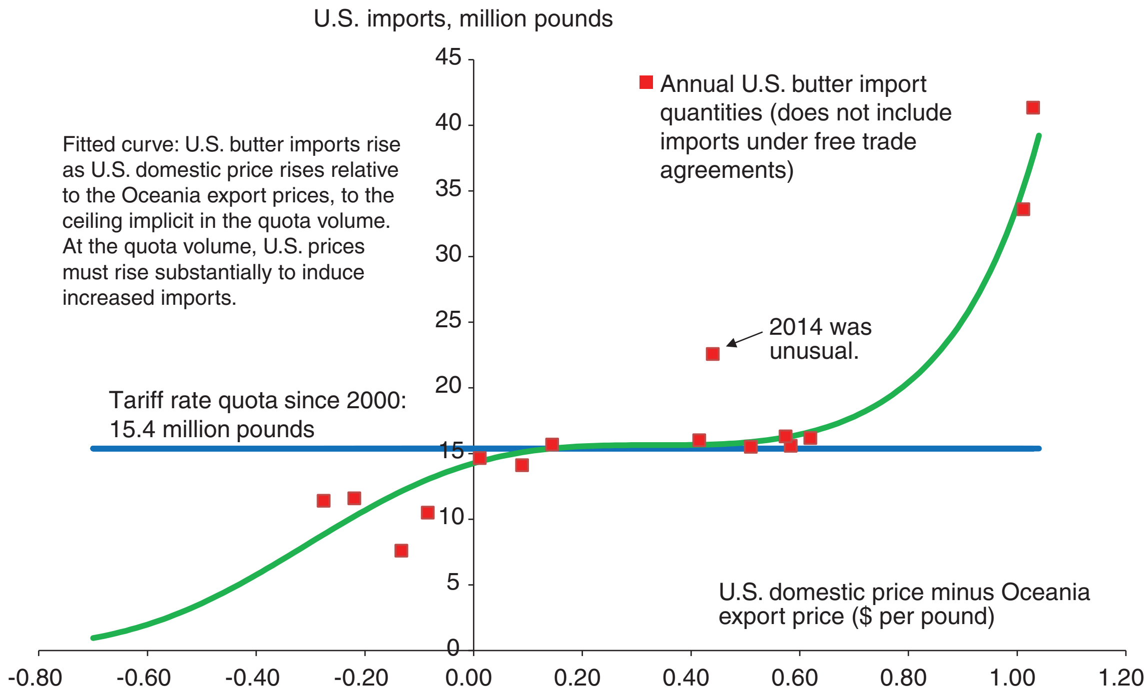
The market for U.S. butter imports provides a clear example (fig. 11). As the U.S. wholesale butter price rises from a low level relative to the Oceania export price, imports rise until they reach about the TRQ level for butter. With a $0.70-per-pound tariff for imports above the TRQ level of 15.4 million pounds, the U.S. price must rise substantially more to attract additional imports above the quota.[28]

[27]TRQs have been set in accordance with Uruguay Round agreements, under which nontariff barriers were converted to TRQs, allowing greater market access.

[28]U.S. butter imports in 2014 appear unusual in that there were substantial over-quota imports even though the average annual U.S. price did not exceed the Oceania price by more than the $0.70 over-quota tariff. However, monthly price variation is a consideration: the Oceania price, $2.04 per pound, substantially exceeded the U.S. price of $1.65 in January 2014. The U.S. domestic price then rose, reaching a high point of $2.85 per pound in September, while the Oceania price fell to $1.35. The wide gap over several months between the U.S. domestic price and the Oceania price likely contributed to butter imports at the over-quota rate.

Figure 11

U.S. butter imports as a function of the U.S. domestic price minus Oceania export price, 2000-2014



Sources: USDA, Foreign Agricultural Service and USDA, Agricultural Marketing Service.

TRQs interacted with the Dairy Product Price Support Program. Without TRQs, price supports would be less feasible since domestic prices in excess of world prices would attract increased flows of imports, driving domestic market prices below support-price levels and creating large inventories of Government stocks. TRQs restricted the flow of imports that would result from high support prices; with the elimination of the price support program, this particular justification for TRQs no longer exists.

The U.S. industry is now a more active participant in international dairy markets because of improved competitiveness, increased global dairy demand, trade agreements that reduced tariffs and other trade barriers, and changes in U.S. and EU dairy policy. Expanded dairy trade brings benefits to U.S. producers and consumers, but it also creates a new source of price volatility and a new set of financial risks for producers.

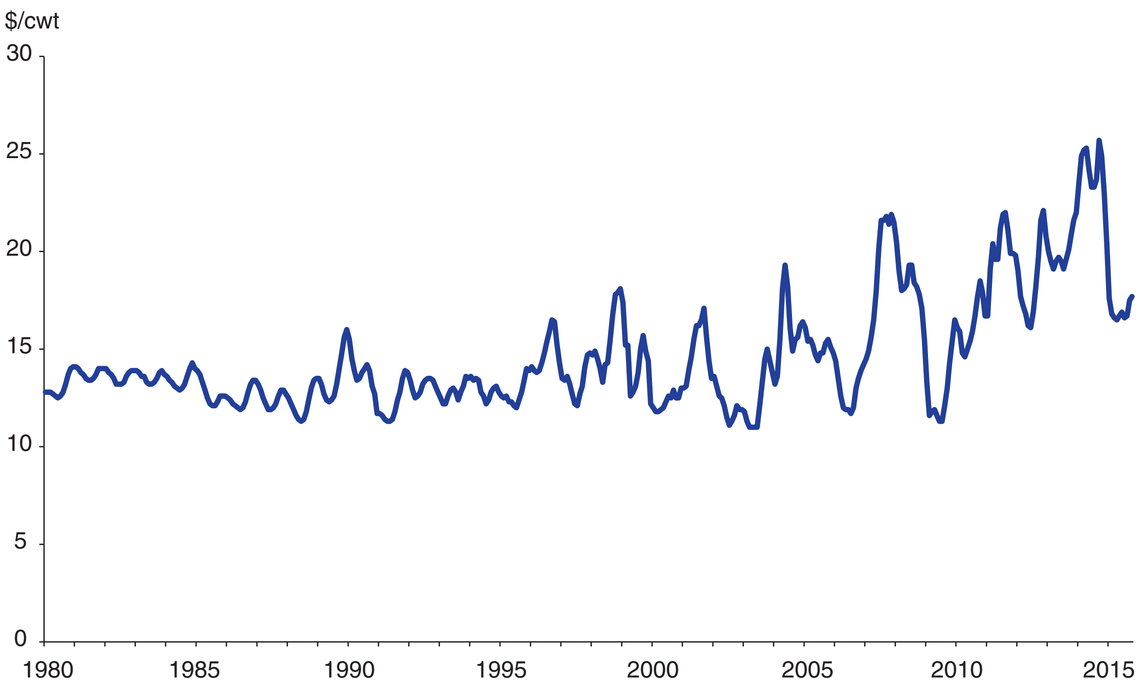
Financial Risks in Dairy Farming

Dairy farmers face significant financial risks. The prices that they receive for their milk and pay for their feed can fluctuate widely, along with their income from farming. Many large dairy farms rely heavily on debt to finance operations (Ifft et al., 2014) and, when margins are low, face the risk of not being able to meet loan obligations out of current operating income.

The volatility of milk prices (along with the associated financial risks) has increased (fig. 12).[29] As measured with the coefficient of variation (CV)—the ratio of the standard deviation of prices to the mean value—volatility for the monthly NASS all-milk price was 3 percent in 1980-84, before rising to 6-7 percent in 1985-89 and 1990-94. It rose again to 11 percent in 1995-99, 15 percent in 2000-04, and 20 percent in 2005-09, before falling back to 15 percent in 2010-14.

Feed prices, which were relatively stable for many years, began rising after 2005, with notably more volatility. Figure 13 shows monthly milk and feed prices over 2000-2015, using the NASS all-milk price and a feed price measure specified in the legislation establishing MPP-Dairy.[30] The mean milk

Figure 12
Monthly milk prices received by U.S. farmers, 1980-2015

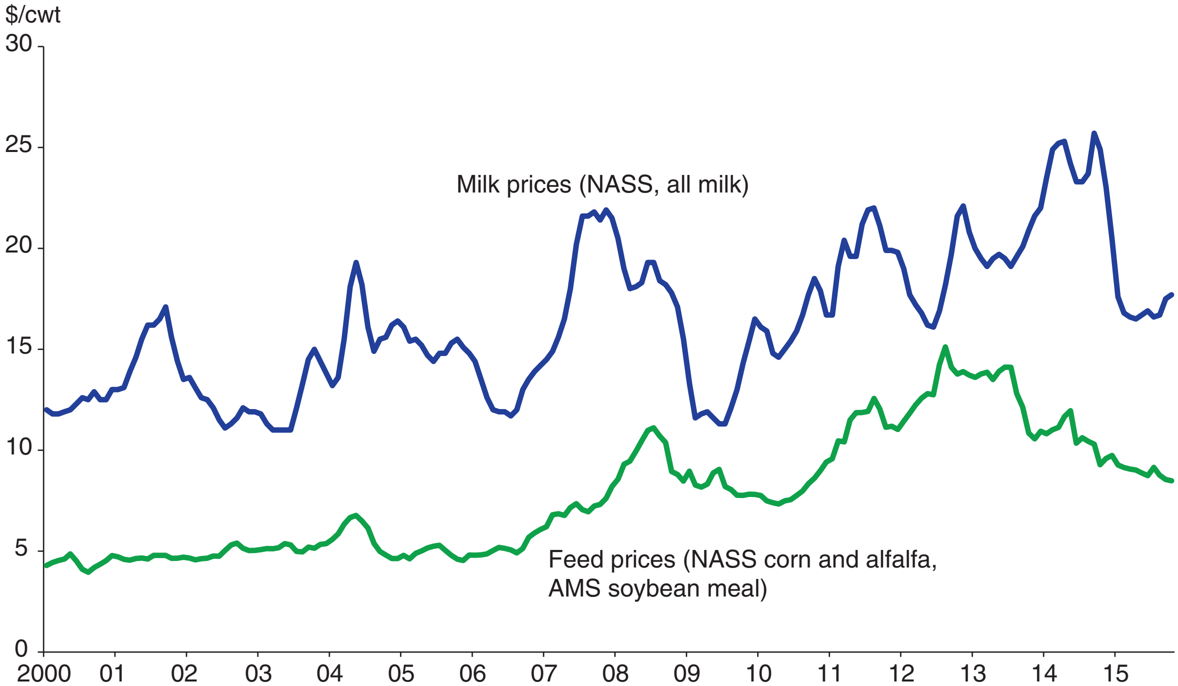


Source: USDA, National Agricultural Statistics Service, Quick Stats, all-milk price.

[29]The NASS all-milk price represents the average price received by farmers, prior to deductions for hauling, promotion, or cooperative dues but including any premiums or discounts. The pricing point is the plant or receiving station. It is a unit value—total payments to farmers, divided by total cwt of milk delivered.

[30]The feed price measure is Pf=1.0728*Pc + 0.0137*Pa + 0.00735 Ps; Pc and Pa are monthly corn and alfalfa prices (each reported in the USDA/NASS price-received series), while Ps is the price of soybean meal reported for central Illinois rail shipments by USDA/AMS. The prices are weighted to reflect the amount of each used to produce 100 pounds of milk.

Figure 13
Monthly milk prices and feed costs, 2000-2015



Source: USDA, National Agricultural Statistics Service (NASS) for milk, corn, and alfalfa prices; USDA, Agricultural Marketing Service (AMS) for soybean meal prices; and USDA, Farm Service Agency for feed price formula.

price during the period was $14.50 per cwt, but prices frequently rose and fell by $5, $6, or even $8 over 4- to 6-month periods. At the same time, feed prices rose sharply to new peaks in July 2008, August 2012, and May 2014.[31]

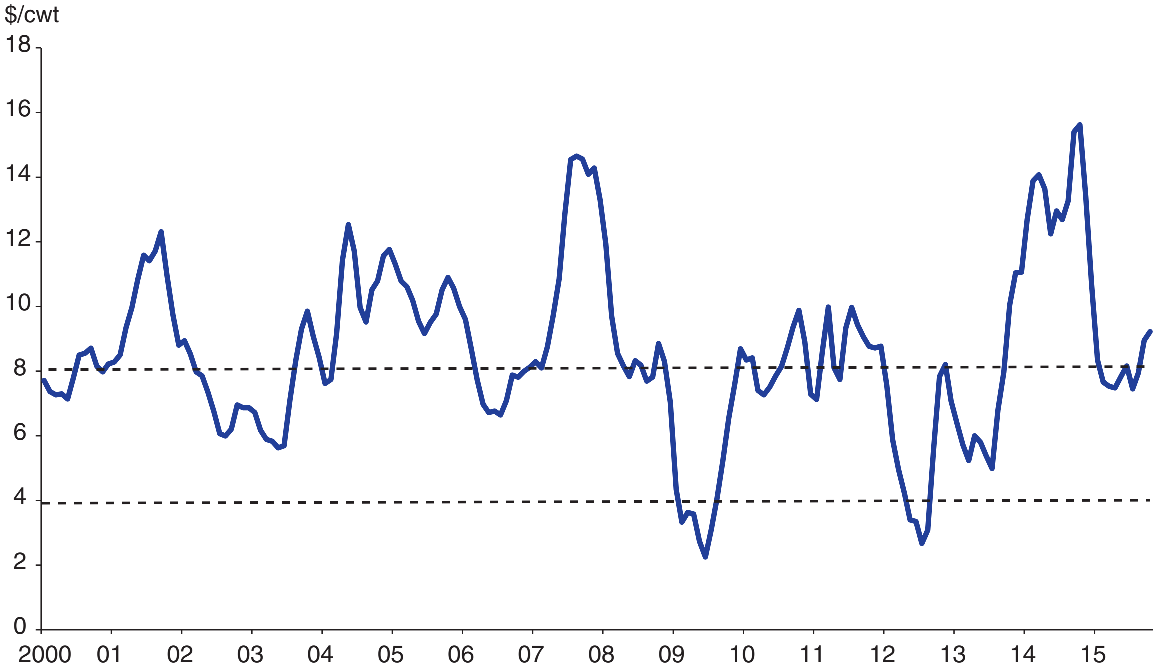
The gap between milk and feed prices clearly shows a sharp margin decline in the summer of 2009 and another, to under $4, in 2012 (fig. 14). This is a national-benchmark margin: the margins faced by specific farms can vary, sometimes substantially, depending on differences in prices paid for feed and prices received for milk. But movements in the benchmark margin correlate strongly with movements in farm-level measures of financial performance, and the benchmark is therefore a useful indicator of dairy financial performance (Wolf et al., 2015).

Why are milk prices so volatile?

Like other commodity markets, certain features of dairy markets make them prone to price volatility. Milk supply varies little, in the short to medium term, in response to price changes. Moreover, dairy product demand responds only weakly to price changes. Consequently, shifts in the demand for dairy products require substantial changes in price to equate quantity supplied with that demanded in dairy markets.

[31]Feed price movements reflected global price developments for the underlying commodities (corn, soybeans, alfalfa), which in turn reflected the global increase in biofuels demand after 2005, shortrun yield shocks driven by weather changes, and commercial and Government storage decisions (Trostle et al., 2011; Wright, 2014).

Figure 14
Monthly milk-feed price margin, 2000-2015



Source: USDA, National Agricultural Statistics Service for milk, corn, and alfalfa prices; USDA, Agricultural Marketing Service for soybean meal prices; and USDA, Farm Service Agency for feed price formula.

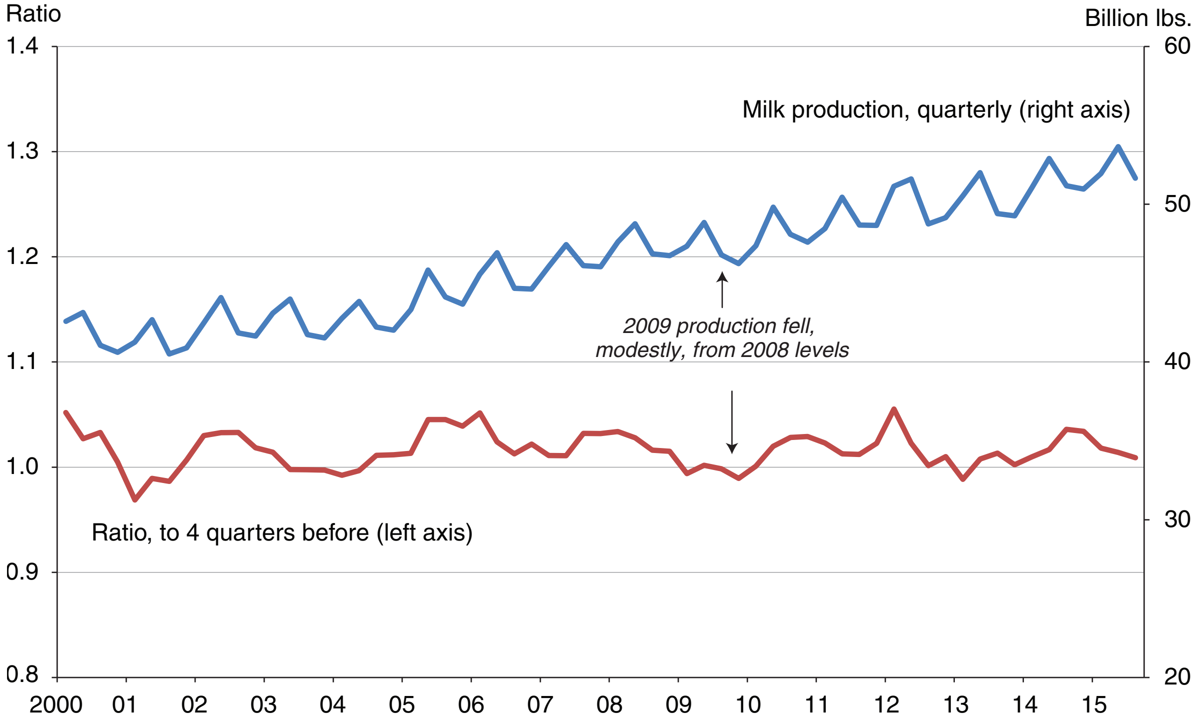
Demand for dairy products may shift because of changes in U.S. income and population. In particular, shifts in incomes associated with business cycles—recessions and expansions—can lead to noticeable and unexpected shortrun changes in demand. Dairy product demand may also shift because of changes in foreign demand for U.S. dairy products. Increased international demand allows for increased production and greater returns for U.S. producers, and it reflects the improved international competitiveness of the U.S. dairy sector. However, the level of exports can change sharply due to economic factors or dairy policy in other countries, weather-related changes in production from rival exporting countries, or changes in exchange rates.

While dairy product demand may shift unexpectedly, milk supply is more predictable, with relatively modest deviations from the trend and seasonal cycle (fig. 15). With ongoing improvements in cow genetics, feed rations, and production practices, milk production per cow has grown steadily by about 300 pounds per year. Production also follows a regular seasonal cycle, peaking in spring and declining in summer and fall.

Milk prices change in response to shifts in supply or demand, and the size of those price changes depends on the responsiveness of dairy product demand and milk supply to price. Consider figure 16, which depicts two different price responses to a decline in dairy product demand. Initially, the demand and supply for farm milk are equated at a price $P_{0,}$ but then demand declines from D_0 to D_1, perhaps because of a decline in incomes for dairy consumers.

In one scenario (S_I), milk production changes little as price changes. Demand is also unresponsive to price changes (that is, quantity increases only slightly as price declines), so milk prices must fall considerably, to P_{1I}, before quantity demanded is again equal to quantity supplied. However, in a

Figure 15
Quarterly milk production, 2000-2015



Source: USDA, National Agricultural Statistics Service, *Milk Production.*

second scenario (S_E), milk supply is considerably more responsive to price, and declines in milk prices elicit substantial declines in milk production. In this scenario, a decline in dairy product demand can be accommodated with a modest fall in price, because supply is more responsive to changes in price. Notice that quantity falls little in scenario S_I, while price falls considerably in response to the demand decline. In contrast, in scenario S_E, quantity falls by more, and the new equilibrium price is only modestly lower.

What do we observe about price responsiveness in U.S. dairy markets? Over short periods, price changes have very limited impacts on milk production. For example, milk prices in 2009 were 35 percent below prices in 2008, but production fell by just 0.4 percent from 2008 (fig. 15) and by 1.8 percent from the 1980-2014 trend.

The visual evidence of figure 15 is consistent with more formal statistical analyses. In the ERS quarterly econometric forecasting model of the dairy sector (Mosheim, 2012; see appendix B), the shortrun elasticity of cow inventories with respect to the farm milk price is estimated to be 0.014, while the shortrun elasticity of milk production is 0.18. That is, a 1-percent increase in price would be expected to elicit a 0.014-percent increase in cow inventories and a 0.18-percent increase in milk production after two quarters. This finding is consistent with other analyses. Chavas and Klemme (1986) reported price elasticities of 0.0 for cows and 0.11 for milk production within a year of a price change, while Bozic and colleagues (2012) reported elasticities for cows and production of 0.09 for each year after a price change. All estimates indicate that milk production responds very little to price changes within a year.

Cow inventories are much more responsive over longer periods.[32] Elasticity estimates for a 3-year span following a price change range from 0.115 to 0.288—still small, but meaningful. Chavas and Klemme (1986) found that the elasticity exceeded 1.0 with a 6-year time span, while Bozic, Kanter, and Gould's (2012) estimates approached 1.0 over 10 years.

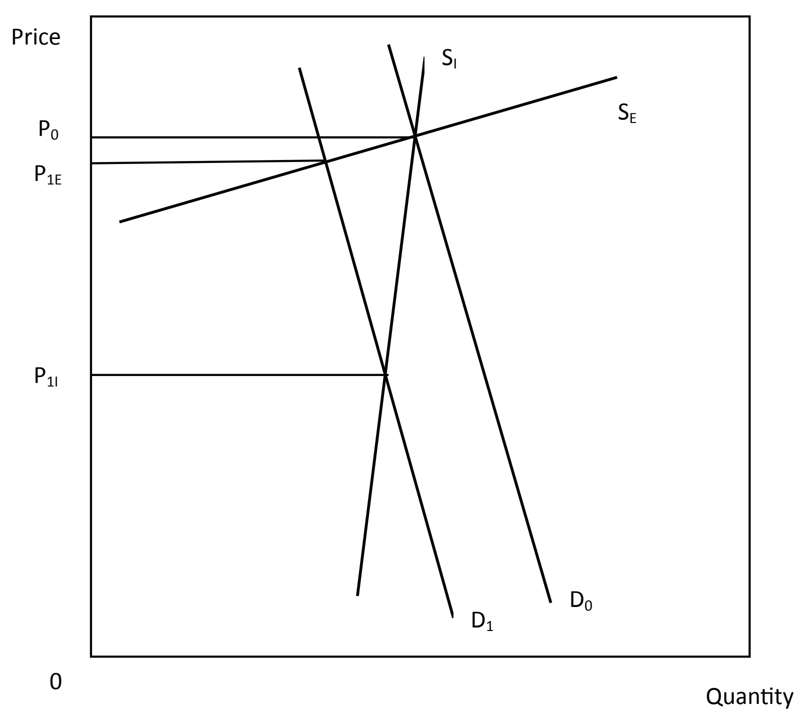
Short- and long-run elasticities vary because of the biological nature of dairy production. Herd expansions take about 3 years: a farmer must get a cow bred, and that cow must give birth to a female calf; the calf must be raised to puberty, bred, and then give birth to a calf before she can begin lactating. Thus, dairy farmers have only a limited opportunity to respond to price changes in the short run, but much greater flexibility over a period of years.

Limited shortrun supply responses to price changes are a major reason for wide price fluctuations in dairy, but longrun responses also matter for policy analyses. Interventions that raise returns to producers, and create lasting economic profits, are likely to elicit substantial increases in production if producers can react over succeeding years.

The sensitivity of milk demand to prices also matters (fig. 16). Domestic demand for most milk products has been rather insensitive to price, meaning that substantial price cuts may be needed to induce increases in milk purchases. Several studies of consumer demand for fluid milk have estimated price elasticities in the range of -0.15 to -0.30 (that is, a 1.0-percent decline in price elicits a

Figure 16

U.S. milk supply and the price response to a demand decline



Source: USDA, Economic Research Service.

[32]Milk yields can be varied in the short run but—within narrow limits and over the long run—follow a trend governed by improved genetics and feeding practices. Inventories are adjusted by culling mature cows and by varying the production and retention of heifers.

0.15- to 0.30-percent increase in quantity demanded).[33] Retail demand for cheese also appears to be relatively insensitive to price, with estimated elasticities ranging from -0.33 (Huang, 1986) to -0.65 (Schmit et al., 2002).

Dairy product relationships may be shifting. Export demand, a growing share of the market, can be quite sensitive to prices. Changes in beverage milk markets, in which other beverages like energy drinks or juices compete more with milk, may make for more elastic retail demand for dairy products, and hence a more elastic demand for farm milk.

Some dairy products may be stored, and the storage option provides a cushion for dairy supply, demand, and prices. During periods of excess supply and low prices, processors may add to stocks in expectation of future price increases, and they may draw stocks down during periods of excess demand and high prices. At the beginning of a quarter, existing commercial stocks of butter, nonfat dry milk, cheese, and other products typically amount to 20-25 percent of production during that quarter, and Government storage adds more capacity. Without the opportunity to store stocks of dairy products and to add to or draw from those stocks, price swings would be much more severe.

Policy can also affect price levels and price fluctuations. Price volatility was dampened when price supports were relevant (figures 9 and 12), albeit at significant costs to taxpayers and consumers. Congress then shifted policy from market interventions aimed at mitigating volatility to programs aimed at managing the income risks associated with volatility.

[33]See, for example, Huang (1986), Kinnucan et al. (2001), or Schmit et al. (2002).

The 2009 Margin Crash

The financial risks inherent in dairy farming came into sharp focus in 2009, when a pronounced decline in milk prices combined with relatively high feed prices to create a pronounced and longlasting decline in the milk-feed margin. The margin crash had a major impact on dairy-sector finances and helped prompt the policy changes in the 2014 Farm Bill. However, the financial impacts of the crash varied across dairy farms of different sizes because of differences in cost structure, financing, input purchasing, milk marketing, and dairy policy. That differential impact across farms also influenced the changes in policy.

Sources of the margin squeeze

The NASS all-milk price peaked at $21.90 per cwt in November 2007, and was still at $19.30 in July 2008, before plummeting to $11.60 by February 2009 (fig. 13). The all-milk price remained below $13 for the next 7 months, before rising back to $16.50 by the end of the year. Meanwhile, benchmark feed prices rose from $7.06 per cwt of milk in November 2007, to a peak of $11.11 in July 2008; they fell during 2009, but remained above $8 until September.

With milk prices dropping against modest declines in feed prices, the national-benchmark milk-feed margin narrowed considerably (fig. 14). From over $14 per cwt in July-November of 2007, the margin fell to $4.34 by the beginning of 2009 and $2.25 by June. It remained below $4 for 6 months of 2009 and below $8 for 12 consecutive months.

Broader developments in the global economy contributed to a fall in dairy product demand. The U.S. economy began slowing late in 2007, and economywide production and incomes then declined in late 2008 and early 2009 as the global financial crisis took hold. Real U.S. per capita disposable income fell by 3.8 percent over 21 months after April 2008.[34] Estimates in the professional literature suggest that the decline in incomes during the recession could have led to declines in domestic dairy product demand of up to 4 percent, although some of that decline is offset by population growth (Huang, 1986; Huang and Lin, 2000; Davis et al., 2010). A decline in dairy demand of 2-3 percent, creating an equivalent amount of excess milk supply, could necessitate a large drop in milk prices to rebalance supply and demand.

During the 2009 recession, the economies of Canada, Japan, and Mexico—major buyers of U.S. dairy products—contracted sharply as well. However, declines in world demand for dairy products did not translate into noticeable declines in consumption; in fact, global consumption of cheese, dry milk powder, and fluid milk increased in 2009 after falling in 2008.[35] Declines (shifts) in demand can induce price drops sharp enough to maintain consumption levels if milk supply is inelastic (unresponsive to price changes).

[34]U.S. Department of Commerce, Bureau of Economic Analysis, http://www.bea.gov/national/.

[35]USDA Foreign Agricultural Service, Production, Supply and Distribution database.

Figure 17 shows how U.S. milk production, exports, and commercial stocks of dairy products responded to the global pressures, using data from 2007 through 2011.[36] The data are quarterly and expressed as year-over-year ratios (the value for exports in the 1st quarter of 2007 is the ratio of exports in that quarter to exports in the first quarter of 2006).

U.S. milk production increased steadily through 2007 and 2008, with year-over-year volumes up 1-3 percent (fig. 17). Production then fell by 3 percent in the first quarter of 2009 (compared to first quarter, 2008), and fell slightly in the third and fourth quarters as well.

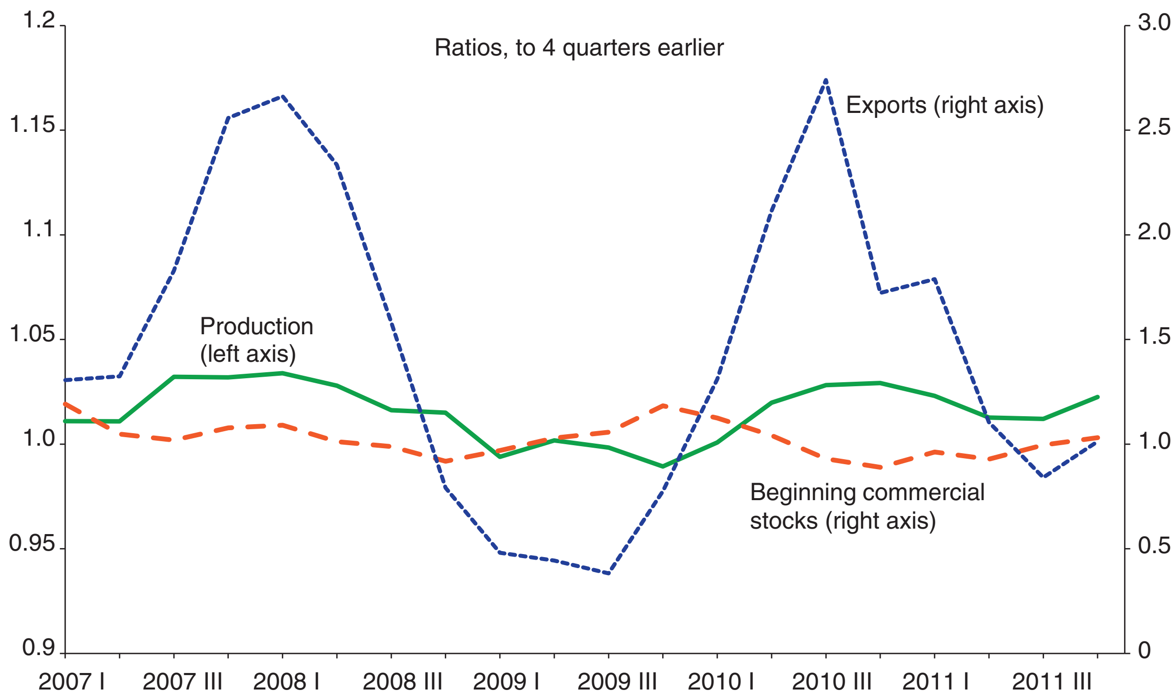
Dairy exports surged in the last two quarters of 2007 and the first three of 2008, with year-over-year increases of 30 to 165 percent. Part of the increase reflected reduced production in Oceania due to an extended drought, but it also reflected increases in global dairy product demand and improved U.S. competitiveness.

However, in the fourth quarter of 2008, U.S. exports fell by 21 percent from a year earlier, followed by declines of 50-60 percent in the first three quarters of 2009. Declines in domestic and foreign demand for dairy products meant that milk supply exceeded the demand for farm milk at the prices prevailing in the summer of 2008. Milk prices would have to fall—inducing increases in consumption, decreases in supply, or increases in storage—until demand and supply were recalibrated.

In the short run, milk supply responds to price signals, but quite weakly. Dairy cow inventories fell by 2.6 percent between 2008 and 2009, but because culled cows are usually less productive than retained

Figure 17

Quarterly domestic production, exports, and stocks, 2007-11



Source: USDA, Economic Research Service.

[36]For exports and stocks, the fat content of the various products are added and converted to the equivalent amount of milk.

cows, production fell by just 0.4 percent. Dairy product demand responds, modestly, as prices for milk and dairy products decline. Prices must therefore fall substantially to rebalance supply and demand.

Some of that price decline was cushioned by moving products into storage in anticipation of later price increases. Commercial stocks increased from the second quarter of 2009 through the second quarter of 2010 (fig. 17). Government net removals of dairy products—primarily CCC purchases under the price support program—also increased in 2009-10. Stocks from each source were drawn down in 2010 as exports and domestic purchases expanded.

The events of 2009—a serious global financial crisis and recession, accompanied by drought and recovery in rival exporting countries—placed extraordinary pressure on U.S. dairy producers. While the combination of events was unprecedented, similar pressures may occur in the future.

Financial effects of the margin crash

The financial impact of the 2009 dairy crisis was severe. Thirty-five percent of dairy farms had negative net farm income in 2009, with gross income falling short of cash expenses, compared to 12 percent in 2007.[37] The industrywide rate of return on equity fell to -4.7 percent from 4.3 percent 2 years earlier.

Dairy farmers collectively lost about $10 billion of equity during 2009 and $15 billion over 2008-09 (table 10). They took on $4.3 billion in net new debt in 2009, a 23-percent increase in the total, and these loans largely went to finance operations rather than investment. New capital expenditures in 2010, the year following the crash, were only one-third the value of 2007 expenditures.

In 2008, 10 percent of the households operating small dairy farms (less than 100 cows) had negative household income, having to draw on savings or loans for household consumption. That figure more than doubled, to 22 percent, in 2009, while many other farms realized very small household incomes.[38] Operators of larger farms were not spared: 70 percent of households operating farms with at

Table 10

Dairy industry finances, 2000-13

Year	Equity	Debt	Capital expenditures
		$ Billion	
2000	67.6	16.0	4.0
2001	72.0	15.0	3.2
2002	71.1	15.7	3.2
2003	75.9	16.3	2.2
2004	78.7	17.0	2.8
2005	90.1	17.4	3.7
2006	101.2	18.9	3.5
2007	98.3	19.0	4.1
2008	93.2	19.4	3.5
2009	83.2	23.7	2.6
2010	91.8	23.9	1.4
2011	99.0	22.1	2.8
2012	94.8	22.8	2.9
2013	98.5	23.2	3.5

Notes: Covers all farms for which dairy accounts for at least half of production. Equity and debt are measured as of the end of the year noted.

Source: USDA, Agricultural Resource Management Survey, all versions, 2000-2013.

[37]These estimates are drawn from the ARMS whole-farm finance dataset (appendix A).

[38]Household income combines income from the farm business with off-farm income, which may arise from off-farm employment or from pensions, returns on financial assets, and the like. Farm business income subtracts cash expenses, depreciation, and some other non-cash expenses from the farm's gross income, and then further subtracts any payments to other owners of the farm. It represents the return to the principal operator family's labor, management, and capital.

least 1,000 cows had negative household income in 2009, and median household income in that group fell from $393,099 in 2008 to -$289,913 in 2009.

Many large dairy farms were expanded or established in the decade just before the financial crisis. A herd of 2,000 milk cows, with 800 heifers, represents an asset value of over $5 million. Other capital assets for the dairy enterprise (housing, milking facilities, feed, milk, manure storage structures, and related machinery/vehicles) typically tie up another $10-13 million.[39] That is separate from any investment in crop production (for feed), which requires additional land, equipment, vehicles, and storage.

Few farm families have the financial wherewithal to fund such investment out of their own savings, so large dairy farms often carry significant amounts of debt. On average, dairy farms carried debt equal to 13 percent of their assets at the end of 2008, but 19 percent of the largest farms (2,000 head or more) carried debt that exceeded 60 percent of their assets (table 11).

The price squeeze placed great pressure on balance sheets. Because larger dairy farms carried far more debt, per dollar of assets, than smaller farms, they were more exposed to balance sheet risks. Mean debt-to-asset ratios rose from 13 to 17 percent in 2008-09, but rose much more for the largest farms, from 32 to nearly 50 percent for the largest size class.

Farms with at least 2,000 head took on $3.7 billion in new debt in 2008-2010, or 78 percent of all new debt in the industry. Six percent of these large farms were insolvent in 2009 (debt exceeded the value of their assets), compared to 0.4 percent of all other dairy farms. One major developer of dairy farms was unable to obtain further financing from its lenders, and entered bankruptcy proceedings in 2010 (Etter, 2010).

Table 11
Debt position of dairy farms by herd size, 2008-10

	Mean debt-to-asset ratio (%)			Percent with debt exceeding 59.9% of assets			Percent with debt repayment capacity less than zero		
	2008	2009	2010	2008	2009	2010	2008	2009	2010
				-Percent of production-					
Milk production	27	34	34	12	23	16	20	41	15
				-Percent of farms-					
All farms	13	17	16	3	5	4	19	31	21
Herd size (milk cows)									
<50	10	11	11	2	1	2	14	22	26
50-99	11	16	16	2	4	5	12	32	14
100-199	17	20	17	1	7	2	23	32	15
200-499	27	22	25	10	6	7	24	46	25
500-999	33	29	35	13	16	16	30	49	16
1,000-1,999	34	48	36	13	41	13	18	62	22
>1,999	32	49	44	19	41	26	19	52	13

Source: USDA, Agricultural Resource Management Survey, all versions, 2008-10.

[39]The estimate for milk cows is from NASS Agricultural Prices from July, 2015. The estimate for other capital assets is drawn from data from the 2010 ARMS dairy version.

Table 11 also reports on farms whose debt obligations exceeded the income available for coverage.[40] That measure rose sharply for farms in all size classes in 2009 as net cash income fell. During 2009, farms accounting for 41 percent of industry production had debt obligations that exceeded income available for debt coverage; the figure exceeded 50 percent for farms in the largest size classes. Debt coverage improved in 2010, but debt-to-asset ratios fell only modestly for the largest farms, and many of them remain vulnerable should interest costs rise or farm income decline.

Farm-level financial performance during the margin squeeze

The 2009 margin crash imposed losses on most dairy producers. However, the financial impact varied across small, midsize, and large farms in the crash and in recovery in 2009-10. Larger farms have different cost and debt structures than smaller farms, and policy, through the MILC program, was designed to provide less support to larger farms when prices fell. We use the ARMS whole-farm finance dataset to track changes in dairy farm financial performance in 2008-9 and in 2009-10.

Figure 18 reports average rates of return on equity (ROE) by herd size class.[41] During 2005-08, the strong relationship between herd size and average ROE stands out, consistent with net returns (table 4). Given the potential profits to be earned by large farms, experienced operators could attract debt and investor capital to expand, and could earn a substantial income by doing so.

ROE declined, and was negative, in every size class during 2009, and it declined the most for farms in the two largest classes (fig. 18). Financial performance then bounced back in 2010, with the largest farms showing the strongest improvement. The link between profits and farm size was, in fact, stronger in 2010 than in 2005-08.

Changes in financial performance during 2008-2010 were concentrated in the cash components of farm financial accounts. In tables 12 (2008-09) and 13 (2009-10), we decompose changes in net cash income into selected components: milk income, Government payments, feed expenses, expenses other than feed, and income other than milk and Government payments.[42]

Net cash income fell for all farm classes in 2009, but the two largest classes experienced the largest declines (table 12). The average 2009 NASS all-milk price, $12.80 per cwt, was $5.50 below the 2008 average price, and declines in milk income—ranging from $4.45 to $5.90 per cwt—reflect that fall, with no apparent link to herd size.

Changes in other income and expense categories offset some of the lost milk income. Specifically, changes in feed expenses and Government payments added roughly $2 per cwt to net cash income for farms with 50-1,000 head, while providing very little support for the largest farms.

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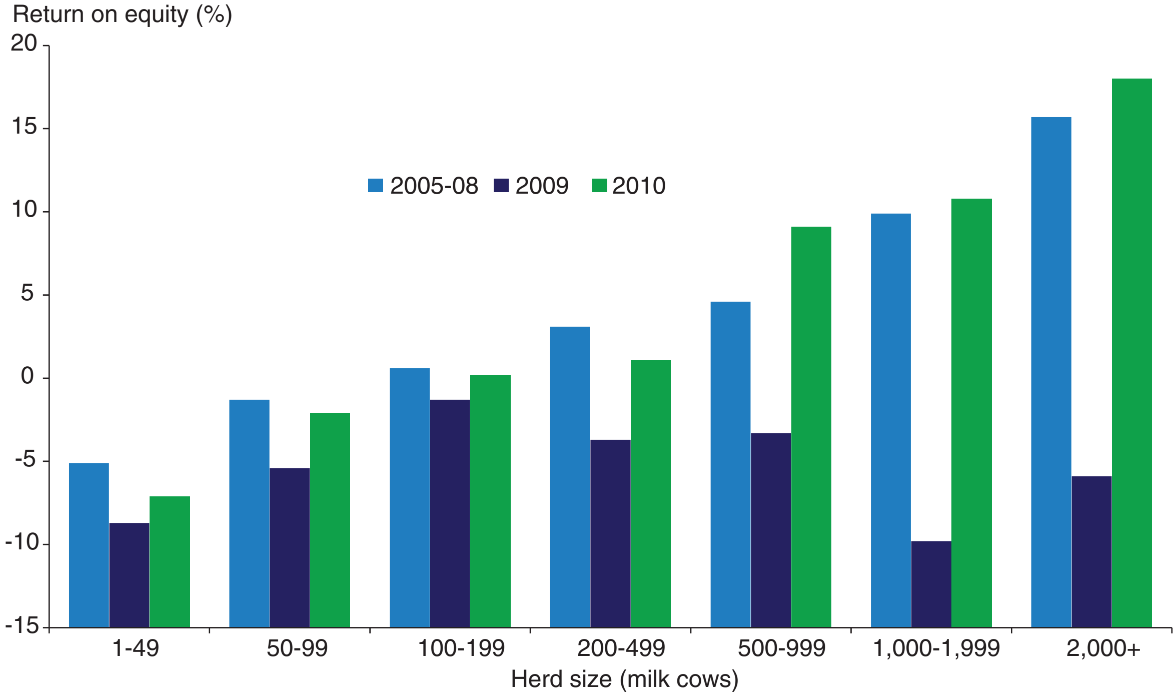
[40]Debt obligations are the interest and principal payments on debt, while the income available for debt coverage includes depreciation and net farm income. These are estimated by ERS from data provided in ARMS.

[41]In the ARMS financial accounts, ROE is measured as net farm income, minus a charge for unpaid labor and management provided by operators, divided by equity, which in turn is the difference between farm business assets and farm business debt. See appendix A for details.

[42]We focused this analysis on those farms (most of the dataset) with a primary focus on dairy that remained open all of the year. As such, we restricted the whole-farm finance dataset to farms that generated at least 75 percent of gross commodity income from dairy products, and deleted records with unusually high or low reported annual milk yields.

Figure 18

Dairy farm profitability, by herd size class, 2005-2010



Source: USDA, Agricultural Resource Management Survey, all versions, 2005-2010. See appendix A for derivation of return on equity.

Table 12

Changes, 2008-09, in selected components of net cash income by herd size

	Herd size (milk cows)						
Item	<50	50-99	100-199	200-499	500-999	1,000-1,999	2,000+
	2008-2009 change ($/cwt)						
Net cash income	**-2.34**	**-2.05**	**-1.00**	**-2.80**	**-1.14**	**-3.13**	**-4.21**
	Contribution to change in net cash income						
Milk, payments, feed	**-4.03**	**-3.11**	**-2.24**	**-3.29**	**-2.41**	**-4.32**	**-4.93**
Milk income	-5.22	-5.90	-4.79	-5.40	-4.45	-5.37	-4.78
Government payments	+0.53	+1.08	+1.18	+0.95	+0.29	+0.20	+0.10
Purchased feed expense	+0.66	+0.71	+1.37	+1.16	+1.75	+0.85	-0.25
Other costs	**+2.29**	**+1.61**	**+1.13**	**+0.63**	**+0.89**	**+0.77**	**+0.38**
Land-related	+0.82	+0.77	+0.43	+0.07	+0.17	+0.52	+0.25
Maintenance and repair	+0.66	+0.50	+0.09	+0.28	+0.16	+0.15	+0.16
Other income	**-0.63**	**-0.55**	**+0.11**	**+0.14**	**+0.28**	**+0.42**	**+0.34**

Notes: A positive sign on an expense category indicates a *decline* in that expense, contributing to *increased* net cash income. A positive sign on an income category indicates an *increase* in income, contributing to *increased* net cash income. “Land-related” expenses include rents, fuel, seed, chemicals, and custom work.

Source: USDA, Agricultural Resource Management Survey, all versions, 2008-09.

Most Government payments to dairy farms in 2009 came from the MILC program. Farmers with cropland enrolled in commodity programs received direct payments, and some received conservation payments under the Environmental Quality Incentives Program. However, the *changes* noted in table 12 reflect the MILC program and its design, as payments under the other programs did not change in any systematic way.

Higher Government payments contributed an additional $1.08 per cwt to 2009 income on farms with 50-99 cows and $1.18 on farms with 100-199 head (table 12), thereby offsetting 18 and 25 percent, respectively, of the reduction in milk income on those farms.[43] However, consistent with the MILC program's production-based payment caps, contributions declined as herd size increased, to 10 cents per cwt in the largest class.

Purchased feed expenses fell 15 percent, on average, in 2009 as cash prices for corn and alfalfa declined, providing some financial relief from falling milk prices. Changing feed prices should have a more immediate effect on larger farms, because purchased feed provides more of their total feed requirements. Declines in purchased feed expenses added $0.66 to $0.71 (per cwt) to 2009 net cash income for farms with less than 100 milk cows, and $1.16 to $1.75 among midsize farms (table 12). Higher Government payments and lower feed expenses combined to offset, by $2.00-$2.50 per cwt, declines in milk income for small and midsize farms.

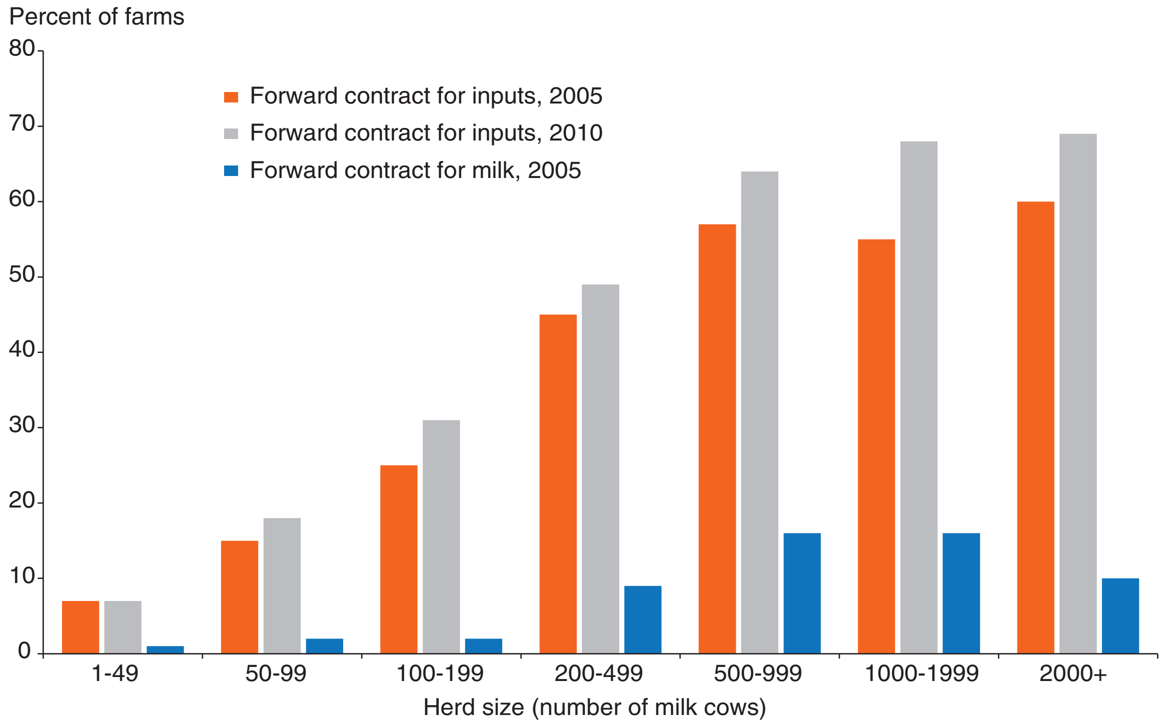
However, lower feed expenses had a much smaller impact ($0.85) among farms with 1,000-1,999 head, and farms in the largest size class saw their feed expenses *rise* in 2009 even as cash feed prices fell. This is unexpected, since the largest farms purchase more feed, per cwt of milk production, and hence should benefit from falling feed prices.

Feed purchasing strategies likely played a role. ARMS calculations of net cash income reflect cash accounting principles, based on receipts and expenses incurred through the year. With feed prices falling during most of 2009, but then rising in 2010, forward-looking farms could expand purchases of feed during 2009 to take advantage of low prices, thus increasing 2009 feed expenses per cwt. Farms can also lock in input prices in advance by forward contracting; most large farms use forward contracts for some inputs, and the share using forward contracts rose between 2005 and 2010 (fig. 19). Prices for grain purchased under forward contracts tend to fluctuate less than cash prices, and to lag changes in cash prices—remaining above cash prices when prices are falling and falling behind when prices are rising. Because of this, the largest farms had a smaller increase in feed expenses in 2008, when feed prices rose, and a smaller decline (and increases for many) in 2009, when feed prices fell.

In general, other dairy expenses declined in 2008-09, in strong inverse relation to herd size (table 12). Land-related expenses—seeds, chemicals, fuel, land rentals, and custom services—fell in 2009, and substantially on smaller farms, which grow more of their own feed. Maintenance and repair expenses also fell sharply in 2009, again by more on smaller operations. It is not surprising that, under major financial pressures, potentially elective expenses would in fact be delayed.

[43]We can check the accuracy of ARMS-based farm responses against administrative data. A farm with constant monthly production, all eligible for payments, would have received $1.15 per cwt for the year, while farms with eligible production concentrated in late Winter, Spring, and Summer, when monthly MILC payments were higher, would have received a slightly higher annual average payment. http://fsa.usda.gov/Internet/FSA_File/milc_rates.pdf . Average values reported in ARMS—$1.08 for farms with 50-99 head, $1.18 for 100-199 head, and $0.95 for 200-499 cows—are consistent with the MILC payment rates reported by FSA for 2009.

Figure 19
Use of forward contracting by dairy farms, 2005 and 2010



Source: 2005 and 2010 Agricultural Resource Management Survey, version 4.

Price recovery and financial performance in 2010

Milk-feed margins recovered in 2010 (fig. 14), and the industry rebuilt $8.6 billion of equity (table 10). However, the rate of improvement varied markedly with farm size; returns on equity in 2010 exceeded pre-crisis levels at the largest farms but fell short among smaller farms.

Differential changes in milk/feed prices and Government payments played important roles, as in 2008-09, but this time in reverse. Net cash income increased in all size classes, although the increases were noticeably larger among farms with at least 1,000 head (table 13). With the NASS all-milk price reaching $16.30 in 2010—$3.50 above the 2009 average—milk income rose.[44]

Policy played a mixed role in 2010. Congress authorized expanded purchases of cheese and dairy products by USDA's Food and Nutrition Service during fiscal year 2010 (October 2009 through September 2010); expanded USDA purchases would be expected to increase prices for both dairy products and farm milk. Congress also authorized additional direct payments to dairy producers under the Dairy Economic Loss Assistance Payment Program, based on production up to a cap of 6 million pounds (total payments in fiscal year 2010 came to $273 million). However, direct payments under the MILC program fell during 2010 as prices recovered. Farms that had been the primary beneficiaries of MILC payments in 2009 (those with 50-500 head) saw total direct Government

[44]Milk prices rose less at the largest farms (table 13). Relatively few farms forward contract for milk (fig. 19; Wolf and Olynk Widmar, 2014). However, larger farms are more likely to, and some may have carried contracts that lagged the 2010 price increases. Note that "other income" also declined for the largest farms, a development largely driven by declines in 2010 payments for milk delivered during the prior year. These deliveries were likely priced at 2009 levels, and hence also lagged the 2010 price increases.

Table 13
Change, 2009-10, in selected components of net cash income by herd size

Item	Herd size						
	<50	50-99	100-199	200-499	500-999	1,000-1,999	2,000+
	2009-2010 change ($/cwt)						
Net cash income	**+0.78**	**+2.43**	**+0.83**	**+1.63**	**+1.56**	**+3.18**	**+2.94**
	Contribution to change in net cash income						
Milk, payments, feed:	**+2.13**	**+3.11**	**+1.17**	**+1.77**	**+3.20**	**+3.67**	**+3.46**
Milk income	+3.18	+4.14	+3.14	+3.01	+3.23	+3.08	+2.55
Government payments	-0.73	-1.06	-1.06	-0.87	-0.29	-0.19	-0.11
Purchased feed	-0.32	+0.03	-0.91	-0.37	+0.26	+0.78	+1.02
Other costs	**-1.27**	**-0.95**	**-0.15**	**-0.31**	**-1.62**	**-0.42**	**+0.11**
Land-related	-0.48	-0.56	-0.23	-0.31	-0.86	-0.33	-0.01
Maintenance and repair	-0.29	-0.22	-0.12	-0.19	-0.18	-0.02	-0.09
All other costs	-0.50	-0.17	+0.20	+0.19	-0.58	-0.07	+0.21
Other income	**-0.08**	**+0.27**	**-0.29**	**+0.17**	**-0.02**	**-0.07**	**-0.62**

Notes: A positive sign on an expense category indicates a decline in that expense, contributing to increased net cash income. A positive sign on an income category indicates an increase in income, contributing to increased net cash income. "Land-related" expenses include rents, fuel, seed, chemicals, and custom work.

Source: USDA, Agricultural Resource Management Survey, all versions, 2009-10.

payments fall—by around $1 per cwt—as milk prices and revenues rose (table 13). Declining payments took a much smaller bite out of large farm revenues.

Changes in purchased feed expenses contributed $1.02 per cwt to net cash income at the largest farms, and 78 cents at those with 1,000-1,999 head, while purchased feed expenses rose for some smaller classes. This pattern likely reflects greater forward contracting for feed among the larger farms, with changes in cash price affecting contract prices with a lag. Hence, smaller farms realized the benefits of falling feed prices in cash market purchases in 2009, while larger farms did not realize those lower 2009 cash prices in contract purchases until 2010.

Farms reacted to the margin crash and recovery along multiple dimensions. Farms—particularly large operations—used forward contracts to smooth movements in feed prices. Smaller farms put off maintenance and repair activities to future years, while all farms managed to reduce expenses associated with their own crop production. Policy, primarily through the MILC program, smoothed income fluctuations for its target beneficiaries of small and midsized operations.[45] Nonetheless, financial performance of the U.S. dairy sector deteriorated sharply, prompting an effort to redesign policy so as to provide protection against price risks for large and small farms.

[45]As in the 1980s, there was also a herd reduction program, but this was operated privately. Cooperatives Working Together (CWT), a federation formed in 2003 through the National Milk Producers Federation, managed a dairy herd retirement program from 2003 to 2010 under an antitrust exemption provided to cooperatives by the Capper-Volstead Act. The program was funded by assessments on member milk marketings; an expert hired by CWT argues that the program reduced the national milk cow inventory by about 1 percent in 2009, and raised 2009 milk prices by about 70 cents per cwt (Brown, 2009). While the program encouraged herd retirements, it did not dictate farm entry or expansion decisions.

A New Policy Initiative: Dairy Margin Protection Program

Scale economies in dairy farming provide strong incentives to invest in large operations for those who can assemble the needed managerial talent, usually from family and close associates. Shifts of production to larger farms have contributed to increased efficiency, lower milk prices, and sharp increases in net exports as the U.S. dairy industry's international competitiveness improved.

However, milk and feed price volatility heightens risks for dairy farmers, as illustrated by the 2009 margin crash. The Milk Income Loss Contract (MILC) program offset some of the revenue loss for smaller farms, but large farms realized little revenue protection and the high levels of debt required to finance many large farms created further liquidity risks for some. The experience of 2009 provided a major impetus for the redesign of dairy programs in the 2014 Farm Bill, with an expanded focus on providing margin protection to all kinds of farms through MPP-Dairy.[46]

Program design

MPP-Dairy is a voluntary risk management program authorized through 2018. It offers protection to dairy producers when the difference between the NASS all-milk price and a national-benchmark feed cost (called the "actual dairy producer margin" in the legislation) falls below a threshold, with escalating premiums, selected by the producer. The program does not set milk or feed prices, but instead offers a cash payment to producers when national-average margins are narrow or negative.

Farms register for coverage with USDA's Farm Service Agency (FSA) by establishing a production history; electing a desired level of coverage; paying a premium, if any, tied to the elected coverage; and paying a $100 administrative fee. The production history is the highest calendar-year total of the farm's milk marketings from 2011, 2012, or 2013.[47]

Catastrophic coverage provides benefits to enrolled operations when the national-benchmark margin falls below $4. It covers 90 percent of the farm's production history and requires no premium, although the operation must pay the administrative fee. Farms may purchase buy-up coverage for 25 to 90 percent of production history, in 5-percent increments, for margin thresholds ranging from $4.50 to $8.00, in 50-cent increments (table 14). The program prioritizes small operations in that premiums rise substantially once enrollees seek to cover more than 4 million pounds of production history.

MPP participants make separate registration and coverage decisions, and the timing of these choices matters. In the initial registration period, from September 2 through December 19, 2014, dairy farmers registered a production history, and then chose to enroll in the program and select a level of coverage. Registration is for the life of the program, through the end of 2018, but farmers who did not register for coverage in 2015 can register in annual signup periods.

The Secretary of Agriculture can adjust established production histories annually to reflect nation-wide increases in milk production; the 2015 adjustment allowed histories established in 2014 to be increased by 0.87 percent for 2015, providing registered farmers with expanded coverage.

[46]7 USC Section 9054; 7 CFR Part 1430.

[47]New dairy farms, in operation for less than 12 months as of February 2014, have a different procedure for establishing a production history, described in FSA documents.

Table 14
Dairy Margin Protection Program premiums by margin threshold

	Tier 1 premium, 2014 and 2015	Tier 1 premium, 2016-2018	Tier 2 premium, 2014-2018
Margin threshold, per cwt	CPH up to 4 million lbs.	CPH up to 4 million lbs.	CPH > 4 million lbs.
		$ per cwt	
$4.00	None	None	None
$4.50	0.008	0.010	0.020
$5.00	0.019	0.025	0.040
$5.50	0.030	0.040	0.100
$6.00	0.041	0.055	0.155
$6.50	0.068	0.090	0.290
$7.00	0.163	0.217	0.830
$7.50	0.225	0.300	1.060
$8.00	0.475	0.475	1.360

Notes: CPH is covered production history. Farms enrolled in MPP-Dairy pay an annual $100 administrative fee, but pay no premiums for catastrophic coverage (a $4 margin covering 90 percent of production history).

Source: USDA, Farm Service Agency..

Adjustments are cumulative, so there is a benefit to registering early, even for producers who expect to receive no payments in 2015.

Coverage choices can be adjusted annually. Thus, a registered producer could elect to purchase $8 margin coverage for a year in which margins were expected to fall below $8, but could choose catastrophic coverage if margins were expected to remain well above $8, and pay just the $100 administrative fee.

A participating dairy farmer receives a "margin protection payment" whenever the national-benchmark margin for a consecutive 2-month period is less than the threshold margin selected by the farm.[48] The payment equals the difference between the threshold and benchmark margins, times the amount of covered production history, prorated to a 2-month period. Thus, payments are not based on farmers' own margins, but on a national benchmark. Producers' premiums help fund payments; if premiums are insufficient, the difference is met through Government outlays.

Initial enrollment in MPP-Dairy

Initial registration and coverage elections were completed in December 2014 for coverage in 2015; 24,748 operations, or 55 percent of licensed dairy operations in the United States, enrolled (table 15).[49] Larger farms were seemingly more likely to enroll, as the production history of enrolled farms amounted to 80 percent of aggregate U.S. milk production (206,046 million pounds) in 2014.

[48]The national-average margin is that used throughout this report (figure 13 and footnote 30)—the difference between the NASS all-milk price and a feed price formula set in the legislation.

[49]Only licensed dairy operations can sell milk. There were 45,344 in 2014 and 49,331 in 2012, substantially less than the 64,000 farms with milk cows in 2012 (table 1). The difference lies in farms that have cows but sell no milk; almost all such farms have fewer than 10 cows, and they generally use the milk for home consumption.

Table 15
2015 enrollment in Dairy Margin Protection Program

Item	Number of farms	Registered production history	
		2014	2015
		Million pounds	
All licensed dairy farms	45,344		
Farms registering production history	25,102	164,925	164,885
Farms enrolled in MPP	24,748	166,359	166,319

Notes: Some farms registered their production history for MPP, without enrolling in the program. 2015 milk production the aggregate registered production history established in the sign-up period, while 2015 production history is the 2014 number, increased by 0.87 percent to adjust for changes in national production.

Source: USDA Farm Service Agency

Enrolled farms clustered at four threshold margins (table 16). Forty-four percent chose the lowest (catastrophic) coverage of $4.00, while 41 percent clustered at midlevel threshold margins of $6.00 and $6.50, and 7 percent chose high threshold margins of $7.50 and $8.00. Farms choosing buy-up coverage could elect to cover anywhere from 25 to 90 percent of their production history, but most chose to cover 70-90 percent (table 16).

Coverage choices varied systematically with herd size. The mean production history among farms choosing catastrophic ($4 threshold) coverage was 8.92 million pounds, compared to 7.72 million pounds among farms choosing a $6.00 threshold, 3.46 million pounds for farms choosing a $6.50 threshold, and 2.96 million pounds for farms choosing a $7.50 threshold.

Enrollment rates varied widely across the country (table 17). Among major dairy States, the lowest rates of enrollment, whether by share of farms or production history, were in the Northeast (Pennsylvania, New York, and Vermont), while the highest rates were in the Southwest (Arizona, New Mexico, and Texas).

In January 2016, USDA released 2016 MPP-Dairy enrollment, based on registration and coverage decisions made by farmers through September 30, 2015. MPP-Dairy enrollment fell to 23,328 farms; since farms enroll for the life of the program, the decline reflects the net effect of the closure of enrolled farms and new enrollment by farms that were previously not enrolled. As in 2015, enrollment rates varied widely across States, in line with the 2015 patterns in table 17, and larger operations were more likely to be enrolled.

Enrolled farms made noticeable changes in coverage choices, shifting toward catastrophic coverage. Seventy-seven percent of enrolled farms, representing 88 percent of covered production, chose catastrophic coverage for 2016, compared to 44 percent of farms representing 62 percent of covered production in 2015. They primarily shifted from coverage choices at threshold margins of $6.00 and $6.50: 17 percent of farms, with 8 percent of covered production, chose those thresholds for 2016, compared to 42 percent of enrolled farms and 29 percent of covered production in 2015.

How do MPP and MILC payments compare?

The MPP is a complex program. Indemnities vary with the benchmark margin, the threshold margin chosen (from $4 to $8), and the share of production history covered, while producer premiums vary with the threshold margin and the amount of production that is covered. In table 18, we compare payments that farms would have received under the MILC program with the net MPP indemnities

Table 16
Dairy Margin Protection Program enrollment by coverage level, 2015

Margin threshold	Number of operations	Production history (million lbs.)	Covered production (million lbs.)	Covered production as percent of history
$4.00	10,888	97,091	87,382	90.0
$4.50	136	482	426	88.4
$5.00	741	6,534	5,747	88.0
$5.50	505	2,803	2,368	84.5
$6.00	3,828	29,584	24,591	83.1
$6.50	6,457	22,306	17,119	76.7
$7.00	502	1,007	826	82.0
$7.50	1,430	4,229	3,020	71.4
$8.00	261	1,007	583	57.9
Total	24,748	166,319	142,063	85.4

Notes: Covered production is the share of production history that is covered in MPP-Dairy.

Source: USDA, Farm Service Agency.

(indemnities minus premiums) that farms would have received in the crisis year of 2009, had the MPP been in effect.

The example includes five different MPP options: catastrophic coverage, and plans with two threshold margins ($6.50 and $8.00) and two shares for covered production (90 percent and 50 percent). Because MILC payments and MPP premiums vary with production, we compare four different farm sizes: one with 2.9 million pounds of production (the upper limit for MILC payments in 2009), and then farms with 10, 20, and 50 million pounds.[50] If we assume annual production per cow of 20,000 pounds, then these values correspond to herd sizes of 145, 500, 1,000, and 2,500 cows. Our calculation assumes that the MPP would have had no effect on milk production or prices during the period—that is, we use existing monthly prices from 2009 for the comparison.

Under the most recent version of MILC, farms received payments up to a production cap of 2.985 million pounds. Since all four example farms match or exceed the cap, they would all have received the same total MILC payments in 2009 but much different payments per cwt of production. If we compare MILC payments to net indemnities under MPP catastrophic coverage (a $4 margin), smaller farms would have received considerably less (38 cents per cwt versus $1.15) had MPP been in effect in 2009, but farms with 10 million pounds of production would have received the same amount, and larger farms would have received more than they would have under MILC. Total 2009 MILC payments were $880 million. If all producers had registered for catastrophic coverage, MPP payments in 2009 would have been $715 million, but distributed differently, in proportion to production.[51]

[50]Our example elides one important distinction between the programs. MILC payments were based on actual production, and farmers could therefore receive MILC payments for any expanded production up to the cap. MPP payments are based on historic production, and farmers do not receive MPP payments on production in excess of their production history.

[51]Total 2009 production amounted to 1.892 billion hundredweight. Catastrophic coverage MPP would have provided payments of 38 cents per hundredweight on 90 percent of that, or $715 million (administrative payments, of $100 per farms, would have amounted to $6 million).

Table 17

Dairy Margin Protection Program enrollment by State, 2015

State	Percent of: Farms	Percent of: Production	State	Percent of: Farms	Percent of: Production
AL	40	59	NE	82	95
AR	88	108	NJ	69	69
AZ	81	97	NV	95	92
CA	71	79	NH	58	89
CO	78	83	NM	100	96
CT	69	83	NY	49	68
DE	50	86	NC	71	91
FL	67	79	ND	65	77
GA	81	78	OH	37	69
ID	68	94	OK	59	73
IL	77	86	OR	64	91
IN	36	75	PA	29	49
IA	70	86	RI	68	79
KS	62	91	SC	34	38
KY	55	80	SD	82	92
LA	66	80	TN	71	93
ME	68	86	TX	84	93
MD	48	61	UT	80	86
MA	75	94	VT	67	72
MI	56	74	VA	60	75
MN	74	84	WA	65	84
MS	76	74	WV	37	54
MO	51	84	WI	59	78
MT	73	84	WY	40	18

Notes: The percent of farms is the number of farms enrolled in MPP for 2015, divided by the number of licensed dairy operations in the State in 2014. The percent of production is the production history of farms enrolled in MPP (the highest of farm production in 2011, 2012, and 2013), divided by the State's milk production in 2014.

Source: USDA Farm Service Agency

Table 18

Milk Income Loss Contract versus Dairy Margin Protection Program payments, 2009

Program	Margin threshold	CPH	Production history (million pounds): 2.9	10	20	50
	$	%	*Net payment ($ per hundred weight)*			
MILC	-	-	1.15	0.38	0.19	0.08
MPP	4.00	90	0.38	0.38	0.38	0.38
MPP	6.50	90	1.90	1.81	1.74	1.72
MPP	8.00	90	2.66	2.31	2.02	1.94
MPP	6.50	50	1.06	1.06	0.99	0.96
MPP	8.00	50	1.48	1.48	1.22	1.11

Notes: CPH is covered production history. Net payments are payments minus premiums (0 under MILC, and varying with production, production coverage, and coverage under MPP). Net MPP payments are expressed in dollars per hundredweight of production, not dollars per hundredweight of covered production.

Source: USDA Farm Service Agency for MILC payments and MPP parameters.

Premiums for buy-up MPP coverage vary with the threshold margin and the amount of covered production history, so net indemnities vary with farm size. Small farms, had they chosen to cover 50 percent of production history at a $6.50 margin, would have received net indemnities that were less than MILC payments, but the MPP yields higher net payments in all other instances (table 18). The payments would have been substantial, on the order of $0.96 to nearly $2.70 per cwt, and a large farm with the highest level of coverage (90 percent of production, at an $8 level) would have received a gross indemnity of $1,545,000 and a net indemnity (exclusive of premiums) of $970,000. Payments are not capped, so that a farm with 10,000 head, and 200 million pounds of production, would have received net indemnities of nearly $4 million.

Table 18 focuses on 2009, an extreme year when margins fell sharply and indemnities should have exceeded premiums paid. Net indemnities would have been lower in 2012, and negative in years in which margins stayed above $8, since firms would still have incurred premiums, or the $100 administrative fee for catastrophic coverage, while receiving no indemnities.

Nicholson and Stephenson (2014b) use benchmark margin data for the 6-year period 2008-2013 to compare payments under MILC to gross and net indemnities under MPP-Dairy, assuming no changes in margins, and conclude that (1) MPP would have paid more, per cwt of production history, than MILC, particularly for large farms; and (2) net MPP indemnities would have been positive over the period, so that MPP would have offered positive returns for enrollees of any size level and at any coverage chosen.

However, the comparison between and MILC and MPP is sensitive to the time period. Margins were below $8 in 42 of the 72 months in 2008-13, and below $4 in 10 of those months. During the previous 72-month period (2002-2007), margins fell below $8 in 27 months, and never fell below $4. In an analysis covering 2002-2013, small dairy farms (under 100 head) with no more than 4 million pounds of production history would have realized positive net MPP indemnities for any level of coverage chosen. Larger farms would have received positive net indemnities, for all shares of production history covered, if they chose catastrophic coverage ($4) or if they chose to pay higher premiums at a $6 threshold margin. However, net indemnities for larger farms would have been negative if they chose $8 coverage, which would have required a substantial increase in premiums.

Small producers' supply response to payments from MPP-Dairy may differ from their response under the MILC program. Under MILC, each additional pound of milk produced by a small operation would result in a larger total MILC payment, as long as production did not exceed a production cap. Since MPP payments are based on production history, and not current production, the program provides no additional payments for expanded production.

Coverage changes

MPP enrollees can vary their coverage choices annually, selecting higher cost choices in those years in which they expect low margins. That option can raise the net indemnities that enrollees can expect to realize over the course of the program by shifting program support from premium payments to Government outlays.

For example, consider a farm with 10 million pounds of annual milk production (equivalent to about 500 cows). If that farm chose to cover 90 percent of production history at an $8 margin, it would pay premiums of $87,100 per year; at the other extreme, it would pay $100 per year for catastrophic coverage only. Had MPP-Dairy been in effect during 2008-13 and if the farm had elected the highest level of coverage for each year, it would have realized net indemnity payments of $192,750 over the period, adding 32 cents per cwt to the farm's own milk-feed margin (consistent with the findings of Nicholson and Stephenson). However, the farm could have realized greater returns had it selected catastrophic coverage in 2008, 2010, and 2011, and chosen maximum coverage ($8/90%) in 2009, 2012, and 2013. In that case, the farm would have realized net indemnities of $420,600 over the period, or 70 cents per cwt of production, since it would have paid only the administrative charge in years that generated low indemnity payments. Thus, the potential benefits to active management of coverage election can be substantial.

During the initial signup period for MPP, the national-benchmark margin remained above $13 per cwt, until declining to $10.67 in December 2014. Forecasts made in late 2014 projected that benchmark margins would likely remain above $8 in 2015, with only small forecast probabilities of benchmark margins falling below that threshold, and much smaller probabilities of margins below $6.[52] Producers acted in accordance with those forecasts, as over 60 percent of covered production was placed in catastrophic coverage for 2015 (table 16), at minimal expense. In later years, if producers anticipate lower margins, they can purchase buy-up coverage for that year and move covered production to higher threshold margins.

Can producers forecast margins effectively enough to profitably switch between catastrophic and expanded coverage? Such active management can be risky: despite forecasts of margins well above $8, the actual national-benchmark margin fell below $8 for much of 2015, triggering small indemnity payments to producers who chose the $8 threshold margin.

Farmers had until December 2014 to choose coverage for 2015, but in future years they must elect coverage levels by September 30 of the preceding year. So, producers who wish to actively manage coverage will need useful forecasts of benchmark margin components 15 months into the future. There are no active futures markets for the all-milk price, alfalfa, or margins, but there are futures markets for corn and soybean meal, from which one can construct forecasts for alfalfa prices, and there are futures markets for Class III and Class IV milk, which can be used to forecast the all-milk price.

Bozic and colleagues (2012) used futures prices to forecast the national-average margin; the models forecasted the length of price cycles well over 1998-2011, but generally failed to capture the magnitudes of margin spikes and declines. Dairy and feed markets are uncertain and hard to predict. However, farmers do have access to a considerable amount of information on near-term expectations for margins, and there are strong incentives to develop more information to support MPP coverage decisions.

MPP and supply response

Supply response is a prime consideration in the design and performance of dairy programs. Programs can affect the returns to dairy production. Farmers adjusting production in response to changes in returns can affect market prices and net returns. Producer reactions can also affect Government outlays; supply responses to programs have greatly increased Government outlays under certain conditions, which have in turn led to changes in the programs.

[52]The Program on Dairy Markets and Policy, a group of university-affiliated dairy extension economists, provides 15-month-ahead forecasts of margins, based on futures prices, at dairymarkets.org. The interactive data tool generates probabilities of specific margins and expected net indemnities for different levels of coverage. Other organizations use a range of data sources to provide forecasts of prices and margins.

There are three ways in which MPP-Dairy might affect milk production. First, by reducing the financial risk faced by farmers, irrespective of any effect on average prices or margins, MPP-Dairy might induce higher milk supply for any level of prices (Chavas and Holt, 1990). Second, if MPP-Dairy creates higher average returns for farmers, this could also prompt increased production. In each case, the supply response would likely occur over years as farmers adjust herd sizes in response to program incentives. Third, during periods of low milk or high feed prices, dairy producers may reduce production by reducing herd size and by altering feed rations and milking practices to lower milk production per cow. That supply response to low margins is not very large in the near term, but it contributes to a recovery in prices and margins. If MPP insulates farmers against low margins, it may further mute their supply response to falling margins and thereby keep margins low for longer periods. In turn, extended periods of low milk prices could make higher MPP coverage levels more attractive to producers.

Under a cooperative research agreement with ERS, Burdine and colleagues (2014) evaluated the risk reduction potential of Livestock Gross Margin Insurance and the subsequent effect of risk reduction on milk supply. Risk was measured as the downside deviation from the median margin. Burdine and colleagues found that Margin Insurance could reduce farm financial risk considerably. However, they also found that risk had very small impacts on milk production. If those findings carry over to MPP-Dairy, then the likely effects of the program's risk reduction on production levels may be quite small.

If, on average, indemnity payments for MPP-Dairy were exceed premiums paid by dairy producers, the longrun impact on supply could be significant. Chavas and Klemme (1986) and Bozic et al. (2012) estimated longrun price elasticities of supply, for changes in milk prices, that are are close to 1.0; each 1-percent increase in the all-milk price, holding feed costs constant, could be expected to lead to a 1-percent increase in production over the long run—ten years. However, since MPP-Dairy indemnities are paid only on a share of historic production and are decoupled from current production, the supply response for the MPP-Dairy program is likely to be less than long-run responses to price changes. If MPP-Dairy provides positive net indemnities, it could raise expected long-run returns and could therefore affect investment and production in the industry. Increased production would place downward pressure on milk prices, leading to expanded MPP coverage and increased Government outlays.

Nicholson and Stephenson (2014a), hereafter N&S, evaluated the potential short- and intermediate-term impact of MPP-Dairy on production and prices. They apply a simulation model of the dairy sector, with separate components for farm milk supply and pricing, dairy processing, domestic dairy product demand, and dairy product trade. In their baseline model, farmers choose catastrophic coverage on 90 percent of production when they expect margins to exceed $8, cover 75 percent of production at a threshold margin of $6.50 when they expect margins to be between $4 and $8, and cover 90 percent of production, at an $8 margin threshold, when they expect margins to fall below $4. In short, all farmers enroll in MPP-Dairy and cover high shares of production, and they vary thresholds for margin coverage each year in light of expected margins.

In the baseline case, the program causes farmers' supply response to low prices to be attenuated compared to their already limited response. As a result, low prices and low margins last for a longer time once they do occur. N&S project a 5.4-percent reduction in the average all-milk price during 2015-18 under MPP-Dairy, and a 12.3-percent reduction in the national-average margin. Cumulative government payments amount to $3.5 billion over the period, and lower milk prices benefit domestic and foreign consumers through lower product prices.

The impact of MPP in the N&S model is quite sensitive to conditions in the agricultural economy. They simulate a "Major Impacts" alternative under the assumptions that feed prices are 25 percent higher over 2015-18 and that global demand for dairy products declines by 10 percent for a 12-month period starting in 2015. Without MPP-Dairy in that case, margins would decline sharply early in the period, and farmers would reduce milk production, leading eventually to a recovery in prices and margins. With MPP-Dairy in place, farmers' supply response to the initial reduction in margins is sharply attenuated, leading to a 16.2-percent decline in milk prices, a 37-percent decline in national benchmark margins over 2015-18, and an $8.2-billion increase in Government payments. The net indemnities that farmers receive under MPP-Dairy are more than offset by lower prices and margins, while domestic and international consumers benefit from lower product prices following increased production.

N&S contrast that finding to a "Limited Impacts" simulation, which envisions 25 percent lower feed prices over 2015-18 and a 10-percent increase in global demand for 12 months starting in 2015. In that case, the simulated impact of MPP-Dairy is to reduce the all-milk price by 0.8 percent, to reduce the benchmark margin by 1.6 percent, and to generate $1.4 billion in Government payments.

In these simulations, MPP-Dairy leads farmers to be less responsive to reductions in milk and feed prices than they would otherwise be. As a result, milk production is higher, and prices for farm milk and milk products are lower, than they would be without the program. Milk consumers, domestic and foreign, benefit from lower prices. Milk producers receive lower milk prices, but also receive expanded government support through net indemnities. The magnitude of each of these effects is highly contingent upon other developments in the broader dairy economy.

Program adjustments

The N&S simulations highlight several important elements of MPP design and farmer behavior that can affect the policy's impact. We have emphasized supply response—that is, the impact of policy and prices on milk supply—and the conditioning effects of the broader dairy economy.

However, enrollment also matters; in the N&S simulations, all farmers enrolled in the program, and they enrolled high shares of total production, so that the program's effects on supply applied to about 90 percent of milk production. The initial enrollments for MPP-Dairy include farms accounting for 80 percent of 2014 milk production, and 85 percent of their production is covered (table 16); thus, about 68 percent of U.S. dairy production could receive an MPP payment if margins fall below $4.

Actual enrollment, while substantial, is still well below that used in the N&S simulations, so that the likely supply effects of the program would be smaller. However, the difference in enrollment also alters the distribution of costs and benefits from the program. Specifically, farms that do not enroll forgo the expenses associated with premiums, but they also receive no indemnities when margins are low. If MPP-Dairy does lead to lower milk prices and longer periods of low margins, then farms that do not enroll will also bear the costs of lower prices. Smaller dairy farms have been less likely to enroll than larger ones.

The program is authorized through 2018, with reauthorization likely to be taken up in the next farm bill. Several key features of the program may be reviewed, including the timing and duration of coverage elections, the upper limits placed on coverage, the premium schedule for obtaining different levels of coverage, and mechanisms for handling structural change.

Currently, the U.S. Secretary of Agriculture specifies the time period in which coverage decisions are made. In the N&S simulations, farmers made a coverage election in December, just before the coverage went into effect, so they needed to estimate prices 12 months in advance to make a decision. In the actual MPP-Dairy program, 2015 coverage choices were made by December 2015. Coverage selection for 2016 was required by September 30, 2015, and coverage level selections for 2017 and 2018 will likewise be required by September 30 of the previous year.

Current options for coverage elections enable producers to shift program funding from producer-paid premiums to the Government by altering coverage and premium payments each year in accordance with expected risks. Earlier coverage elections, or longer coverage durations—committing to a choice for 2, 3, or 4 years instead of 1—could reduce exposure for the Government.

Catastrophic coverage applies to 90 percent of a farm's production history, and buy-up coverage extends up to 90 percent of production history. In principle, at least 10 percent of production history is uncovered by MPP and hence exposed to full market prices and margins, with consequent supply responses. Policymakers can alter the limits on MPP-Dairy production coverage and thus the shares of production exposed to market prices.

Premiums rise sharply at higher levels of coverage. Premiums are 5.5 cents per cwt to cover up to 4 million pounds of production history at a $6 margin. They rise to 15.5 cents per cwt for coverage exceeding 4 million pounds, and premiums for coverage in excess of 4 million pounds rise to 29 cents, 83 cents, $1.06, and $1.36 for incremental increases in margin coverage (to $8). Sharply higher premiums at the margin may induce farmers to leave more production uncovered, and hence responsive, to market price movements. Lower premiums could encourage more participation and allow producers to increase coverage.

Congress did not address structural change in MPP-Dairy legislation, and USDA, which sought comments on how to account for structural change in its implementation rulemaking, has yet to address the issue. Farms that transition to larger herds rarely do so by making marginal additions to their herds. Instead, they typically expand in bursts, by adding new milking, housing, and feed storage facilities along with hundreds, and occasionally thousands, of cows in a year.

Current rules do not provide for expansions in production history, and a farm that expanded its herd from 250 to 500 cows in 2015 would not be eligible for coverage on the additional production. The rules do allow new farms to establish a production history and secure MPP coverage, based on production in their initial months of operation. This disparity in treatment provides a clear advantage to newly established operations compared to existing operations, and the program could therefore have an effect on the structure of the U.S. dairy sector.[53]

[53]Correspondingly, a farm that reduced its herd size from 250 cows in 2012 to 150 in 2015 would still be able to purchase margin protection coverage based on its 2012 production. This might be financially attractive if MPP actually does return positive net indemnities over time.

Conclusion

U.S. dairy farming faces two major and ongoing changes. One is a structural change toward fewer but larger dairy farms, while the second is a change in dairy product consumption away from fluid milk products and toward manufactured products for domestic and international markets. The two changes interact with one another: structural change toward larger farms reduced industry average production costs and made U.S. dairy products more competitive in international markets, while change in product composition favors larger operations located away from population centers.

There are substantial price risks, and there is evidence that the risks have increased. Price risks are inherent in the economics of dairy markets, and expanded international trade may have added a new component of price risks arising from foreign demand and currency fluctuations.

Dairy policy has long focused on price risks; successive policies have adopted different methods for limiting the impacts of such risks and, at times, have shifted from risk management to income enhancement. The changes in farm structure and in product composition complicate the design of policy to manage price risks. Structural change has created a wide range of farm types, with much differing cost structures and differing financial impacts from any price shifts. Meanwhile, changes in product composition create a new set of international consumers and competitors.

Congress charted a major new direction in dairy policy in the Agricultural Act of 2014 when it introduced MPP-Dairy as a risk management program for dairy farmers. This is a large and complex program, and farmers must make some complicated decisions when choosing a level of enrollment. The program appears to offer value to dairy producers, judging from initial enrollments accounting for 80 percent of U.S. milk production, and model simulations suggest that the protections offered by the program could be more valuable in the future.

The potential effects of the program are subject to two major unknowns. The first concerns the impact of the program on milk production and prices, and hence on Government subsidies. If the program reduces the degree to which milk production responds to changes in milk prices, then it could lead to extended periods of low prices and increased Government support. Because the program was only recently enacted, and because of the complexity of the program's design, we lack strong evidence for the likely effects of the program on production, and will learn from experience.

The second unknown concerns the effect of the program on continued structural adjustment in the dairy sector. Structural change has been a large and constant force in dairy farming in recent years, and it has been partly responsible for increased productivity and improved international competitiveness in the industry. MPP-Dairy has not developed complete rules for handling structural change in the sector. Without rules for managing structural change, the program could reduce incentives to increase herd sizes. The program is designed to expire in 2018, and efforts to revise the program will have to consider structural change.

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Appendix A—Data

The quinquennial census of agriculture, administered by USDA's National Agricultural Statistics Service (NASS), provides comprehensive data on the size and location of U.S. dairy farms, and we use it to assess farm structure. Data on milk production and prices are drawn from monthly, quarterly, and annual NASS surveys, while feed price data are drawn from NASS and from reports by USDA's Agricultural Marketing Service. USDA's Farm Service Agency is the source of data on enrollment in the Margin Protection Program.

Our analysis also relies heavily on data drawn from an annual large-scale survey of U.S. farms, the Agricultural Resource Management Survey (ARMS). The ARMS, which is jointly administered by NASS and the Economic Research Service (ERS), links measures of farm financial performance to farm production and production practices and to farm household resources and finances.

The survey is designed to be comprehensive, covering all types of farms in the 48 contiguous States, and to be representative of U.S. agriculture. Phase III of the survey, conducted in the winter months following the reference year, focuses on farm production and financial outcomes. [54] We use two datasets derived from Phase III in this research.

The ARMS COP dataset

The 2000, 2005, and 2010 Phase III surveys included a dairy version of the questionnaire, with a sample designed to be representative of all dairy producers with at least 10 milk cows, located in 1 of 24 major dairy States. The dataset derived from this questionnaire is called the Cost of Production (COP) dataset, since its primary use is to provide baseline estimates of milk costs of production.[55] It provides detailed estimates of the costs and returns associated with dairy production, and it provides extensive data on production practices that cannot be obtained elsewhere. The 2010 Dairy COP dataset that we use consists of 1,332 farms.

The ARMS whole-farm finance dataset

All ARMS Phase III questionnaires elicit the financial information necessary to construct income statements and balance sheets for farms. Dairy farms are sampled in all ARMS Phase III questionnaire versions in every year and can be identified from questions on end-of-year milk cow inventories, annual milk production, and milk sales revenue. We developed the whole-farm finance dataset to track changes in dairy farm finances, with a particular focus on developments during the margin crash and recovery in 2008-2010. The measures refer to financial outcomes for the whole farm, including the dairy enterprise and any other crop or livestock enterprises that the farm might have. Dairy farms tend to be rather specialized, so changes in the dairy enterprise's finances drive whole-farm results for most of them.

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[54]Phase II of the survey focuses on production practices and resource use for selected field crops. Phase I is a screening survey, used to identify farms for selection into Phases II and III. More background on the ARMS, including copies of questionnaires, may be obtained at http://www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices.aspx.

[55]Congress requires USDA to provide annual estimates on milk costs of production. ERS provides estimates for baseline years from ARMS, and updates baseline data with NASS data on changes in input and product prices to estimate costs of production for non-baseline years. Readers may obtain more information on ERS milk COP estimates at http://www.ers.usda.gov/data-products/milk-cost-of-production-estimates.aspx.

In 2008, the full Phase III sample consisted of 34,000 farm operations, from which 21,816 useable surveys were obtained (a response rate of 64 percent). Of those, 1,454 were identified as dairy farms, because they realized most of their gross income from milk sales (appendix table A-1). Other years analyzed in this report have similar original sample sizes and response rates. The total number of dairy farm respondents varies from 1,284 (in 2009) to 3,352 (in 2010).[56] The survey is not a panel, with the same farms reporting in each year, but more aptly viewed as successive cross-sections.

Key measurement choices in the datasets

The full ARMS sample, used for the whole-farm finance dataset, is stratified into classes sorted by farm location, major commodity, and sales class, and sampling probabilities vary across strata. Each sample farm represents a number of other like farms and carries a sampling weight that allows us to generate population estimates for the measures of interest. Similarly, farms in the dairy COP version each carry a separate weight that allows us to generate population estimates for the COP version's universe (dairy producers with more than 10 cows in 24 dairy States). All of our analyses use the relevant sample weights to realize population estimates.

COP cost and return estimates and whole-farm dataset financial measures are reported as unit values for class and industry aggregates. For example, the estimates of total cost and the gross value of production, per cwt, reported in table 4 are the sum of total costs in each category, divided by the sum of production in each category. In the financial analyses of tables 12-13, feed expenses per cwt are the sum of feed expenses divided by the sum of production in a class.[57]

Appendix table A-1

Number of observations in finance & COP datasets

	Herd size (milk cows)							
	1-49	50-99	100-199	200-499	500-999	1000-1999	>1999	All
	Number of ARMS records for finance dataset							
2005	316	428	376	357	186	93	58	1,814
2006	200	357	308	322	216	95	50	1,643
2007	172	325	325	320	172	73	55	1,478
2008	96	303	315	291	167	85	54	1,454
2009	182	291	260	238	105	90	95	1,284
2010	828	936	653	433	173	159	111	3,352
	Number of ARMS records for cost-of-production (COP) dataset							
2005	316	428	376	357	186	93	58	1,814
2010	240	373	322	203	83	64	47	1,332

Source: USDA Agricultural Resource Management Survey (ARMS) The sample is drawn from all ARMS Phase III versions in 2006-2010, and from version 4 only in 2005 (other versions in 2005 did ask for the number of milk cows). More dairy farms were included in the ARMS sample in 2005 and 2010 because dairy versions were administered in those years.

[56]The total number of respondents is higher in 2010 because dairy farms were oversampled for the 2010 dairy COP version. We only use dairy version respondents for 2005 because other 2005 versions did not ask for the number of milk cows in dairy herds.

[57]The unit values reported in tables 4, 8, and 10-13 are therefore not simple averages across farms, adjusted for sampling weights, but are instead weighted by sampling weights and by production, to reflect industry outcomes. Tables 5-7 are simple averages across farms, adjusted for sampling weights, because we want to represent the average farm in those tables, and not the average unit of output.

The COP measures focus on the costs and returns to the farm's dairy enterprise, and not the financial performance of the whole farm. COP accounting therefore has to take account of transactions between the dairy enterprise and the rest of the farm. For example, the dairy enterprise may generate manure that is used as fertilizer, and that allows the farm's crop enterprise to reduce purchases of commercial fertilizer. The COP accounts estimate a value for the manure generated by the cows, and include that value as part of the gross value of dairy production (that is, noncash income to the dairy enterprise). Similarly, the COP accounts estimate a value for feed grown on the farm and provided to the dairy enterprise, and they include that value as a cost to the dairy enterprise (since it could have been sold off-farm).

The estimates of return on equity (ROE) in figure 18 are derived from the ERS farm financial accounts (appendix table A-2). The estimate starts with net cash farm income, the difference between cash revenues and cash expenses. Noncash expenses and nonmoney income are then added, along with an adjustment for the opportunity cost of unpaid family labor.[58] That gives us the numerator of the return on equity; the denominator is equity, the difference between farm assets and debt.

Appendix table A-2

Calculating return on equity (ROE) for dairy farms, 2010

	Herd size		
	All farms	100-199	>1999
	Dollars per hundredweight		
Gross cash income	18.58	20.64	16.46
minus cash expenses	14.57	15.89	12.91
equals Net cash farm income	4.01	4.75	3.55
minus noncash expenses	1.51	1.90	1.23
minus unpaid labor charges	2.64	4.21	0.49
plus nonmoney income	1.16	1.49	0.89
equals Returns per cwt	1.02	0.13	2.72
	Hundredweight of milk		
times milk production /$ equity	0.0206	0.0134	0.0663
	Percent		
equals Returns/equity (ROE)	2.10	0.17	18.0

Notes: Unpaid labor charges equal hours worked, per cwt of milk produced, by operator and other unpaid labor, charged at the State's average wage for hired labor, plus an adjustment for the management services provided by the operators, set at a constant percentage of net value added. Noncash expenses include depreciation and in-kind compensation of hired labor, while non-money income includes the imputed rental value of the operator's dwelling, commodities consumed by the operator household, and changes in inventories and accounts receivable.
Estimates are a weighted average of all farms in a class, where the weights are production (hundredweight of milk produced).

Source: USDA, Agricultural Resource Management Survey, all versions, 2010.

[58]About 75 percent of farms include the dwelling as part of the farm business, meaning that dwelling expenses are recorded as farm expenses. In these cases, it's important to capture the benefits provided by that asset.

Appendix B—Dairy Econometric Forecasting Model

ERS's "Quarterly Econometric Model for Short-Term Forecasting of the U.S. Dairy Industry" (Mosheim, 2012) was updated with data through the second quarter of 2014 and was re-specified and re-estimated. The model is used for in-sample forecasting and to derive up-to-date short- and long-term elasticities and other variables useful for dairy sector projections.

The original model had to be estimated in a block recursive fashion due to the small number of observations available at the time. In its present form, with more data at hand, the full model can be estimated at once using simultaneous equation methods. An additional equation, for heifer cows, was added to the model. The equations were estimated by seemingly unrelated regression methods. Identification tests were conducted to ensure that forecasts of elasticities could be obtained. After estimation, short- and long-term elasticities were calculated using the parameters of the dynamic specification of various equations. Specifically, this study derives the short- and long-term elasticities of (numbers of) cows and production per cow with respect to all-milk price and production per cow with respect to feed costs. It also presents elasticities of exports and commercial stocks with respect to relative international (average Europe and Oceania)-to-domestic prices for butter and NDM.

Updated model estimates are presented below. The model is composed of 16 behavioral equations and 7 identities. Equations 1-3 cover farm milk supply. Inverse supply equations for dairy products—cheese, nonfat dry milk, butter, and whey—are modeled by equations 4-7. The all-milk price equation (equation 8) is an inverse-derived demand equation for farm milk. Estimates of stocks, imports, exports, and net removals of aggregate dairy products on a fat basis and a skim solid basis are modeled in equations 9-16. Finally, seven identities define milk production and marketing (equations 17-18), the effective all-milk price (equation 18), international relative prices (equation 20), aggregate supply (equation 21), domestic commercial disappearance (equation 22), and the overall balance or equilibrium in the dairy industry defined by equation 23.

In the double logarithmic specification of the equations, the coefficients can be interpreted as elasticities. Parameters with a t-value greater than 1 were considered for specification purposes in order to minimize type II errors. Real values for the price and cost variables are determined by dividing current magnitudes by the GDP (gross domestic product) deflator. The EAMP variable (effective all-milk price, in equations 1, 3, 19) adds the all-milk price and the direct payments that result from the Milk Income Loss Contract (MILC) and net Livestock Gross Margin payments—defined as indemnity payments minus premiums plus subsidies.

Appendix table B-1

Variables and data sources in quarterly dairy forecasting model

Variable and units	Sources
COW, Number of Cows (1,000 head)	USDA National Agricultural Statistics Service (NASS), *Milk Production*
PPC, Production Per Cow (lb./head)	NASS, *Milk Production*
HEF, Number of Heifer Cows (1,000 head)	NASS, *Cattle*
AMP, All Milk Price ($/cwt)	NASS, *Agricultural Prices*
CHP, Cheese Price ($/lb.)	USDA Agricultural Marketing Service (AMS), *National Dairy Products Sales Report*
WHP, Whey Price ($/lb.)	AMS, *National Dairy Products Sales Report*
NDMP, Non Fat Dry Milk Price ($/lb.)	AMS, *National Dairy Products Sales Report*
BTRP, Butter Price ($/lb.)	AMS, *National Dairy Products Sales Report*
FUSE, Farm Use of Milk (Billion lb.)	NASS, *Milk Production, Disposition And Income*
MILC, Milk Income Loss Contract ($/cwt)	Farm Service Agency, Price Support—*Milk Income Loss Contract* http://www.fsa.usda.gov/FSA/webapp?area=home&subject=prsu&topic=mpp-mi
LGM, LGM-Dairy Indemnities (Net $/cwt)	Risk Management Agency, *Summary of Business: Data on Premiums, Subsidies and Indemnities*. http://prodwebnlb.rma.usda.gov/apps/SummaryOfBusiness
FC, Feed Cost ($/cwt)	Economic Research Service, *U.S. milk production and related data (Quarterly)* http://www.ers.usda.gov/datafiles/Dairy_Data/quarterlymilkfactors_1_.xls
TB, U.S. Treasury Bill (%)	*Market yield on U.S. Treasury securities at 10-year constant maturity*, Selected Interest Rates (Daily)-H.15, H15/H15/RIFLGFCY10_N.M (Unique Identifier)
SCP, Slaughter Cow Price ($/cwt)	Agricultural Marketing Service, *Cattle prices, monthly average. Sioux Falls boning utility cows, 800-1,200 lbs.* ($/live cwt, www.extension.iastate.edu/agdm)
CHQ, Cheese Quantity (lb.)	NASS, *Dairy Products*
WHQ, Whey Quantity (lb.)	NASS, *Dairy Products*
NDMQ, NDM Quantity (lb.)	NASS, *Dairy Products*
BTRQ, Butter Quantity (lb.)	NASS, *Dairy Products*
WG, Food Industry Wage ($/hour)	Bureau of Labor Statistics, A*verage Hourly Earnings of Production and Nonsupervisory Employees, Food Manufacturing, CEU3200000008*
EI, Törnqvist Price Index	Economic Research Service, using data from Energy Information Administration on prices and quantities for natural gas, propane, gasoline (refiner price), and electricity
STBFAT, Beg. Stocks Fat (Milk Equivalent)	NASS, *Cold Storage*
IMPFAT, Imports Fat (Milk Equivalent)	Economic Research Service, *Dairy at Glance* http://www.ers.usda.gov/datafiles/Dairy_Data/dairyglance.xls
EXPFAT, Exports Fat (Milk Equivalent)	Economic Research Service, *Dairy at Glance* http://www.ers.usda.gov/datafiles/Dairy_Data/dairyglance.xls
GOVNF, Net Removals Fat (Milk Equivalent)	Economic Research Service, *Dairy at Glance* http://www.ers.usda.gov/datafiles/Dairy_Data/dairyglance.xls
STBSS, Beg. Stocks Skim Solids, (Milk Equivalent)	Economic Research Service, *Dairy at Glance* http://www.ers.usda.gov/datafiles/Dairy_Data/dairyglance.xls
IMPSS, Imports Skim Solids (Milk Equivalent)	Economic Research Service, *Dairy at Glance* http://www.ers.usda.gov/datafiles/Dairy_Data/dairyglance.xls
EXPSS, Exports Skim Solids (Milk Equivalent)	Economic Research Service, *Dairy at Glance* http://www.ers.usda.gov/datafiles/Dairy_Data/dairyglance.xls

Continued—

Appendix table B-1

Variables and data sources in quarterly dairy forecasting model—continued

GOVNRS, Net Removals Skim Solids (Milk Equivalent)	Economic Research Service, *Dairy at Glance* http://www.ers.usda.gov/datafiles/Dairy_Data/dairyglance.xls
GDPDEF, Implicit GDP Deflator	Bureau of Economic Analysis, http://www.bea.gov/iTable/index_nipa.cfm
PCDI, Per Capita Disposable Income	Bureau of Economic Analysis BEA, Personal Income and Outlays, BEA Account Code: A229RC0
BTRPP, Europe, Oceania Butter Price ($/lb.)	AMS, *Dairy Market News*
NDMPP, Europe, Oceania NDM Price ($/lb.)	AMS, *Dairy Market News*
DQ1, Dummy Variable 1st Quarter	
DQ2, Dummy Variable 2nd Quarter	
DQ3, Dummy Variable 3rd Quarter	
t, time trend	
t2, time trend squared	

Appendix table B-2

Behavioral Equations, Quarterly Dairy Forecasting Model

Parameter estimates, with t-statistics in parentheses.

1. Cows:

$$\ln COW_t = \beta_1 \ln COW_{t-1} + \beta_2 \ln COW_{t-2} + \beta_3 \ln EAMP_{t-2} + \beta_4 \ln FC_{t-2} + \beta_5 \ln SCP_{t-2} + \beta_6 t^2 + \beta_o$$

1.27 -0.40 0.01 -0.009 -0.04 0.000003 1.09

(14.24) (-4.25) (4.46) (-3.40) (-1.72) (4.49) (2.98)

2. Heifer Cows:

$$\ln \mathrm{HEF}_t = \beta_1 \ln \mathrm{HEF}_{t-1} + \beta_2 \ln \mathrm{HEF}_{t-2} + \beta_3 \ln SCP_t + \beta_4 DQ1 + \beta_5 DQ2 + \beta_6 DQ3 + \beta_7 t + \beta_o$$

0.98

-0.47 - 0.02 -0.03 -0.10 - 0.08 0.002 4.21

(9.33) (-4.56) (-1.34) (-2.46) (-8.60) (-13.97) (5.83) (6.49)

3. Production per Cow:

$$\ln PPC_t = \beta_1 \ln PPC_{t-1} + \beta_2 \ln PPC_{t-2} + \beta_3 \ln PPC_{t-3} + \beta_4 \ln EAMP_{t-2} + \beta_5 \ln FC_{t-2} + \beta_6 DQ2 + \beta_7 t + \beta_o$$

0.19 -0.30 0.34 0.03 -0.03 0.04 0.003 6.42

(2.99) (-6.08) (4.91) (3.02) (-4.12) (12.12) (5.79) (5.36)

4. Inverse Supply of Cheese:

$$\ln CHP_t = \beta_1 \ln BTRP_t + \beta_2 \ln WHP_{t-3} + \beta_3 \ln WG_t + \beta_4 \ln EI_{t-2} + \beta_5 \ln TB_t + \beta_6 \ln CHQ_{t-4} + \beta_7 DQ1$$

0.63 0.23 2.41 0.22 0.22 0.51 -0.07

(11.98) (6.83) (3.23) (2.39) (3.58) (3.79) (-2.89)

$$+\beta_8 DQ2 + \beta_9 DQ3 + \beta_{10} t + \beta_{11} t^2 + \beta_o$$

-0.07 -0.03 -0.01 0.0002 -15.91

(-2.57) (-1.27) (-2.21) (2.24) (-4.88)

5. Inverse Supply of Butter:

$$\ln BTRP_t = \beta_1 \ln CHP_t + \beta_2 \ln NDMP_t + \beta_3 \ln WHP_t + \beta_4 \ln WG_{t-4} + \beta_5 \ln TB_{t-4} + \beta_6 \ln BTRQ_{t-4}$$

1.02 -0.53 0.27 3.65 0.38 0.06

(10.65) (-5.15) (5.40) (4.57) (4.28) (1.04)

$$+\beta_7 t + \beta_8 t^2 + \beta_o$$

-0.01 0.0002 -10.91

(-2.75) (3.39) (-4.55)

6. Inverse Supply of NDM:

$$\ln NDMP_t = \beta_1 \ln NDMP_{t-1} + \beta_2 \ln BTRP_{t-1} + \beta_3 \ln WHP_t + \beta_4 \ln WG_{t-1} + \beta_5 \ln TB_{t-1} + \beta_6 \ln NDMQ_{t-1}$$

0.71 -0.15 0.31 2.14 0.14 0.04

(15.10) (-3.57) (9.12) (3.85) (2.45) (1.13)

$$+\beta_7 t^2 + \beta_o$$

0.000005 -6.88

(0.25) (-4.61)

7. Inverse Supply of Whey:

$$\ln WHP_t = \beta_1 \ln WHP_{t-2} + \beta_2 \ln BTRP_t + \beta_3 \ln CHP_t + \beta_4 \ln EI_{t-4} + \beta_5 \ln TB_t + \beta_6 \ln WHQ_{t-2}$$

0.52	0.84	-0.68	0.47	0.41	0.38
(5.46)	(4.70)	(-2.86)	(2.28)	(2.73)	(1.61

$$+ \beta_6 t + \beta_7 t^2 + \beta_o$$

-0.04	0.0007	-8.26
(-2.32)	(3.34)	(-1.91)

8. All-Milk Price:

$$\ln EAMP_t = \beta_1 \ln COW_t + \beta_2 \ln PPC_t + \beta_3 \ln NDMP_t + \beta_4 \ln CHP_t + \beta_5 \ln WHP_{t-1} +$$

-1.16	-0.44	0.23	0.46	0.03
(-2.27)	(-4.97)	(9.39)	(14.98)	(2.15)

$$\beta_6 \ln BTRP_t + \beta_7 \ln FC_t + \beta_o$$

0.09	0.14	6.61
(4.13)	(6.29	(3.47)

9. Beginning Commercial Stocks (Fat Basis):

$$\ln STBFAT_t = \beta_1 \ln STBFAT_{t-1} + \beta_2 \ln BTRPT_{t-4} + \beta_3 \ln PCDI_{t-1} + \beta_o$$

0.31	0.16	2.85	-28.19
(3.66)	(3.20)	(5.34)	(-5.13)

10. Imports (Fat Basis):

$$\ln IMPFAT_t = \beta_1 \ln IMPFAT_{t-1} + \beta_2 \ln BTRPT_{t-1} + \beta_o$$

0.35	0.18	0.05
(3.38)	(2.92)	(1.80)

11. Exports (Fat Basis):

$$\ln EXPFAT_t = \beta_1 \ln EXPFAT_{t-1} + \beta_2 \ln BTRPT_{t-3} + \beta_o$$

0.70	-0.40	0.14
(9.41)	(-3.13)	(2.59)

12. Fat Net Removals (Fat Basis):

$$GOVNRF_t = \beta_1 GOVNRF_{t-1} + \beta_2 GOVNRF_{t-2} + \beta_3 \ln PCDI_{t-1} + \beta_o$$

0.60	-0.35	-0.70	7.37
(5.68)	(-3.38)	(-2.86)	(2.87)

13. Beginning Commercial Stocks (Skim Solid Basis):

$$\ln STBSS_t = \beta_1 \ln STBSS_{t-1} + \beta_2 \ln NDMPT_{t-2} + \beta_3 \ln PCDI_{t-1} + \beta_o$$

0.50	0.08	1.36	-13.09
(7.72)	(1.90)	(5.30	(-5.02)

14. Imports (Skim Solid Basis):

$$\ln IMPSS_t = \beta_1 \ln IMPSS_{t-4} + \beta_2 \ln NDMPT_{t-1} + \beta_o$$

0.86	0.52	- 0.08
(15.85)	(3.95)	(-2.83)

15. Exports (Skim Solids Basis):

$$\ln EXPSS_t = \beta_1 \ln EXPSS_{t-1} + \beta_2 \ln NDMPT_{t-2} + \beta_o$$

0.92	-0.16	0.15
(22.25)	(-1.73)	(2.32)

16. SS Net Removals Block (Skim Solids Basis):

$$GOVNRS_t = \beta_1 GOVNRS_{t-1} + \beta_2 GOVNRS_{t-2} + \beta_3 \ln PCDI_{t-1} + \beta_o$$

0.83	-0.39	-7.60	79.94
(8.98)	(-4.28)	(-4.43)	(4.45)

Identities

17. Milk Production

$$MILK_t = COW_t * PPC_t$$

18. Marketing

$$MKT_t = MILK_t - FUSE_t$$

19. Effective All-Milk Price

$$EAMP_t = AMP_t + MILC_t (MPP_t) + \text{LGM-Dairy}_t$$

20. Relative Domestic to International NDM and Butter Prices:

$$NDMPT_t = \frac{NDMP_t}{NDMPP_t}, \quad BTRPT_t = \frac{BTRP_t}{BTRPP_t}$$

21. Total Supply

$$TS_{ti(i=FAT,SS)} = MKT_t + STB_{ti(i=FAT,SS)} + IMP_{ti(i=FAT,SS)}$$

22. Domestic Commercial Disappearance

$$DCD_{ti(i=FAT,SS)} = TS_{ti(i=FAT,SS)} - STE_{ti(i=FAT,SS)} - EXP_{ti(i=FAT,SS)} - GOVNR_{ti(i=FAT,SS)}$$

23. Overall Balance

$$0 = (MILK_t - FUSE_t - DCD_{t\,(i=FAT,S\ )} - GOVNR_{t\,(i=FAT,S\ )}) + (STB_t - STE_t)_{(i=FAT,S\ )} + (IMP_t - EXP_t)_{(i=FAT,S\ )}$$