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# Livestock Gross Margin-Dairy Insurance: An Assessment of Risk Management and Potential Supply Impacts

Kenny Burdine  
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Don P. Blayney  
Leigh J. Maynard





United States Department of Agriculture

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## Abstract

Public risk management policies for dairy producers have the potential to induce expansion in milk supplies, which might lower farm-level prices and offset risk-reduction benefits. An evaluation of USDA's Livestock Gross Margin-Dairy (LGM-Dairy) insurance program finds economic downside risk significantly reduced, with potential to induce modest supply expansion (0 to 3 percent) if widely adopted. Supply impacts are likely limited due to relatively low participation levels and a minimal ("inelastic") supply response to risk. LGM-Dairy is more flexible and convenient than other risk management tools, such as hedging directly in futures or options markets, especially for small farms.

**Keywords:** dairy, gross margins, risk management, LGM-Dairy, insurance, milk supplies, livestock

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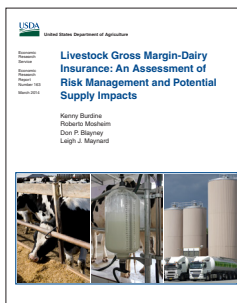
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# Livestock Gross Margin-Dairy Insurance: An Assessment of Risk Management and Potential Supply Impacts

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## What Is the Issue?

Livestock Gross Margin-Dairy (LGM-Dairy) is a risk management tool that enables dairy producers to purchase insurance against decreases in gross margins—the difference between revenues and feed costs. LGM-Dairy offers features seen in only a few other insurance and risk management tools. As a type of index insurance that makes payments based on broader market conditions rather than individual farm outcomes, it reduces the likelihood of common insurance problems such as riskier behavior by the insured to increase indemnities (“moral hazard”) or information gaps that make it difficult for the insurer to determine appropriate premiums (“adverse selection”). It also gives dairy producers the ability to insure a margin, not just the output price. Lastly, LGM-Dairy is available through local insurance agents and is offered in scales appropriate for any size dairy operation. Less appealing to producers may be the very short buying period for an LGM-Dairy contract and the program’s rules and specifications.

The introduction of LGM-Dairy in 2008 coincided with increased market volatility in both input (feed) and output (dairy) prices, making it an attractive risk management tool. However, funding allocated to all Federal Crop Insurance Corporation livestock insurance programs for expenses that include administrative and operating (A&O) subsidies and premium subsidies paid by the Government on behalf of participating producers is limited to \$20 million per reinsurance year, which prevents producers from using LGM-Dairy insurance as a year-round risk management strategy.

Initial and ongoing 2012 farm bill legislative efforts included a dairy margin insurance plan similar to LGM-Dairy but with different operating parameters. Among the key differences are the levels of margins to be insured and the determination of premium rates. Information on the effectiveness of the existing LGM-Dairy program as a risk management tool and its impact on milk supplies will help inform continued efforts to understand the impacts of policies for dairy risk management.

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## What Did the Study Find?

Among the key findings of the economic analysis are:

- Had LGM-Dairy been widely available during the entire period studied (2001-11), reductions in risk would have ranged from 28 to 39 percent in the 13 dairy-producing regions analyzed.
- While the risk reductions were significant, use of LGM-Dairy was shown to have little effect on the average producer margins across regions, which would have changed by -1 to 2 percent.
- Based on the estimated risk-reduction levels, and risk elasticities derived from the literature and risk modeling, the potential for LGM-Dairy to induce an expansion in milk supplies, if it had been more widely available and adopted, was modest across regions, ranging from 0 to 3 percent. The upper end of this range is unlikely because producer participation has been far below 100 percent to date, and because the upper estimate requires producer supplies to respond strongly to changes in risk. The main incentive for producers to expand supply comes from subsidies currently offered on the LGM-Dairy insurance premiums.

Generally, results suggest that insuring both output prices and feed costs is more effective for managing risk than insuring output prices alone and appears to produce similar risk management performance across the selected regions. LGM-Dairy, as a gross margin insurance program, is more flexible in terms of coverage than other risk management tools, such as hedging in futures or options markets, which likely makes LGM-Dairy more attractive for small farms.

## How Was the Study Conducted?

The study consisted of two parts, the first of which was an analysis of the effectiveness of LGM-Dairy as a risk management tool. Using monthly cash and futures prices for milk, corn, and soybean meal, researchers calculated gross margins (milk price minus feed costs) with and without the use of LGM-Dairy as a risk management tool. Although the program was established in 2008, outcomes were simulated using data from January 2001 to April 2011.

The second component was estimating the likely effects of risk reduction on milk production. Researchers collected milk production data from multiple sources for a subset of the period used above (first quarter 2006 to fourth quarter 2010). Regression analysis was employed to estimate production response to market risk. Results from supply modeling were used in conjunction with results from risk estimation to evaluate the likely impacts on production.

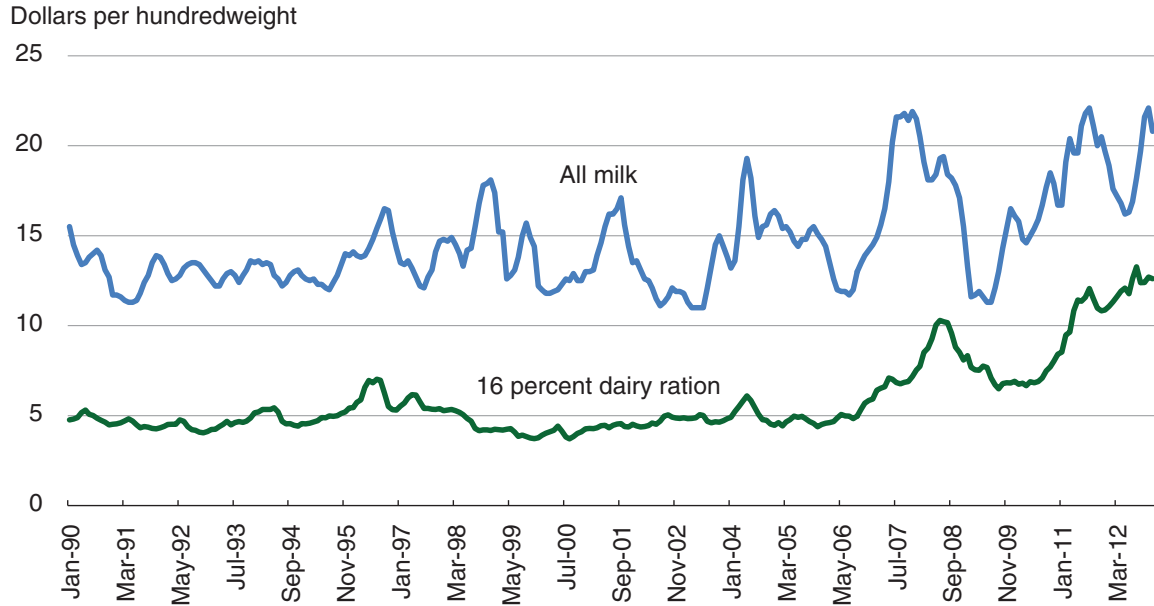
# Livestock Gross Margin-Dairy Insurance: An Assessment of Risk Management and Potential Supply Impacts

## Introduction

Over the last 20 years, producers of all agricultural products have increasingly faced challenges stemming from price volatility. Dairy producers have faced rapidly changing milk prices and input prices, primarily for feeds, and the associated impacts of those changes on profitability. The monthly average U.S. all-milk price was highly volatile from 1990 to 2012, particularly during the later years of that period (fig. 1). Factors that may account for the increasing variability in milk prices include increased U.S. involvement in, and dependence on, export markets and weather events in both the United States and Oceania (Australia and New Zealand) that affected production and dairy stock levels. More recently, dairy producers also faced higher feed costs that affected operational and investment decisions.

Traditional price risk management tools, such as forward contracting and the use of futures and options markets, present opportunities to manage the risks associated with price volatility, but they also present challenges. Dairy producers generally have struggled to adopt futures and options trading as a means of price protection. The futures contracts available are only a cross-hedge opportunity for the all-milk price, with a very uncertain basis risk (see glossary). And, scale issues often

Figure 1  
**Average U.S. all-milk price and feed costs**



Sources: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service and Gould (2011).

prevent smaller dairy operations from using milk futures and options (Harwood et al., 1999). The Livestock Gross Margin for Dairy (LGM-Dairy) insurance program was initially developed in response to these challenges.

LGM-Dairy is a relatively new public risk management program overseen by USDA's Risk Management Agency (RMA). It was designed to reduce the negative effects of milk and feed price volatility on U.S. dairy farms (USDA, Risk Management Agency, 2010a) and was first made available in June 2008 for the 2009 livestock reinsurance year and has been available for each reinsurance year since that time.

This study explores whether LGM-Dairy is likely to induce an expansion in the supply of milk if widely adopted. The aggregate demand for farm-level milk is price-inelastic, implying that aggregate dairy farm revenues fall when the milk supply increases (i.e., the supply curve shifts out (to the right)). The study's authors compare historical gross margins over several years with the corresponding outcomes had LGM-Dairy been employed to estimate the degree of risk reduction. They also use supply impact parameters from the literature (Chavas and Holt, 1990; Bakhshi and Kerr, 2009; Lin and Dismukes, 2007) and from original supply modeling within this work to estimate the impact on milk supplies corresponding to the estimated risk reduction level under LGM-Dairy.



## Background

Until recently, output (milk) price risk management was not a key element of decisionmaking by milk producers. This stems from public policies initiated in the 1930s that have generally precluded the need for dairy farmers to address issues related to risk management. Until the passage of the Agricultural Act of 2014, those policies and programs remained in place today, although in modified forms.<sup>1</sup> One such program, Dairy Price Support (DPS), was established in the 1949 Farm Act and lasted in its original form until enactment of the 2008 Farm Act.

The DPS program essentially provided downside price protection by supporting producer milk prices at or above a specified level. This price support was achieved through Government purchases of “surplus” dairy products (American cheese, butter, and nonfat dry milk) at prices announced by USDA, effectively removing the products from the domestic market. While not necessarily preventing milk prices from falling below the support price, the program did help ensure that such low prices would not persist. The program truncated the milk price distribution at the support price level, at least until the early 1990s. At that time, the support prices began to be phased down to such low levels that they rarely trigger sales to the Government and thus provide minimal downside risk protection.

Other policies and programs that have been implemented were designed to provide dairy producers with added income if milk prices were low. These programs included dairy herd buyouts, the Milk Income Loss Contract (MILC), and the Dairy Export Incentive Program (DEIP).

### The Dairy Options Pilot Program

Over time, agricultural price policy prescriptions have shifted from direct payments and price supports toward promoting the use of market-based price risk management tools (FAPRI, 2012). Futures and options strategies are commonly used in some agricultural sectors; however, futures and options markets are generally thin for dairy products. In 1999, a Dairy Option Pilot Program (DOPP) was launched to educate milk producers about the use of options and thereby increase the effectiveness of these risk management tools. Findings suggest that DOPP did increase the volume of dairy options traded but also increased their price (Bushena and McNew, 2005).

Other studies suggest that risk reduction could be achieved through the use of dairy futures and options but that several factors limit the effectiveness of such a strategy. First, hedging is most effective in those areas where milk use in cheese production, referred to as class III milk, was greatest; contracts for class IV milk, the milk used for butter and nonfat dry milk production, are generally more thinly traded. Second, findings on futures market indicators, particularly hedge ratios (Stoll and Whaley, 1993), by Maynard et al. (2005) suggest that use of futures and options as a risk management strategy is most practical for very large (high volume) operations. Third, there continues to be a perception that existing public milk pricing policy limits the need for price risk management (Maynard et al., 2005).

Lastly, how does one assess the degree to which the DOPP met its goal of educating dairy producers. Such an assessment is always a challenge when introducing a new marketing tool. Previous research suggests that comprehensive training on put options increased the comfort level of producers, but

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<sup>1</sup>The analysis presented in this study preceded passage of the Agricultural Act of 2014.

many producers felt they required even more training. Also, many producers still saw using futures and options as a gamble rather than a price risk management tool (Ibendahl et al., 2002).

## Livestock Gross Margin-Dairy Insurance Program

The LGM-Dairy program is an insurance product that provides compensation to dairy producers for qualifying losses paid under the product's specifications (for more information on the program, see box, "How Does LGM-Dairy Work?"). It is one of the array of price risk management tools for livestock provided under the auspices of the Federal Crop Insurance Act, as amended, and offers features seen in few other previous insurance and risk management products. First, LGM-Dairy is a type of index insurance, a characteristic that reduces the likelihood of two common problems associated with insurance—moral hazard and adverse selection (Barnett, 2004). In the case of LGM-Dairy, indemnities are based on futures prices for class III milk, corn, and soybean meal rather than on actual prices received for milk and paid for the feed inputs.<sup>2</sup>

Second, unlike futures and options on milk prices alone, LGM-Dairy offers dairy producers the opportunity to insure a margin similar to employing a "bundled option strategy" (see glossary). The milk price is only one piece of a milk producer's measure of profitability and while basis risk certainly remains, the mechanics of LGM-Dairy provide protection from both a decrease in milk prices and an increase in feed costs.

Third, LGM-Dairy availability through insurance agents rather than commodity futures brokers is perhaps a more preferable arrangement for dairy producers, and the product is offered in levels of coverage appropriate for any size dairy. Finally, increased dairy market volatility preceded the introduction of LGM-Dairy, which made the product more attractive as a risk management tool.

However, the capacity of the LGM-Dairy insurance program is limited. Funds allocated to the livestock insurance programs offered by the Federal Crop Insurance Corporation (FCIC), including LGM-Dairy, have been legislatively capped at \$20 million per reinsurance (fiscal) year for administrative and operating (A&O) subsidies, an amount that could potentially be depleted quite quickly. In fact, the FCIC funds initially allocated to livestock insurance programs for the 2012 reinsurance year were exhausted by December 2011, with sales not expected to resume until October 2012 (USDA, Risk Management Agency, 2011). The various RMA livestock insurance programs, including LGM-Dairy, were reauthorized for the 2013 reinsurance year. It has been suggested that the limited funding and inconsistent availability have prevented producers from using LGM-Dairy insurance on a regular basis (Wright, 2012).

LGM-Dairy was first made available for the 2008 reinsurance year (October 2007-September 2008). The milk volume covered accounted for only a small share of total milk production during the period, measured in billions of pounds. Total milk volumes covered by LGM-Dairy policies have grown but are still relatively small (table 1). The liability has also increased since the product was introduced, and LGM-Dairy policies in 2012 accounted for almost 97 percent of the livestock policies purchased.

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<sup>2</sup>Contract specifications can be found at: [www.cmegroup.com](http://www.cmegroup.com).

## How Does LGM-Dairy Work?

The complete instructions for purchasing Livestock Gross Margin-Dairy (LGM-Dairy) products can be found at <http://www.rma.usda.gov/livestock/>. A short summary is provided here. LGM-Dairy is similar to a “bundled option strategy,” purchasing a put option on class III milk futures as well as call options on corn and soybean meal futures. For a short window of time each month, from the last business Friday of each month until the next evening, producers can purchase the insurance for a 10-month period beginning with the second month after the offering month. For example, on the last business Friday of March, coverage can be purchased for milk produced the following May through February.

When insurance is purchased, the producer specifies the amount of milk that he or she produces and plans to insure, as well as expected quantities of corn and soybean meal (SBM) to be fed to reach that level of milk production. There are default values for feed usage, as well as minimums and maximums that can be declared. The prices for milk, corn, and SBM used to determine the margin guarantee are based on a 3-day average of futures market closes for those 3 contracts in the offering month. Following the previous example, on the last business Friday in March, the margin guarantee for the months of May through February would be based on the respective nearby futures closes for each of the 10 contract months for those 3 commodities for the last business Wednesday of March through the last business Friday of March. For example, if on the last business Wednesday-Friday of March, the May class III futures closes were \$16, \$17, and \$18 per hundredweight (cwt), the guarantee price for May would be based on the average, or \$17 per cwt. This same approach is used for corn and soybean meal futures.

As opposed to the guaranteed gross margin, the actual gross margin is later determined by the 3-day average settlement price for class III milk, corn, and SBM on the last 3 trading days of that month. For example, the actual gross margin for June is determined by the prices on the last 3 trading days of June. The indemnity received is the difference in the guaranteed gross margin and the actual gross margin, minus any applicable deductible. Producers can choose to insure their gross margins for any time period within the available 10 months. For example, a producer could insure over the entire 10 available months or choose any number or combination of months to insure. Regardless, indemnities are paid at the end of the insured period whether it is the full 10-month period or a single month.

It is also important to note that indemnities are paid on a gross basis. For example, a producer who insured his or her gross margin in each of the 10 months separately might well receive an indemnity in only 2 or 3 months of the entire period. Conversely, if the same producer chooses to insure the gross margin for the entire 10 months, he or she may not receive an indemnity at all as better months may offset the effect of the weaker months in aggregate (Gould and Cabrera, 2011). This difference is reflected in the premium paid by the producers.

Table 1

**Summary statistics related to Livestock Gross Margin-Dairy insurance policies**

Reinsurance year	Amount covered	Share of U.S. production	Liability	LGM-Dairy share of all LGMs
	<i>Cwt</i>	<i>Percent</i>	<i>Million \$</i>	<i>Percent</i>
2009	401,680	0.02	4.7	10.5
2010	1,872,499	0.10	24.9	31.9
2011	46,172,815	2.37	869.6	81.3
2012	40,504,408	2.03	704.5	96.5
Partial 2013	34,188,752	NA	600.0	89.4

LGM = Livestock Gross Margin. cwt = hundredweight. NA = Not available.

Source: USDA, Economic Research Service using data from Federal Crop Insurance Corporation.

## Supply Response and Risk Management

Much of the analysis of agricultural product supply response to risk is based on the work of Chavas and Holt (1990), who modeled corn and soybean acreage decisions by potentially risk-averse producers as a function of price variances and covariances. Chavas and Holt found evidence of wealth effects, implying decreasing absolute risk aversion, some price variance terms were significant, and nontrivial acreage responses were predicted for price support programs.

Bakhshi and Kerr (2009) modified the Chavas and Holt (1990) methodology to isolate insurance effects from market and wealth effects in an application to Canadian field crops. The insurance effects were statistically and economically significant, prompting the authors to conclude that decoupled government payments were production distorting, in conflict with their World Trade Organization (WTO) Green Box status. Lin and Dismukes (2007) also found statistically and economically significant impacts of revenue risk on both soybean acreage and the share of crop acreage planted to soybeans. Not all studies produced evidence of supply response to risk. Luh and Stefanou (1989) found no evidence of supply response to risk based on data from Pennsylvania dairy farms during 1977-84, and Liang et al. (2011) found revenue variance responses with small magnitudes.

## Methods Used To Estimate Risk Reduction and Supply Impact

As mentioned in the summary, this study addresses two primary questions. First, how effective is LGM-Dairy as a margin risk management tool? To make that assessment, researchers developed a simulation approach based on examining historical margins and the effects of LGM-Dairy on those margins had the product been in place. Second, assuming risk reduction is achieved, how much of an impact on production (milk supply) would be expected as a result? For information on the approach used to determine the efficacy of LGM-Dairy, see box “Formulating the Model for Gross Margin Risk Analysis” and the results that follow. The supply impacts are discussed in the section “Results From Estimating the Risk Elasticity of Supply.”

To summarize, the model underlying the simulation approach is based on risk being defined as the downside squared deviation from a median gross margin. In turn, the gross margin is defined as the milk price minus a feed cost using default feed quantities for corn and soybean meal. Aggregate gross margins are estimated for 13 regions over successive 10-month periods from January 2001 to April 2011, both with and without LGM-Dairy insurance.

The aggregate gross margins constructed for each region using regional mailbox milk prices (net prices received), a regional corn price where available, and national soybean prices represent the “without LGM-Dairy margin insurance” case. The estimates of the gross margin “with the margin insurance” are derived by subtracting insurance premiums and adding indemnities to the aggregate margins estimated without the LGM-Dairy margin insurance.

The analysis relies on two other key assumptions: (1) that LGM-Dairy margin insurance was available each month, and (2) that the milk producers chose to cover 100 percent of their milk production each month over 10 successive 10-month periods. The downside margin risk reduction associated with the assumed LGM-Dairy availability and production coverage is determined for each region.

## Formulating the Model for Gross Margin Risk Analysis

The presumption that using LGM-Dairy does reduce milk producers' risk means the analyst(s) must choose how to define "risk." Often, deviation from some measure of central tendency is selected as that definition. However, milk supply is expected to respond negatively only to downside risk, so only the downside deviations were considered. The other choice to be considered is the measure of central tendency. The mean is often the initial choice, but it may not represent typical outcomes if the distribution of gross margins is heavily skewed. Instead, deviations from the median gross margin were used.

A convention of measuring risk using root mean squared deviations that weight large deviations more heavily than small deviations is applied. Lastly, risk is measured over each 10-month LGM-Dairy contract period, and it is assumed that the producer purchases pooled insurance every month, with each contract representing 10 percent of production during the 10-month contract period (essentially a moving average approach). In this way, 100 percent of each month's production is insured over 10 successive, overlapping LGM-Dairy contract periods. To summarize, risk is defined as root mean squared downside deviations from the median gross margin as defined in LGM-Dairy over a 10-month contract period.

## Estimating the Gross Margin Risk for Dairy Producers

Participation in LGM-Dairy requires payment of insurance premiums. The premiums were calculated from the same simulation data used to construct the actual LGM-Dairy premiums. The data are posted at the "Understanding Dairy Markets" website (Gould, 2011) under the section "Underlying Data." The calculation methods follow the guidelines in place since December 17, 2010 (USDA Risk Management Agency, 2010b), and the scenario calculated assumes the default feed ration values of 0.5 bushels (bu) of corn and 4 pounds of soybean meal per hundredweight (cwt) of milk produced, pooled coverage for 10-month contract periods, and a zero deductible.

For each month in each contract period, 5,000 simulated prices of milk, corn, and soybean meal were provided, allowing the calculation of 5,000 simulated "actual" gross margin values. By comparing these values to the gross margin guarantee value for the corresponding contract period, 5,000 simulated indemnities were calculated. The average of the simulated indemnities, plus a 3-percent load, represented the unsubsidized premium used in the analysis. For reference, premiums were also calculated that included an 18-percent subsidy, which as of June 2013 is associated with a zero deductible (USDA, Risk Management Agency, 2009). Actual policies purchased by farmers spanned a range of deductibles.

After accounting for the premium that is paid with certainty, the remaining impact of participation is indemnity payments, which occur when the Actual Gross Margin falls below the Gross Margin Guarantee. Historical data from January 2001 through April 2011 were used to calculate margins and indemnities from January 2002 to May 2010 as if LGM-Dairy had been in place during the entire period. The calculations follow the default feed coefficients and other contract specifications used in 2011 and do not use prior calculation methods, such as the basis adjustments for milk and corn that were used before July 2009. A zero deductible was assumed so the maximum risk reduction could be evaluated. With no deductible, the Gross Margin Guarantee is equal to the Expected Gross Margin.

The Gross Margin Guarantee is the sum over each 10-month contract period of monthly gross margins calculated from appropriately deferred futures prices for class III milk, corn, and soybean meal. The historical deferred futures prices are conveniently collected online in the "Underlying Data" section of Gould (2011). Gross margin guarantee calculations were performed using assumed parameters for the milk quantity insured (1 cwt), a zero deductible, and default feed coefficients of 0.5 bu/cwt for corn and 0.002 ton/cwt for soybean meal.

The Actual Gross Margin was calculated using the same parameters and formulas, again using historical data provided online by Gould (2011). In this case, “actual” prices represent the average of the final 3 days of milk, corn, or soybean meal futures settlement prices before expiration. For months with no futures contract, a weighted average of surrounding months is used instead. At this point, indemnities were calculated.

The term “Actual Gross Margin,” while necessary for the calculation of indemnities, does not describe the gross margin realized by an individual producer in a specific location. The effectiveness of LGM-Dairy at reducing gross margin risk might vary widely across space, especially in locations or times where the class III prices represented less than the majority of the all-milk price. For clarity, a producer’s local gross margin is referred to here as “Realized Gross Margin.” The most feasible way to approximate Realized Gross Margin is to use region-specific mailbox milk prices, available online from Gould (2011), and State-level monthly average corn prices where possible (USDA, National Agricultural Statistics Service, various years). National average soybean meal prices are used, as the 10 cash markets for which USDA’s Agricultural Marketing Service collects soybean meal prices align poorly with the regions evaluated in the present analysis.

Just as producers who hedge in futures and options markets face basis risk, participants in LGM-Dairy face an analogous risk in that changes in realized gross margins may not be highly correlated with indemnity payments. There are two causes of potentially low correlation, the first being that national-level class III milk and corn price changes are imperfectly correlated with State- and regional-level price variation. The second cause is that indemnities do not necessarily occur when absolute gross margin levels fall; indemnities occur when gross margins fall from higher expected levels during the life of an insurance contract. One can receive indemnities when gross margins are high but not as high as expected, and one can fail to receive indemnities when gross margins are very low. This is the nature of using futures and options markets as elements of the insurance product.

Historical monthly mailbox milk prices were gathered for the following available regions: Northwest, California, New Mexico, Texas, Minnesota, Wisconsin, Illinois, southern Missouri, Michigan, Ohio, Kentucky, Florida, and New England. State-level monthly-average corn prices were available for a subset of these regions: Texas, Minnesota, Wisconsin, Illinois, Missouri, Michigan, Ohio, and Kentucky. Regional Realized Gross Margins were approximated using as much localized data as were available, and these represent outcomes without participation in LGM-Dairy. Indemnities were added to the Realized Gross Margins, and premiums were deducted, to calculate the net Realized Gross Margins with participation in LGM-Dairy.

Regional average Realized Gross Margins, with and without participation, were next calculated over the period January 2002 to May 2010 under two scenarios: no premium subsidy and an 18-percent premium subsidy. These results are useful in estimating supply response to gross margin levels. Similarly, root mean-squared deviation from median outcomes was calculated for each region, and each premium subsidy level, with and without participation in LGM-Dairy.

In summary, the gross margin was calculated with and without insurance (including both indemnities received and premiums paid), the measure of risk was calculated for both scenarios, and the percentage reduction in risk attributable to LGM-Dairy was calculated. Using risk response elasticities from the literature and original dairy supply modeling results, an associated percentage change in supply was attributed to LGM-Dairy’s impact on margin risk levels.

In addition to affecting risk, LGM-Dairy can also affect the mean level of gross margins, either because of loaded or subsidized premiums. The percentage change in mean gross margins over each 10-month contract period was calculated and applied to price elasticity of supply estimates to predict the percentage change in supply due to policy-induced changes in margin levels.

## Results of Gross Margin Risk Analysis

Findings suggest that LGM-Dairy was effective in reducing the risk levels of dairy producers. The results reported in this section are based on the model framework and assumptions described in the previous section. The results that any individual producer might expect would be adjusted to reflect actual prices and feeding decisions. The root mean-squared deviation from the median margin was found to be considerably smaller when LGM-Dairy was used than when it was not used. The results are quite robust, as a considerable reduction in risk level was found for each of the regions analyzed, ranging from 28 percent in Minnesota to 39 percent in Florida (table 2). Moderate risk-reduction levels help account for the popularity of the program.

Findings reveal that risk reduction was indeed achieved in each of the 13 regions included in the analysis. Previous analysis of the Dairy Options Pilot Program found risk reduction across regions, but the reduction was greater in those regions where cheese manufacturing (class III use) was higher (Maynard et al., 2005). The results of this analysis would suggest that basis risk across regions is perhaps less of a concern than previously thought because similar risk reduction rates were found in all regions. Factors that may account for this effect include the index mechanism itself, the inclusion of feed costs in LGM-Dairy, and the assumed price risk strategy of insuring 100 percent of monthly output over 10 successive insurance contracts.

Table 2  
**Risk reduction associated with LGM-Dairy (January 2002 - May 2010)**

Region	Risk level* without LGM-Dairy	Risk level* with LGM-Dairy	Reduction in risk
	<i>Dollars per cwt</i>	<i>Dollars per cwt</i>	<i>Percent</i>
Northwest	21.06	13.49	36
California	20.76	13.23	36
New Mexico	19.16	12.65	32
Western Texas	19.59	12.65	35
Minnesota	21.36	15.29	28
Wisconsin	22.03	15.71	29
Illinois	23.49	15.92	32
Southern Missouri	21.56	14.50	33
Michigan	23.61	15.18	36
Ohio	22.75	15.23	33
Appalachian	20.72	14.31	31
Florida	21.92	13.45	39
New England	25.35	17.58	31

\*Risk level is defined as the root mean-squared downside deviations from the median gross margin. Insurance assumptions include zero deductible and 18 percent premium subsidy. Risk levels are the aggregate over the relevant 10-month period.

cwt = hundredweight. LGM = Livestock Gross Margin.

Source: USDA, Economic Research Service, based on model results.



While consideration of risk reduction levels is certainly important, so, too, are evaluations of realized margins with and without LGM-Dairy. LGM-Dairy premiums contain a 3-percent catastrophic reserve load (see glossary), which is expected to result in lower average margins for those producers using LGM-Dairy. Premium subsidies, however, are expected to more than offset the impact of the reserve load, possibly producing a net gain in average margin. Thus, supply growth could occur from both lower risk and higher average returns. However, as shown in table 3, the change in average margin ranged from -1 to 2 percent, with virtually no change when locations were pooled.

Results reported in tables 2 and 3 both assume a zero deductible, which is associated with an 18-percent premium subsidy. Higher deductibles are generally associated with higher percentages in subsidy levels (the LGM-Dairy subsidy level for the highest deductible was raised after this analysis was completed to a maximum of 50 percent). Still, the analysis also examines risk reduction and gross margin impacts for alternative levels of deductible and their associated premium subsidy, as choosing among the deductible amounts is an option available to producers. Table 4 reports the risk reduction and gross margin results averaged across all regions. The greatest risk reduction and lowest margin penalty occur simultaneously when the deductible level is zero, suggesting there is little incentive for producers to choose higher deductible levels, despite the increased premium subsidy.

Table 3

**Average realized margin by region (January 2002 - May 2010)**

Region	Aggregate margin without LGM-Dairy	Aggregate margin with LGM-Dairy	Change in margin
	<i>Dollars per cwt</i>	<i>Dollars per cwt</i>	<i>Percent</i>
Northwest	121.62	124.27	2
California	115.69	118.15	2
New Mexico	114.73	117.03	2
Western Texas	122.59	124.70	2
Minnesota	137.98	137.95	0
Wisconsin	138.46	136.77	-1
Illinois	138.07	136.35	-1
Southern Missouri	136.15	134.48	-1
Michigan	134.99	133.31	-1
Ohio	140.99	139.22	-1
Appalachian	147.21	145.50	-1
Florida	168.01	166.26	-1
New England	146.40	144.24	-1

\*Insurance assumptions include zero deductible and 18 percent premium subsidy. Aggregate margins are reported over the relevant 10-month period.

cwt = hundredweight. LGM = Livestock Gross Margin.

Source: USDA, Economic Research Service, based on model results.

Table 4

**Risk reduction and gross margin impacts of Livestock Gross Margin-Dairy participation under various deductible subsidy combinations**

Deductible	Corresponding premium subsidy	Risk reduction	Change in average gross margin
<i>Dollars per cwt</i>		<i>Percent</i>	
0.00	18	33	0
0.20	21	31	-1
0.40	25	28	-1
0.60	31	25	-1
0.80	38	23	-1
1.00	48	20	-1
1.50	50	14	-1
2.00	50	9	-2

cwt = hundredweight.

Source: USDA, Economic Research Service, based on model results.

## Results From Estimating the Risk Elasticity of Supply

Estimating the milk supply response to a risk-reducing policy tool such as LGM-Dairy requires two major steps: estimating risk reduction (described in the preceding section) and estimating marginal supply response to a unit of risk reduction (a risk elasticity). Chavas and Holt (1990) and subsequent related studies (e.g., Lin and Dismukes, 2007) estimated both price and risk elasticities of supply. In this study, the milk supply component of the ERS forecasting model documented in Mosheim (2012) was used to estimate supply response. As in the previous section, the focus here is on the results of the modeling effort rather than the details (see appendix).

The impact of risk on production, defined as production per cow (PPC), was significant at roughly the 90-percent level but very small at -0.006. This result implies that a 10-percent reduction in risk would lead to an increase in production of less than 1 (.6) percent. This small, marginally significant finding is consistent with the findings of Luh and Stefanou (1989). Given the range of risk elasticity estimates from the literature and the results of the ERS modeling effort, a sensitivity table was deemed an appropriate way to present supply impact estimates. Note, also, that the risk elasticity of -0.006 estimated using the ERS model, which falls below the low end of this analysis, would suggest risk impacts of approximately zero (table 5).

Table 5  
**Expected supply response given risk-reduction level and elasticities**

Region	Reduction in risk	Supply impact: $E_{risk} = -0.10$	Supply impact: $E_{risk} = -0.05$	Supply impact: $E_{risk} = -0.025$
<i>Percent</i>				
Northwest	37	3.66	1.83	0.91
California	37	3.72	1.86	0.93
New Mexico	34	3.36	1.68	0.84
Western Texas	36	3.59	1.80	0.90
Minnesota	28	2.84	1.42	0.71
Wisconsin	29	2.89	1.44	0.72
Illinois	33	3.29	1.64	0.82
Southern Missouri	35	3.52	1.76	0.88
Michigan	36	3.58	1.79	0.89
Ohio	35	3.46	1.73	0.87
Appalachian	33	3.27	1.64	0.82
Florida	39	3.86	1.93	0.96
New England	31	3.12	1.56	0.78

Source: USDA, Economic Research Service, based on model results.

Based on the estimates in table 5, short-term milk production impacts associated with use of LGM-Dairy are small. Even at the highest risk elasticity levels, supply impacts never exceed 4 percent and the estimated risk elasticity of -0.006 derived from the ERS modeling effort is consistent with supply impacts well below 1 percent. Note, also, that the responses indicated in table 5 assume full participation in LGM-Dairy. Actual participation has been much lower, suggesting correspondingly lower supply impacts. Further, it is worth noting that longrun supply response would likely be even smaller.

Table 5 shows the supply impact attributable to risk only. The other source of supply impact is changes in average gross margin, with premium subsidies reducing the negative supply impact of LGM-Dairy premiums. Given the nationwide average-margin change of zero percent associated with the zero-deductible alternative shown in table 4, average-margin changes are expected to be a negligible source of aggregate supply effects, so most of the supply effects should come from risk reduction.

## Conclusions, Implications, and Areas for Further Research

This study examines the implications of LGM-Dairy. From the perspective of the dairy producer, LGM-Dairy appears to offer an opportunity to reduce downside gross margin risk by approximately one-third when measured as downside deviations from the median gross margin over a 10-month period. Evidence from the present analysis and prior literature also suggests that LGM-Dairy may offer risk reduction exceeding that provided by hedging with dairy options alone. The findings from this study reveal that reductions in risk are similar across regions, a result that alleviates potential concerns that programs of this type are not as effective for producers in regions who supply a large share of their output to fluid markets (high class I use areas).

Other analyses of programs similar to LGM-Dairy have added to the knowledge base for evaluating such programs in the future. These include works by Bozic et al. (2012) and Stephenson (2012), which examine recent legislative proposals for a voluntary dairy margin insurance program for U.S. milk producers. Note that these legislative programs are very different from the existing LGM-Dairy program. As the “safety nets” for agricultural producers are further considered, even more information about the LGM-Dairy program will likely be requested.

For risk reduction, a clear advantage of LGM-Dairy over using price futures and options is the ability to protect a margin rather than a single output price. Unlike class III dairy options, which can only be triggered when milk prices fall, indemnities can be received on LGM-Dairy policies when milk prices fall, feed prices rise, or some combination of the two. Further research in this area might involve analyzing the risk-reduction effects of LGM-Dairy in situations where corn and soybean meal are not the primary feeds being purchased (such producers can still purchase LGM-Dairy but must convert the feeds they are using to corn/soybean feed equivalents), where only minimal amounts of purchased feeds are used, or where the dairy operation relies largely on home-grown feeds. An additional “basis risk” would exist for grazing operations or for operations that purchase and feed large quantities of hay or other feeds beyond corn and soybean meal.

While one might assume that reduced risk would have supply effects, the literature reviewed was not especially robust as to the magnitude of this effect. Results of direct risk modeling using quarterly milk price and production data suggest a shortrun supply increase of less than 1 percent if all producers participated in LGM-Dairy. Given that actual participation has been much lower, partly due to limited funding and program availability, the estimated supply impact over the last few years would be even lower.

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## Glossary

*Actuarial soundness:* An insurance term describing a situation in which indemnities paid, on average, are equal to total premiums collected.

*Adverse selection:* A situation in which an insured has more information about his or her risk of loss than does the insurance provider and is better able to determine the soundness of premium rates.

*Basis:* The difference between a specific futures price and a specific cash price for the same or related commodity.

*Basis risk:* The risk associated with an unexpected widening or narrowing of the basis between the time a hedging position is established and the time that it is lifted.

*Bundled option insurance:* In the case of LGM-Dairy, similar to buying both call options on multiple feeds to limit higher feed costs and a put option to set a floor on milk prices.

*Catastrophic reserve load:* An adjustment intended to account for infrequent, severe events that are not fully captured in the base premium rate.

*Deductible:* The portion of the expected gross margin that producers elect not to insure. Per hundredweight (cwt) deductible amounts range from zero to \$2.00 per cwt in 10 cent increments. The deductible equals the selected per cwt deductible times the sum of target marketings across all months of the insurance period.

*Downside deviation from median:* In the case of this analysis, the difference between the median risk level and actual risk level that was used to evaluate the risk reduction effects of LGM-Dairy.

*Forward contract:* An agreement between two parties (such as you and someone who buys your products) that calls for delivery of, and payment for, a specified quality and quantity of a commodity (such as a particular crop) at a specified future date. The price may be agreed upon in advance or determined by formula at the time of delivery or other point in time.

*Futures contract:* An agreement priced and entered into on an exchange to trade at a specified future time a commodity, or other asset, with specified attributes (or in the case of cash settlement, an equivalent amount of money).

*Gross margin guarantee:* The expected total gross margin minus the deductible for an insurance period.

*Hedging:* Buying or selling in a futures or options market intended as a temporary substitute for the later actual sale or purchase of a commodity. Its aim is to protect against adverse price movements prior to the actual transaction.

*Indemnity:* The compensation received by an individual for qualifying losses paid under an insurance policy. The indemnity compensates for losses that exceed the deductible up to the level of the insurance guarantee.

*Moral hazard:* The ability of an insured to increase his or her expected indemnity by actions taken after buying the insurance.



*Options contract:* A contract that gives the holder the right, without obligation, to buy or sell a futures contract at a specific price within a specified period of time, regardless of the market price of the futures.

*Premium:* An amount of money paid to secure risk protection. Option buyers pay a premium to option sellers for an options contract. Similarly, the purchaser of an insurance policy pays a premium to obtain coverage.

*Reinsurance:* A method of transferring some of an insurer's risk to other parties. In the case of LGM-Dairy, USDA's Federal Crop Insurance Corporation shares the risk of loss with each private insurance company delivering policies to producers. Private reinsurance also exists, in which case, a private reinsurer assumes responsibility for a share of the risk in return for a share of the premiums.

*Risk:* Uncertainty about outcomes that are not equally desirable. Risk may involve the probability of making (or losing) money, harm to human health, negative effects on resources (such as credit), or other types of events that affect welfare.

*Target marketings:* The quantities of milk producers elect to insure in each month of the insurance period.

## Appendix - Aggregate Supply Response Modeling

Underlying the model is a shortrun, or restricted, aggregate profit function specification that in the most general terms is defined as:

$$(1) \pi^* = \max_y \{p^* y - VC(y, w^*) - K - \frac{1}{2} \lambda y^2 \sigma^2\}$$

where:  $\pi^*$  is expected profit;

$p^*$ ,  $\sigma^2$  are ex ante mean and variance of output price;

$y$  is output;

$w^*$  is a vector of ex ante input prices;

$VC(y, w^*)$  is variable cost;

$K$  is capital; and

$\lambda$  is the coefficient of risk aversion.

First-order conditions imply that marginal cost equals marginal revenue. Since risk was modeled in equation (1), this first-order condition will mean that the profit-maximizing firm will produce a lower level of output in a riskier environment than otherwise,

$$(2) p^* - MC(y, w^*, K) - \lambda y \sigma^2 = 0.$$

From this first-order condition, a shortrun output supply function takes the form,

$$(3) y^{SR} = y(p^*, w^*, \sigma^2, K).$$

A specification of the shortrun function presented in Moschini and Hennessy (2001) is:

$$(4) y_t = \alpha_o + x_t' \beta + \delta_1 \mu_t + \delta_2 \sigma_t^2 + \varepsilon_t,$$

where

$y_t$  is supply;

$x_t'$  is a vector of other variables affecting decisions;

$\mu_t$  is the ex ante output price mean;

$\sigma_t^2$  is the ex ante output price variance;

$\alpha_o, \beta$  (a vector),  $\delta_1, \delta_2$  are parameters to be estimated;

$\varepsilon_t \sim N(0, \sigma^2)$ ; and  $t$  indexes the observations.

This functional form is employed to model the uncertainty inherent in the variation of expectations of future milk prices, as compared with the first model that uses only actual price data for analysis.

The empirical specification of the statistical supply model consists of three equations, with the dependent variables being production per cow, cow numbers, and the all-milk price. These equations are not simultaneous but have a recursive specification. The first “run” of the model yields empirical estimates of the supply response to both price and expected price, which can then be applied to the estimated policy-induced magnitudes of price and risk changes to estimate total supply impacts of LGM-Dairy. Two specifications are presented. One is identified with the cash market, which serves as a baseline, and the second seeks to incorporate risk to various degrees. The “first-run” model provides an empirical supply function and is used to derive an elasticity of supply.

Two situations are examined, the first being the cash market situation where the producer uses only prices to make decisions that will have an economic impact sometime in the future for his or her enterprise once milk is sold in the market. This can be thought of as a naïve model where producers make decisions based on current prices. Second, a model is developed that integrates expected price and its variance (at this point only the output price is considered), with expected prices defined by deferred futures prices. The second model allows estimation of a risk elasticity of supply. The results of the estimation of the two models are presented in tables A2 and A3.

## Data Sources for Aggregate Milk Supply Modeling

The data for estimating the statistical supply models came from several sources. The basic information on herd size (COWS), milk per cow (PPC), and the all-milk price are from USDA’s National Agricultural Statistics Service (NASS). Supply is defined as cow numbers multiplied by output per cow in the two models. The all-milk price, AMP, is viewed as the incentive price to dairy farmers. In the second model, a futures price for AMP, denoted by AMP\*, is needed, which is derived in turn from class III and class IV futures information. These future class prices were converted to real values by employing the Gross Domestic Product (GDP) deflator as forecasted by USDA’s Interagency Commodity Estimates Committee (ICEC). The other variables include slaughter cow price (SCP), feed cost price (FC), a dummy variable for the spring quarter (DQ2), and time trends.

A regression of the AMP price on class III and class IV prices was employed to convert the future class prices into AMP\* projections. The last 200 future closing prices available for a particular contract that expires in the quarter being projected were employed for quarters I 2006 through IV 2010. Expected mean and variance were calculated from these announcements. AMP data are available in *Agricultural Prices*, a monthly USDA publication. Feed costs and slaughter cow prices are either historical data or forecasts obtained from ICEC, which forecasts eight quarters for FC, SCP, and the GDP deflator, with the number of observations employed as inputs for the models denoted in parentheses. All prices are deflated by the GDP deflator. Summary statistics for key variables are shown in table A1.

## Specification and Estimation of the Supply Models

The following models intend to capture the effect of risk on production decisions by dairy farmers. First, in what is called the “market model,” farmers use published prices to make production decisions, a behavior inherently riskier than that captured in the second model, where farmers employ the futures market. The latter estimation, the “futures market model,” is an augmented version of

Table A1

**Variable and sample means (standard deviation) (number of observations in squared parentheses)**

Variable (quarters) (Units)	Mean	Std. Dev.	Variable (quarters) (Units/Definition)	Mean	Std. Dev.
COWS [20] (Thousands)	9,192	83	FC[28] (Feed cost price, 2005 \$)	7.12	1.34
PPC [20] (Pounds/Cow)	5,111	141	DQ2 [28] Spring	0.21	0.42
AMP* [20] (All-milk price "Futures," 2005 \$)	14.61	1.00	t [28] (time trend)	15	8.23
AMP [20] (All-milk price, 2005 \$)	14.77	2.91	t2[28] (time trend2)	276	246
SCP [28] (Slaughter cow price, 2005 \$)	52.71	8.08	GDP deflator [28] (2005 = 1)	1.09	0.04

Source: USDA, Economic Research Service, based on model results.

the cash market model, and it employs the expected mean and variance of future all-milk price. The models follow:

### I. Cash Market Model:

(5)

$$\ln COWS_t = \chi_0 + \chi_1 \ln COWS_{t-1} + \chi_2 \ln COWS_{t-2} + \chi_3 \ln AMP_{t-2} + \chi_4 \ln FC_{t-2} + \chi_5 t^2$$

(6)

$$\ln PPC_t = \theta_0 + \theta_1 \ln PPC_{t-2} + \theta_2 \ln AMP_{t-2} + \theta_3 \ln FC_{t-2} + \theta_4 DQ2 + \theta_5 t$$

(7)

$$\ln AMP_t = \alpha_0 + \alpha_1 \ln COWS_{t-2} + \alpha_2 \ln PPC_{t-1} + \alpha_3 \ln SCP_{t-1} + \alpha_4 \ln FC_{t-1}$$

Total milk production is a reflection of the number of cows and their productivity (defined as production per cow). As in any production system, inputs are transformed into outputs using a given technology, in a given environment, and within a specific set of constraints. Two important factors were modeled explicitly in this set of equations—feed costs and the all-milk price.

Equation (5) represents cow inventory. The number of cows is expected to be a function of lagged cow inventory (COWS), lagged price of milk (AMP), and lagged feed costs (FC). Real values for these price and cost variables are determined by dividing current magnitudes by the GDP deflator. Real values for the price variable symbols do not change by dividing by GDP deflator. In the case of the AMP variable, direct payments, such as those from the Milk Income Loss Contract (MILC) program, were added before converting the all-milk price variable to a real value to model the farmer's incentive or effective price. The variable AMP is expected to have a positive lagged effect on the number of cows. It can be expected that as FC (approximately 60 percent of dairy farm operating costs according to USDA's Agricultural Resource Management Survey) increases, all other things being equal, there will be a lagged decrease in herd size. Both AMP and FC effects are related to biological lags, culling, and replacements apart from the other variables. In the double logarithm specification of the equations, the coefficients can be interpreted as elasticities.

Equation (6) captures the combined effect of new technologies and factors like scale economies on cow productivity. Generally, larger operations have higher cow productivity, represented by the variable production per cow (PPC). In equation (7), total farm milk processed is decomposed into PPC and number of cows (COWS), and their respective price (AMP) elasticities show the effect of productivity on AMP as being very inelastic and that of the number of cows as very elastic (i.e., an increase in cow productivity has a larger downward effect on AMP than a comparable percentage change increase in the dairy herd, all other things equal). Feed price increases, ceteris paribus, decrease supply (less milk supply at the same milk price—leftward supply shift), requiring a higher AMP in this equation to equilibrate supply with derived demand.

## II. Futures Market Model:

(8)

$$\ln COWS_t = \chi_o + \chi_1 \ln COWS_{t-1} + \chi_2 \ln COWS_{t-2} + \chi_3 \ln AMP_{t-2}^* + \chi_4 \ln FC_{t-2} + \chi_5 t^2 + \chi_6 \sigma_{\ln AMP_{t-1}^*}$$

(9)

$$\ln PPC_t = \theta_o + \theta_1 \ln PPC_{t-2} + \theta_2 \ln AMP_{t-2}^* + \theta_3 \ln FC_{t-2} + \theta_4 DQ2 + \theta_5 t + \theta_6 \sigma_{\ln AMP_{t-2}^*}$$

(10)

$$\ln AMP_t^* = \alpha_o + \alpha_1 \ln COWS_{t-2} + \alpha_2 \ln PPC_{t-1} + \alpha_3 \ln SCP_{t-1} + \alpha_4 \ln FC_{t-1} + \alpha_5 \sigma_{\ln AMP_{t-3}^*}$$

(11)

$$\sigma_{\ln AMP_t^*} = V_o + V_1 \sigma_{\ln AMP_{t-1}^*} + V_2 t + V_3 \sigma_{\ln AMP_{t-2}^*} + V_4 t^2$$

The expectation, employing Chavas (2004, chapter 8), is that production under uncertainty will have a negative effect on cow numbers and production per cow and a positive effect on the all-milk price. That is, the elasticity of supply under uncertainty will be steeper (less responsive) than that where the underlying price information is more certain. Two estimations are conducted to determine empirically the quantitative effect of risk. From the equations (5) through (11) estimated for both the cash market model (presented in table A2) and the futures market model (presented in table A3), predicted supply functions are derived for the cash (fig. A1) and futures (fig. A2) markets.

These models are estimated using nonlinear three-stage least squares. The first model uses NASS prices and the second employs both the expected mean and variance of futures prices. Coefficients with a t-value greater than 1 were considered for specification purposes to decrease type II errors as suggested in Kennedy (2008, p. 90). Also, on theoretical grounds, some variables with t-values less than 1 were considered.

From the above model, predicted results on the number of cows and production per cow can be employed to derive a supply function, and two sets of prices are used to make inferences about risk: the all-milk price from NASS (the cash market) and the derived all-milk futures price, both described above. The most essential result from the two figures is the derived price elasticity of supply that declines as more uncertainty is assumed by producers, an approximation to what Chavas (2004, p. 99) calls the marginal risk premium.

Table A2

**Cash market model (t statistics in parentheses)**

Parameter	Estimate	Parameter	Estimate	Parameter	Estimate
$\chi_0$	5.32 (4.50)	$\theta_0$	12.92 (13.09)	$a_0$	158.30 (2.61)
$\chi_1$	0.64 (3.16)	$\theta_1$	-0.52 (-4.51)	$a_1$	-15.02 (-2.47)
$\chi_2$	-0.23 (-1.21)	$\theta_2$	0.05 (2.88)	$a_2$	-2.59 (-2.13)
$\chi_3$	0.02 (3.95)	$\theta_3$	-0.06 (-3.80)	$a_3$	0.60 (1.89)
$\chi_4$	0.01 (1.37)	$\theta_4$	0.02 (2.76)	$a_4$	0.68 (2.02)
$\chi_5$	-2.00E-5 (-2.40)	$\theta_5$	0.007 (10.87)		

Source: USDA, Economic Research Service, based on model results.

Table A3

**Futures market model, expected all milk price mean and variance (t statistics in parentheses)**

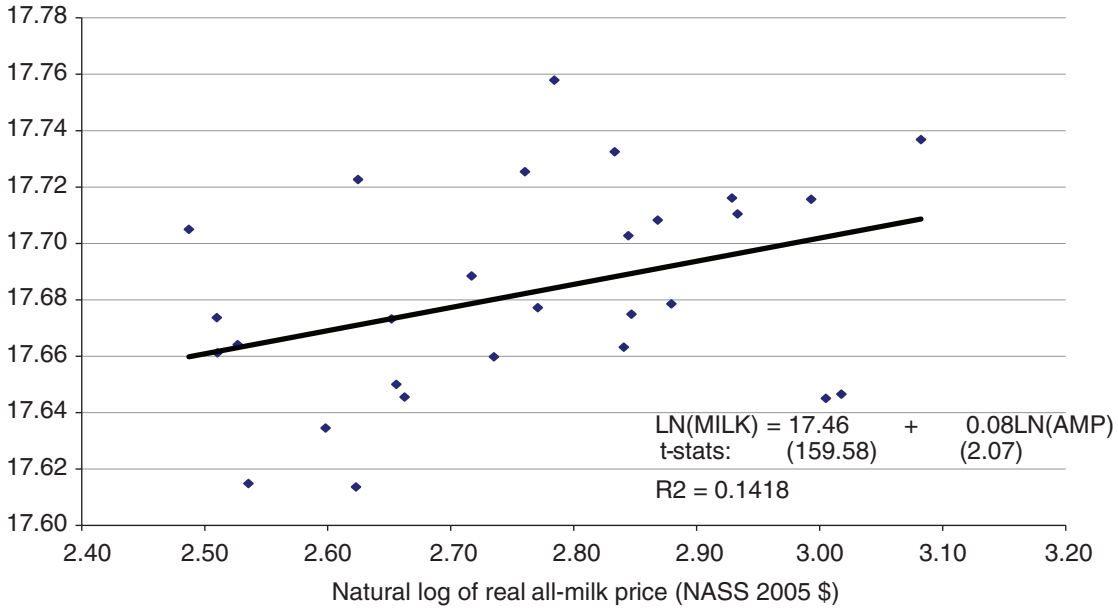
Parameter	Estimate	Parameter	Estimate	Parameter	Estimate
$\chi_0$	0.00 (0.00)	$\theta_0$	13.60 (18.75)	$a_0$	-17.77 (-0.50)
$\chi_1$	1.00 (5.88)	$\theta_1$	-0.64 (-7.48)	$a_1$	2.28 (0.63)
$\chi_2$	-0.02 (-0.07)	$\theta_2$	0.17 (3.34)	$a_2$	-0.12 (-0.21)
$\chi_3$	0.10 (2.63)	$\theta_3$	-0.07 (-2.50)	$a_3$	0.12 (0.64)
$\chi_4$	-0.04 (-1.58)	$\theta_4$	0.02 (5.88)	$a_4$	0.08 (0.34)
$\chi_5$	0.000004 (0.25)	$\theta_5$	0.007 (12.51)	$a_5$	-0.04 (-2.02)
$\chi_6$	-0.0008 (-0.82)	$\theta_6$	-0.006 (-1.91)	$v_o$	-6.58 (-2.71)
		$v_1$	0.10 (0.47)	$v_3$	-0.25 (-0.89)
		$v_2$	0.76 (2.32)	$v_4$	-0.03 (-2.59)

Source: USDA, Economic Research Service, based on model results.

Figure A1

**Supply function in cash market**

Natural log of milk production (in billion pounds)



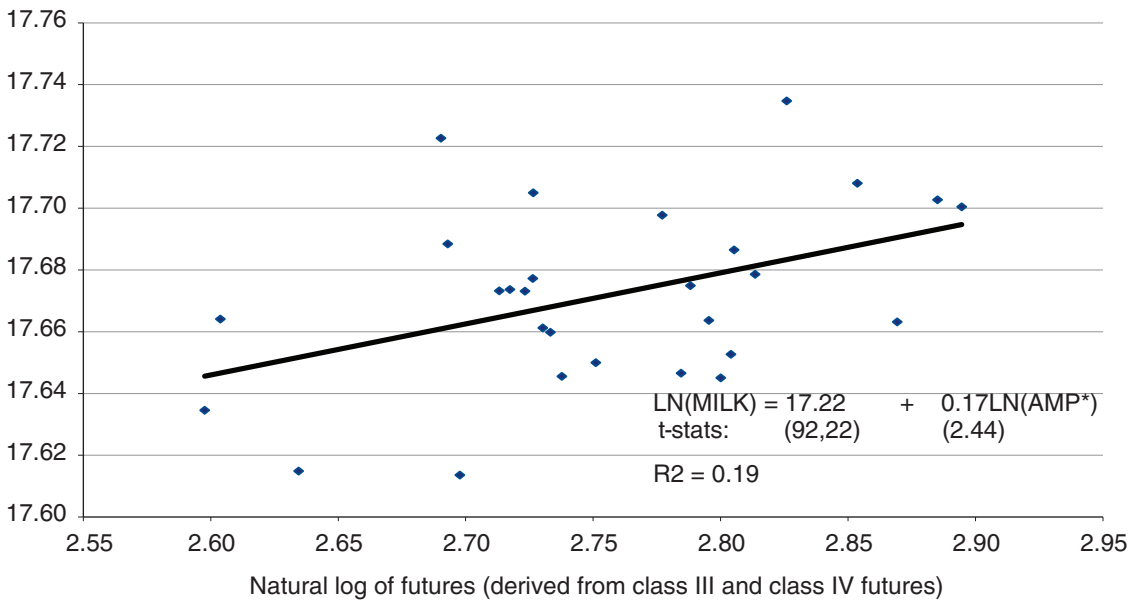
NASS = USDA, National Agricultural Statistics Service.

Source: USDA, Economic Research Service, based on model results.

Figure A2

**Supply curve under uncertainty (use of futures market)**

Natural log of milk production (in billion pounds)



NASS = USDA, National Agricultural Statistics Service.

Source: USDA, Economic Research Service, based on model results.