SPATIAL ECONOMETRIC MODEL OF MILK SUPPLY AND DEMAND: ANALYSIS OF THE FARM BILL DAIRY TITLE

A Thesis

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Master of Science

by

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ABSTRACT

State level milk supply and demand are modeled on a monthly basis to examine expected payments, government loss ratios, and economic welfare implications of margin insurance programs, both with and without supply controls, in the U.S. dairy industry. A technique is developed to properly calibrate a spatial econometric supply and demand system utilizing instrumental variables to model correlated input and output prices at both the state and national levels. Supply controls are found to improve producer surplus at the expense of consumer surplus and overall economic welfare, in expectation costing the U.S. economy an estimated $105 million per month. Rather than interfering with supply in the market, margin insurance program savings could more efficiently be generated by increasing premiums. Adverse selection can be more properly managed by basing premiums on market expectations and current conditions, as opposed to codifying premium levels for the life of the program in the legislation.

BIOGRAPHICAL SKETCH

Dustin Baker was born October 5, 1989 in Alma, Michigan. He graduated from St. Louis High School in May 2008. Dustin grew up on a small sheep and cattle farm in mid-Michigan and was extensively involved in 4-H, FFA, and athletic teams throughout his childhood. After beginning his college career as an animal science major, Dustin was granted the degree of Bachelor of Science in agribusiness management with a specialization in political economy from Michigan State University in 2012.

In his free time, Dustin enjoys traveling, playing sports, agricultural policy, youth mentoring, skiing, and supporting his beloved Michigan State Spartan athletic teams. Dustin will earn his Master of Science in Applied Economics and Management from Cornell University in May 2014. After graduation, Dustin plans to move to Washington, D.C. to begin a career in agricultural policy.

For my father, who always challenged me to make my mark. I love and miss you, so very much.

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This thesis is the culmination of the efforts of many individuals, and I could not possibly provide the type of recognition everyone deserves, but I will try my best. I would not be where I am today if it were not for the all-star supporting cast I have the privilege to claim in my personal and professional circles, and I am deeply indebted to them all for the support and guidance they have offered.

I would like to begin my thanking my family for being there every step of the way since I moved to Ithaca. From phone calls with my inquisitive grandparents to chats with my sister about Michigan State athletics, they helped me stay grounded and provided the motivation needed to push through the research process. In the months leading up to my beginning at Cornell, my family underwent a tremendous amount of adversity, but through my mother's leadership, love, and support, we have come out closer than ever. I owe so very much to her, and I draw strength from her unconditional love.

In addition, I have been blessed by a tremendous set of friends who have been with me every step of the way. These cheerleaders have stuck with me and taught me the importance of surrounding yourself with individuals who make you a better person and were always willing to pick up the phone to chat after a bad day or congratulate my successes. My buddies from my undergraduate career at Michigan State in particular are of far better quality than I deserve, and I am forever indebted to their friendship and camaraderie.

Of course, none of this research would have been possible if it were not for the guidance and instruction provided by my advisor. I thank my committee chairman, Dr. Joshua Woodard, for his understanding, insight, but most importantly his patience with me as I trudged along through the research process. I appreciate Dr. Woodard's willingness to take me under his guidance to approach a hotly-debated issue and apply

novel techniques and modeling frameworks to achieve interesting and meaningful results. His creativity and ability to approach questions from new angles was vital to this research, and I believe this sort of cross-disciplinary approach will continue to be vital in my professional career.

My committee members including Dr. Marin Bozic and Dr. Andrew Novakovic provided a tremendous amount of insight into the dairy industry and expertise when it came to analyzing dairy markets. Their diverse backgrounds and thorough understanding of the policies at hand helped ensure accuracy in modeling and credibility to results.

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The help provided by Linda Sanderson helped guide me through all the forms and processes required to successfully complete a graduate degree at Cornell University also must be noted. The emails and reminders helped ensure I was where I needed to be and proper forms were filled out at all times, or at least the majority of the time. Her work behind the scenes does not go unnoticed and is appreciated by everyone in the department.

My time at Cornell University was made possible in part due to the financial contributions of from the Robert Smith Fund for Teaching Excellence. The generosity is very much appreciated I am very thankful for its contributions to my education.

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CHAPTER 1

INTRODUCTION

Statement of the Problem

Beginning in the 1990s, farm level milk prices began to exhibit levels of severe volatility that had not been seen since the introduction of federal price supports in the 1940s (Nicholson and Fiddaman, 2003). Corn and other feed prices increased rapidly starting in 2007, in conjunction with federal incentives to blend ethanol in gasoline. The Great Recession had demand side impacts to further depress milk prices. With this combination of conditions, a consensus emerged among leaders in the U.S. dairy industry during the 2013 Farm Bill debate that the time had come to create a federal dairy safety net focused on insuring milk price over feed cost margins. This stands in somewhat in contrast to the traditional milk price support, which primarily relied on milk price as the trigger. The previous Dairy Title program, the Milk Income Loss Contract (MILC), contained quantity based payment limits, and large farms would typically hit their maximum payments within the first several months of the year if the contract triggered, leaving them mostly exposed to milk price risk. These provisions left larger farms more open to price risk. Meanwhile, a debate also emerged over whether new programs would have supply controls implemented as well. The argument advanced was that the margin insurance program should be coupled with supply controls to depress government costs, and to assist in expediting the market to adjust in times of low margins. Ultimately however, supply controls were not included in the final version of the Agricultural Act of 2014.

While some studies exist analyzing the effects of the proposed dairy margin insurance program, both with and without supply controls, the few studies are inconclusive and lack a thorough analysis of how supply controls would likely impact price and quantity levels, especially at the regional level. The Dairy Security Act (DSA), which was the dairy proposal in S. 954, utilizes supply controls in addition to its margin insurance program. Nicholson and Stephenson (2010) conduct a national level analysis with a partial supply model which assumes exogenous price discovery, and argue that they would result in increased average all-milk price, reduce cumulative milk production, and decrease government costs compared to the baseline, whereas other studies by Nicholson and Stephenson (2011) conclude that the average all-milk price would be decreased as a result of supply controls, and lead to an increase in production.

The alternative proposal in H.R. 2642 as passed by the House of Representatives in July 2013, known as the Dairy Freedom Act (DFA), omitted supply controls. These studies found that under that policy, milk production would be virtually unchanged. Other studies have argued that supply control measures would not pose long-term obstacles to growth (Brown and Madison, 2013; Newton et. al, 2013).

Previous studies focusing on the national effects of the proposed margin insurance tend to assume constant participation rates among similarly sized farms across the country. That is, a 500 cow dairy farmer in New York State has the same probability of participation and identical risk preferences to a 500 cow dairy farmer in Florida or Idaho. Given the composition and heterogeneity of dairy producers, as well as the differences in growth trajectories across the country, this may be a questionable assumption. Several studies have also noted the likely disparities in the recipients of benefits from the newly proposed margin insurance programs and the transfer of benefits from innovative to stagnant producers (Balagtas, 2013; Newton, Thraen, and Bozic, 2013; Woodard and Baker, 2013).

This study, to our knowledge, is the first of its kind to examine state-level price and quantity effects in milk markets resulting from the dairy margin insurance programs, both with and without supply controls, as well as the actual language in the Agricultural Act of 2014 (2014 Farm Bill). The majority of the literature suggests supply controls in the margin insurance programs would have little effect on the market, thus they are fiscally responsible. However, existing studies ignore the likely possibility that there would be differing participation in different regions (Woodard and Baker, 2013), ignore welfare losses, and likewise do not depend upon properly instrumented supply and demand models. This study attempts to quantify the impact of supply controls in terms of welfare gains and losses, expected payments, and output. Presumably, supply controls, if significant enough to impact government expenditures, would have an effect in the milk marketplace. If this is the case, these effects should be able to be quantified and there should exist winners and losers as a result of their market distorting effects. This study attempts to put a dollar value on the cost of supply controls to the economy at large as a result of wealth transfers and deadweight losses.

Participation in margin insurance with supply controls would be driven by many factors. These factors include personal ideologies, investment trends, and regional price trends. Given that the proposed programs are all based on national prices and national feed costs, states with differing bases to national level prices will enjoy or suffer differing allocations of benefits as a result if participation is not uniform.

A variety of econometric approaches are taken to accurately model state level milk supply and demand in the United States utilizing data obtained from the United States Department of Agriculture (USDA), United States Census Bureau, and the United States Bureau of Economic Analysis. These data are collected on the monthly state level, annual state level, monthly national level, and annual national level for robustness purposes. Relevant variables are derived from previous studies on regional and national level supply models (Chavas, Kraus, and Jesse, 1990; FAPRI, 2004; AMS, 2007; Bozic, Kanter, and Gould, 2012; Weersink and Tauer, 1990). In order to produce a reasonable model of the actual market for dairy products in the United States, a state-level demand model is also estimated in order to construct estimates of equilibrium price and quantity impacts, building upon approaches from previous studies on milk demand (FAPRI, 2004; Kaiser, 2000; Schmitt and Kaiser, 2002; Kaiser and Dong, 2006; Kaiser, 2010; AMS, 2007).

This study adds to the existing dairy market literature by utilizing an instrumental variable approach to estimate milk supply and demand. Previous literature suffers from poor identification because it lacks instrumentation for endogenous variables. When modeling a supply and demand system to achieve equilibrium quantities and price, it is necessary to utilize instrumental variables to obtain consistent and identified estimates of the model parameters. Typically, failure to properly instrument for the endogeneity of prices will result in biasing of price elasticity coefficients toward zero.

Furthermore, this study is the first to implement a spatial econometric approach to the estimation of a milk supply and demand model. By doing so, exogenous shocks to given states are no longer independent of one another, but rather reverberate throughout the system, subject to time and distance decay. This spatial consideration is an important component of this study, and is more reflective of real world price dynamics in agricultural markets. For example, consider an increase in feed prices in New York. This shock is likely to have an effect on overall milk production in Pennsylvania and Vermont because of the proximity to one another and the flow of goods across state lines, but the shock in New York is expected to have less of an effect on milk production in Arizona. The spatial network approach developed in this study allows for these neighborhood relationships to exist and to more accurately model state level markets than those that ignore the spatial structure of the data.

In addition, this study is one of the first, if not the first, to develop and implement a properly calibrated spatial econometric supply and demand model anywhere in the literature. From the models estimated using the data described above, simulations of future price paths of relevant prices and quantities are generated. The aim of the study is to develop a disaggregated model of milk supply and demand to be extended for many other uses in the future, particularly in analyzing policy effects at the regional level. After acceptable and plausible supply and demand models are estimated, different scenarios are simulated. The supply and demand equations are solved for state level milk price and quantity, which aggregate up to the national level milk price and quantity. The simulation is calibrated utilizing the parameters from the supply and demand models and information obtained from the futures and options markets to ensure price paths are consistent with the actual risks inherit in the marketplace. Cholesky decomposition and Euler methods are utilized to ensure sufficient correlation exists between the relevant futures contract random walk price paths and state level price paths implied as a result of estimating conditional characteristic spatial models. The explicit spatial structure and relationships are automatically built in between cash and futures prices at both the state and national levels.

Understanding the potential economic impacts on the U.S. dairy industry in general and at the regional level of dairy margin insurance is important for evaluating the effectiveness of these programs. Expected payments are calculated and governmental loss ratios are also computed. Results are interpreted in terms producer revenue, consumer and producer surplus, price and quantity, as well as national welfare effects and deadweight loss to the economy at large.

Organization of Thesis

Following the introduction, this thesis proceeds in the following manner. First, background information detailing the makeup of the U.S. dairy industry and its geographic differences is provided. This is necessary to develop an understanding of the major milk producing areas in the U.S., milk production and price trends, and the differences in types of farms by region. Dairy policy prior to the 2014 Farm Bill is then briefly described. Next, a detailed review of the two competing margin insurance proposals (DFA and DSA) leading up to the 2014 Farm Bill is provided. Finally, the provisions of the eventual Dairy Title in the 2014 Farm Bill are described.

Next, data utilized in developing the models are described, summarized, and analyzed. Replications of previous studies are attempted, but the uniqueness of the specific needs for this study underscore the need for a novel, new approach to modeling the milk markets. A walk-through of the various approaches to model the system is conducted, along with the associated statistical tests to validate the approaches used.

Next, simulations are conducted to estimate impacts of supply controls and expected payment rates. Baseline scenarios are run to analyze expected indemnities, government loss ratios, and welfare considerations under DFA, DSA, and the actual provisions in the Dairy Title of the 2014 Farm Bill. The last section concludes and suggests areas for future research.

CHAPTER 2

BACKGROUND AND OVERVIEW

Overview of the U.S. Dairy Industry

The United States dairy industry is a vital component of the rural agricultural economy. Nationwide, the annual economic impact of the dairy industry is more than $100 billion (NMPF, 2007). Milk is produced in all 50 states, although the amount of milk produced in each state varies dramatically, with approximately 87% produced in the top nineteen states. With approximately 9.3 million cows, the United States is the worldwide leader in fluid milk production.

The dairy industry is a dynamic, ever-changing market marked by a long running trend of consolidation (Shields, 2010). The total milk cow herd in the U.S. decreased markedly from the mid-20th Century until the early 1990s, at which point the rate of change decreased to the plateau where it remains today (Figure 1).

Losses in total number of dairy farms nationwide decreased from well over 1 million in 1965 to less than 65,000 today, which an average loss of 2000 to 5000 farms per year in recent years. These decreases in total farm numbers can be visualized in Figure 2. This decrease in total farm numbers has been offset by increased production per cow, translating to an increasing trend in total production throughout this time period. These trends are displayed in Figures 3 and 4, respectively.

This is not to say states felt the squeeze of consolidation in similar manners, however. During this time period, certain states and regions witnessed a contraction of

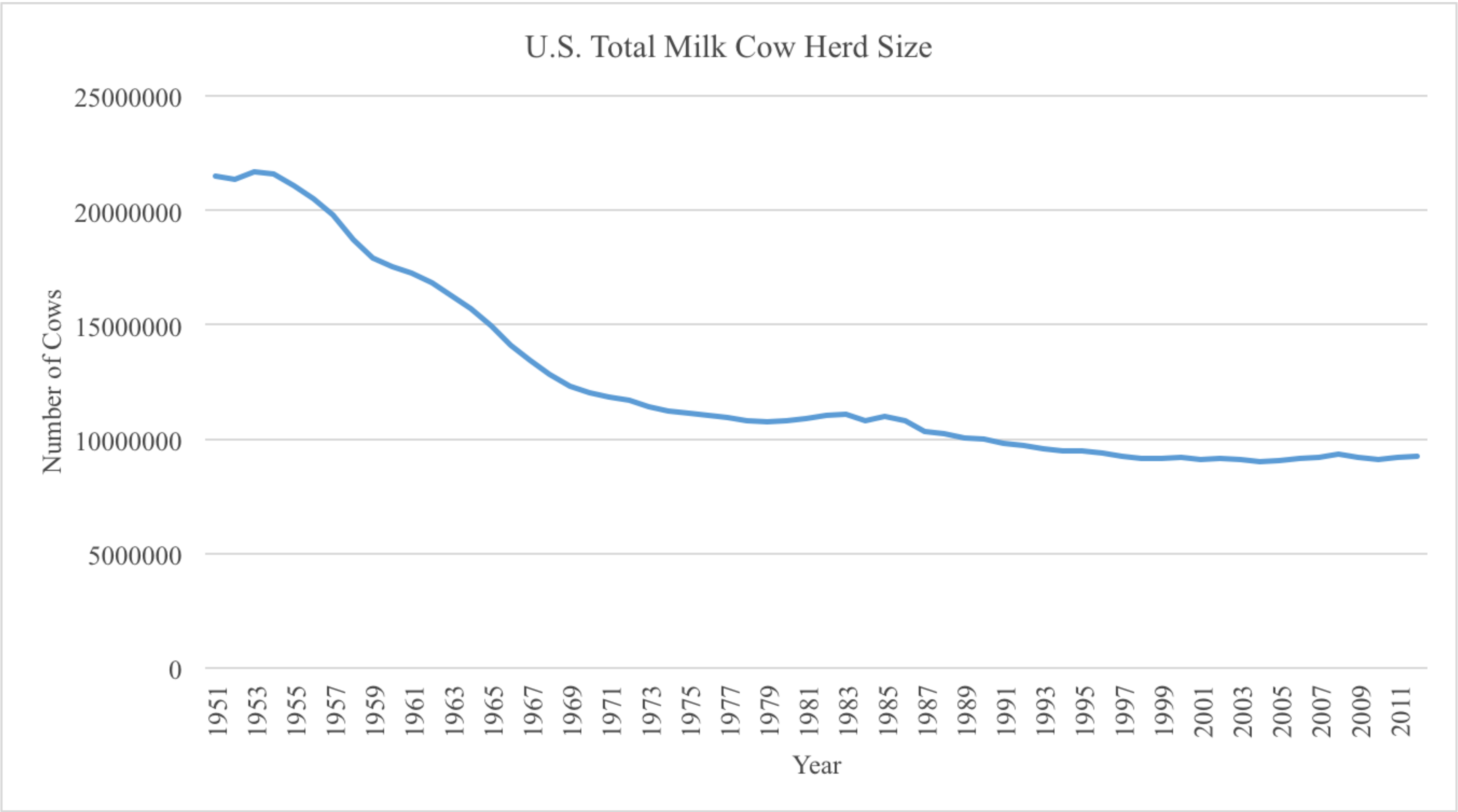
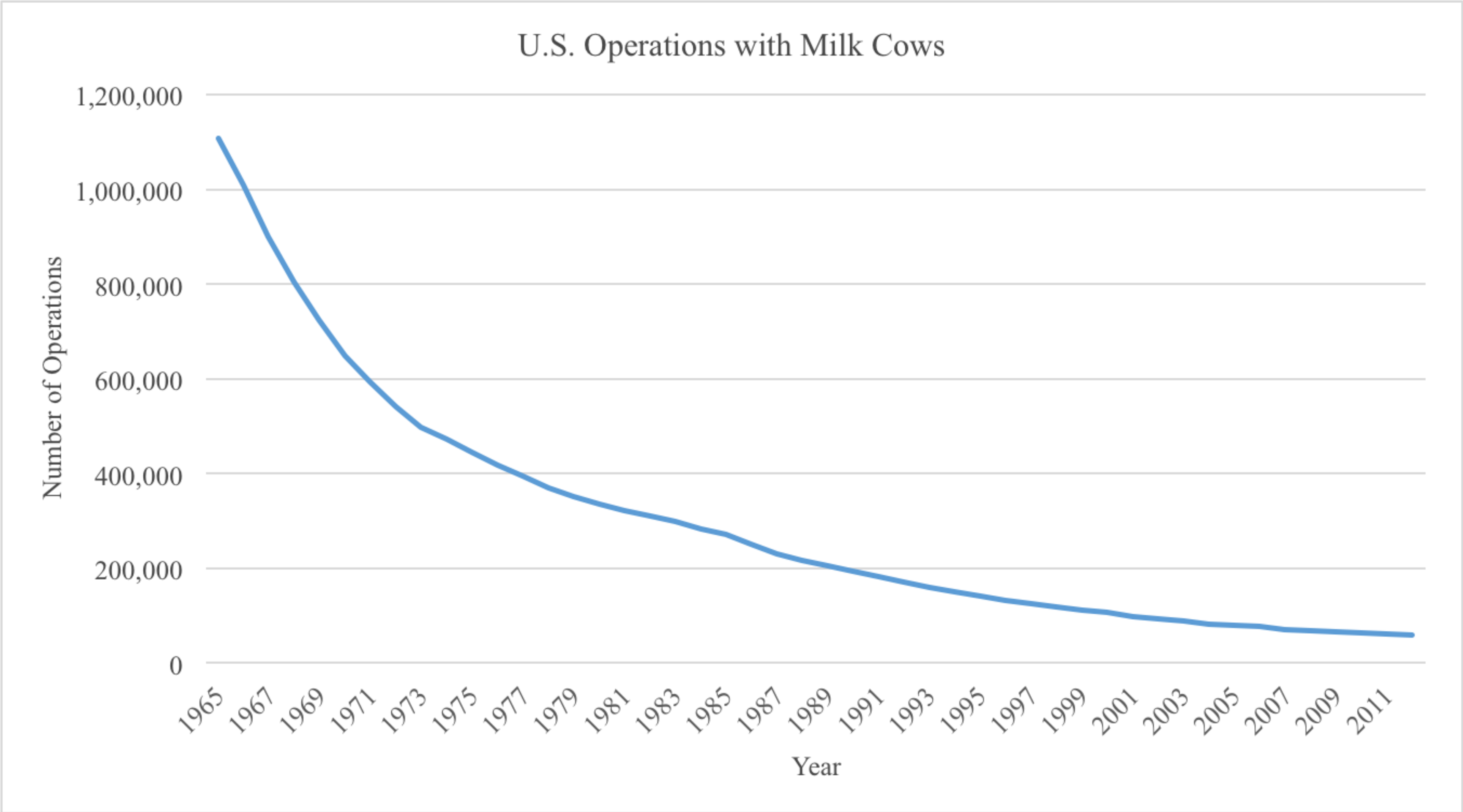


Figure 1.U.S. Total Milk Cow Herd Size, 1950-2012, National Agricultural Statistics Service (NASS), Available online at http://quickstats.nass.usda.gov/



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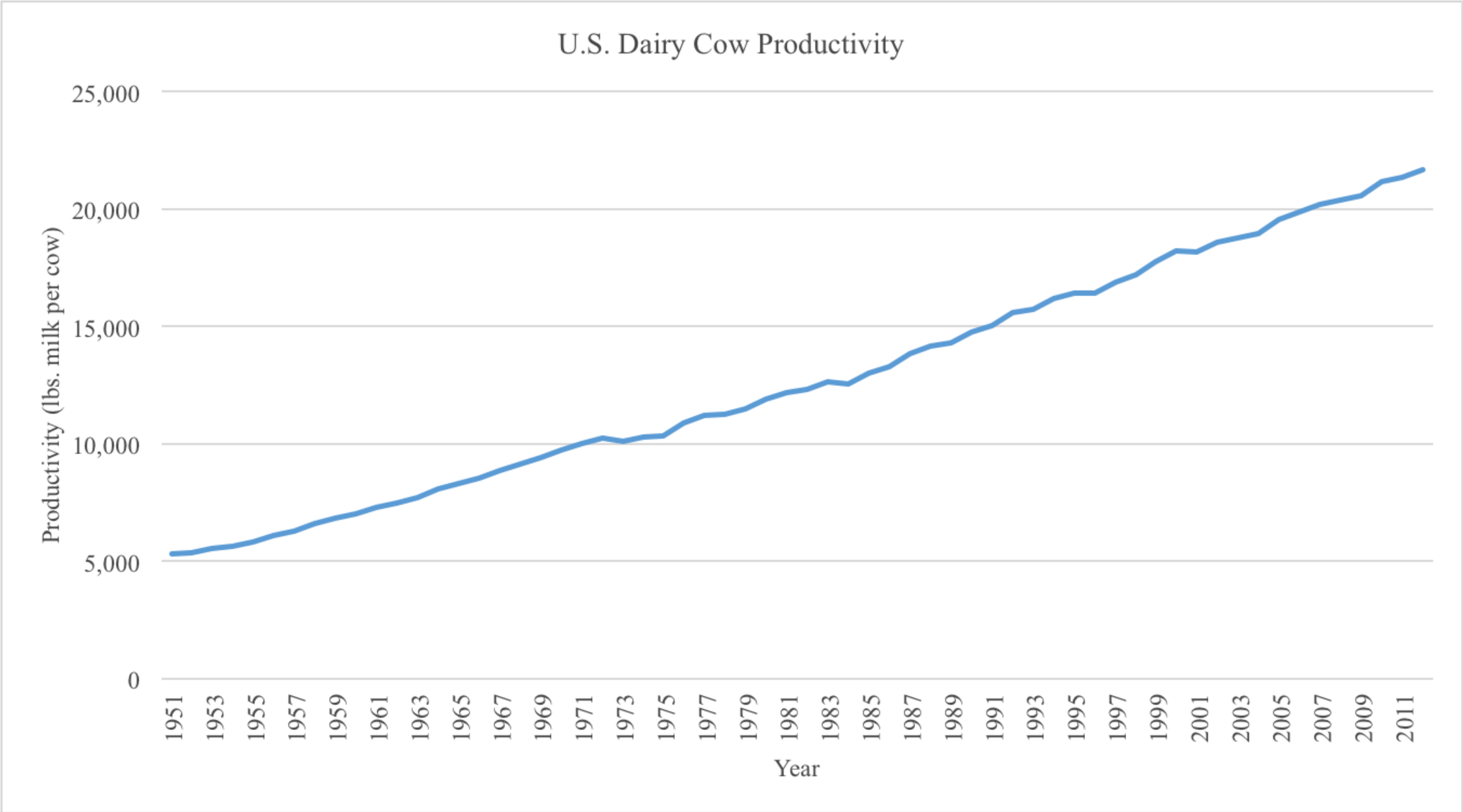

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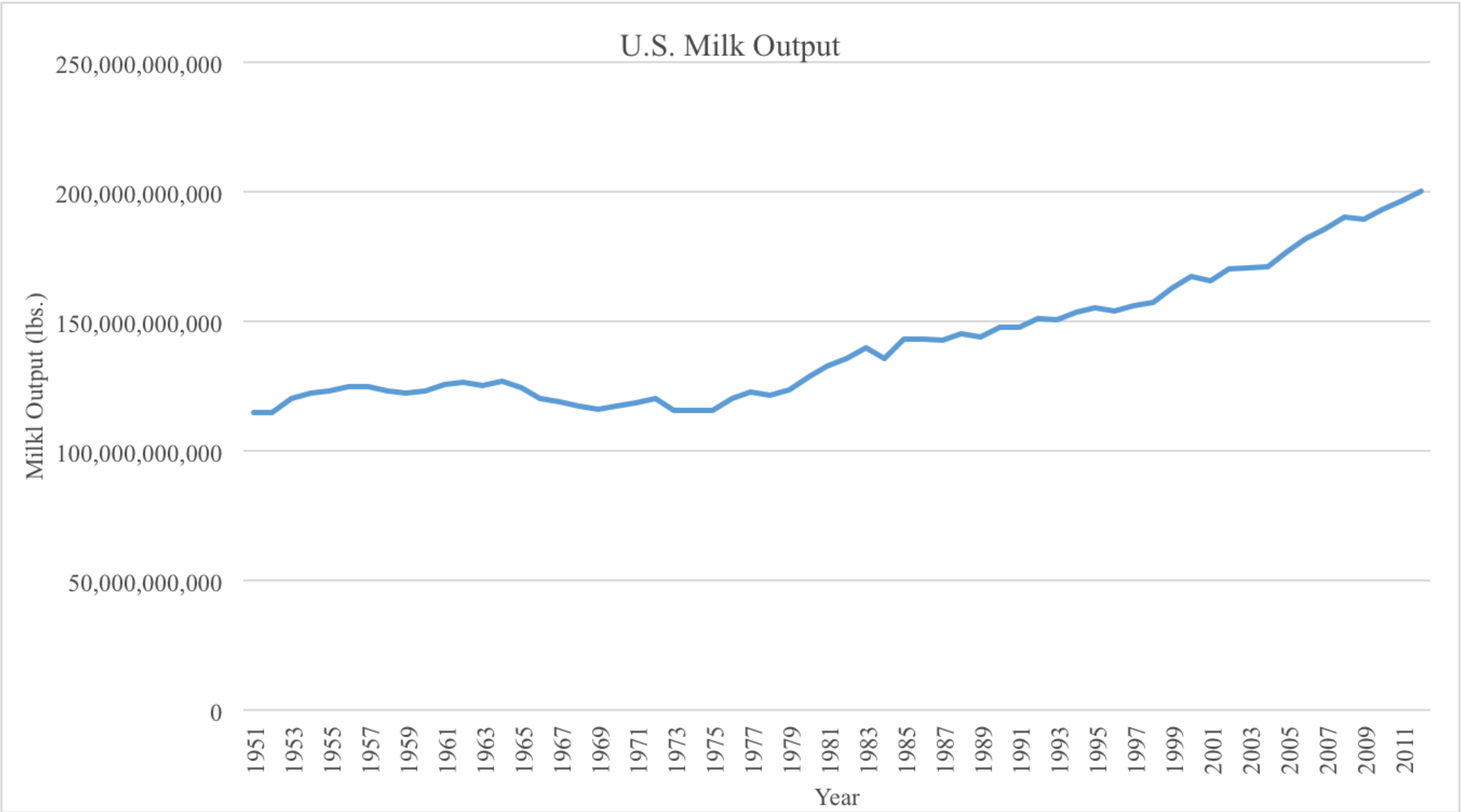

Figure 4. U.S. Milk Output, 1950-2012, National Agricultural Statistics Service (NASS), Milk-Production, Measured in lb, Available online at http://quickstats.nass.usda.gov/

output and dairy farm numbers, whereas others experienced unprecedented growth, particularly in the West. Peterson (2002) contrasts these two types of farms as "traditional-style dairies" and "Western-style dairies". The traditional-style dairy consists of a smaller herd and relies on comparatively more land holding used for forage, whereas the Western-style dairy consists of a larger herd and relies more heavily on purchased feeds. The rapid increase in total milk production the Western states of the United States (highlighted in red) over the past six decades can be viewed in Table 1.

Table 1. Emergence of Western Milk Production

1960		1980		2000		2012	
State	Production (Million lbs.)	State	Production (Million lbs.)	State	Production (Million lbs.)	State	Production (Million lbs.)
WI	17,780	WI	22,380	CA	32,245	CA	41,801
MN	10,272	CA	13,577	WI	23,259	WI	27,224
NY	10,171	NY	10,974	NY	11,921	ID	13,558
CA	8,059	MN	9,535	PA	11,156	NY	13,196
PA	6,878	PA	8,496	MN	9,493	PA	10,493
IA	5,940	MI	4,970	ID	7,223	TX	9,596
MI	5,173	OH	4,310	TX	5,743	MN	9,071
OH	5,125	IA	3,994	MI	5,705	MI	8,889
IL	4,229	TX	3,625	WA	5,593	NM	8,149
MO	3,685	WA	2,942	NM	5,236	WA	6,234

Source: National Agricultural Statistics Service (NASS), Available online at http://quickstats.nass.usda.gov/

As a result of the discrepancies between the two types of management profiles, a traditional dairy must acquire more land holdings to produce its feed, whereas a Western-style dairy is able to focus on capital expenditures and improved technology while simply purchasing the additional feed required. The difference in percentage of feed costs purchased among Western-style and traditional-style dairies can be viewed in Figure 5.

During the emergence of the Western states and these Western-style dairies onto the national milk scene, feed costs were relatively stable and predictable. As time progressed, particularly since the early to mid-2000s, feed cost volatility increased dramatically, leaving these Western-style dairies open and exposed to the risk due to their feed purchasing patterns. As Peterson (2002) points out, these states also happen to be, on average, larger in size than their Eastern and Midwestern counterparts. Selected states' average milking cow herd sizes in 2012 are summarized in Figure 6. Because of the vast differences in herd sizes among states, it is clear that the existing dairy policy consisting of payment caps based on milk production, such as those found in the MILC program (described in next section), do not fit the production practices or makeup of a significant portion of the U.S. dairy industry. Simply put, it is difficult to create a one-size-fits-all solution for the wide array of producers in such a diverse, heterogeneous industry. Wolf (2003) indicates that sunk costs lead to higher adjustment costs for farmers in traditional areas. Emerging areas, particularly in the West, were able to spread initial fixed costs over more animals, and were able to utilize dry lot production systems and reduce asset fixity. This adoption of increases in technology is what allowed the Western states and the Western-style dairies to explode onto the scene and garner a significant amount of market share over the past three decades while employing larger, more productive herds as a result of technology and capital structure. The milk production per cow in these Western-style dairies tends to be much higher than those in traditional areas, as well (Miller and Blayney, 2006).

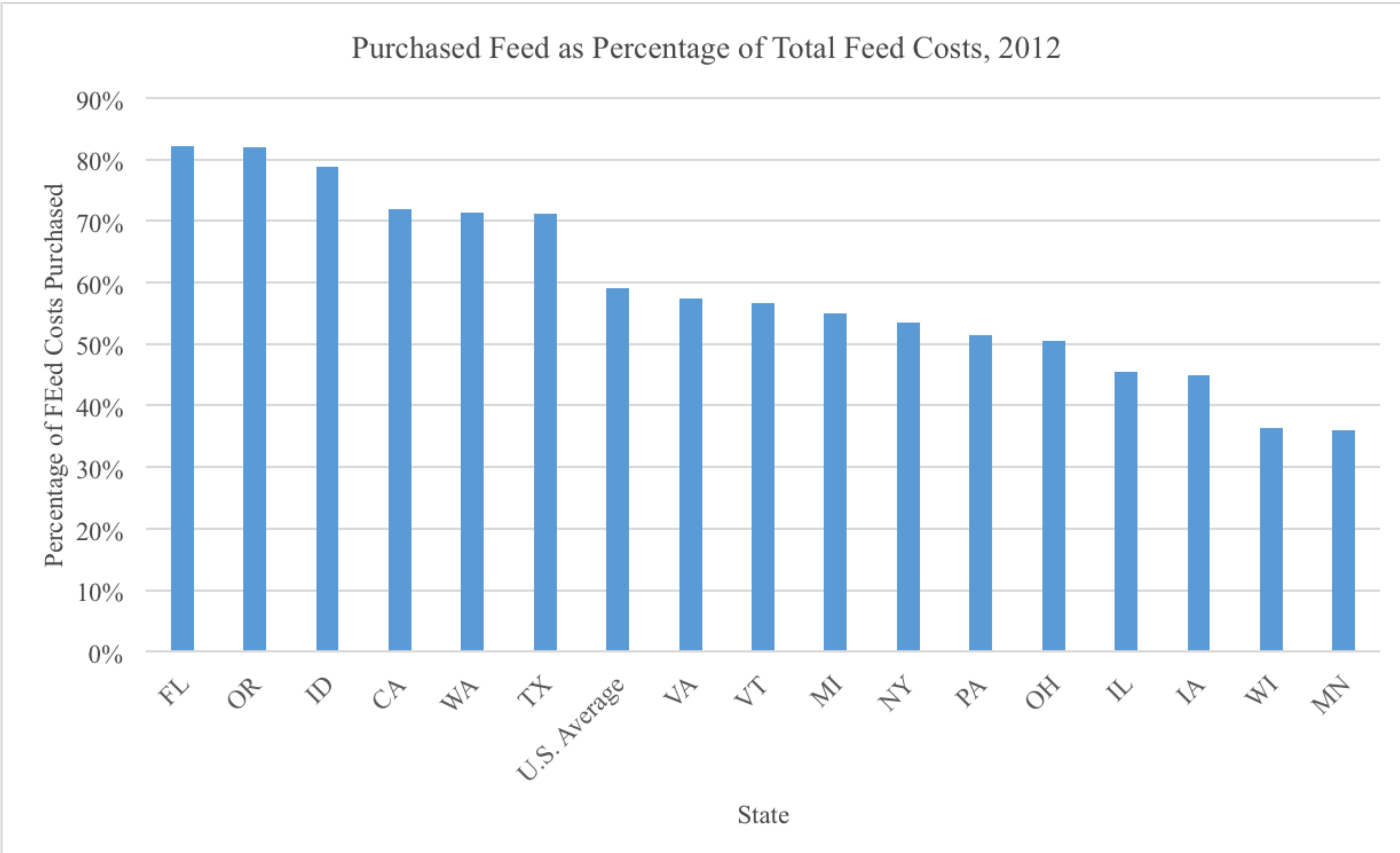

Figure 5. Purchased Feed as Percentage of Total Feed Costs, 2012, Economic Research Service (ERS), Milk cost of production by State, 2013, Available online at http://www.ers.usda.gov/data-products/milk-cost-of-production-estimates.aspx#.U15gY8eT57c

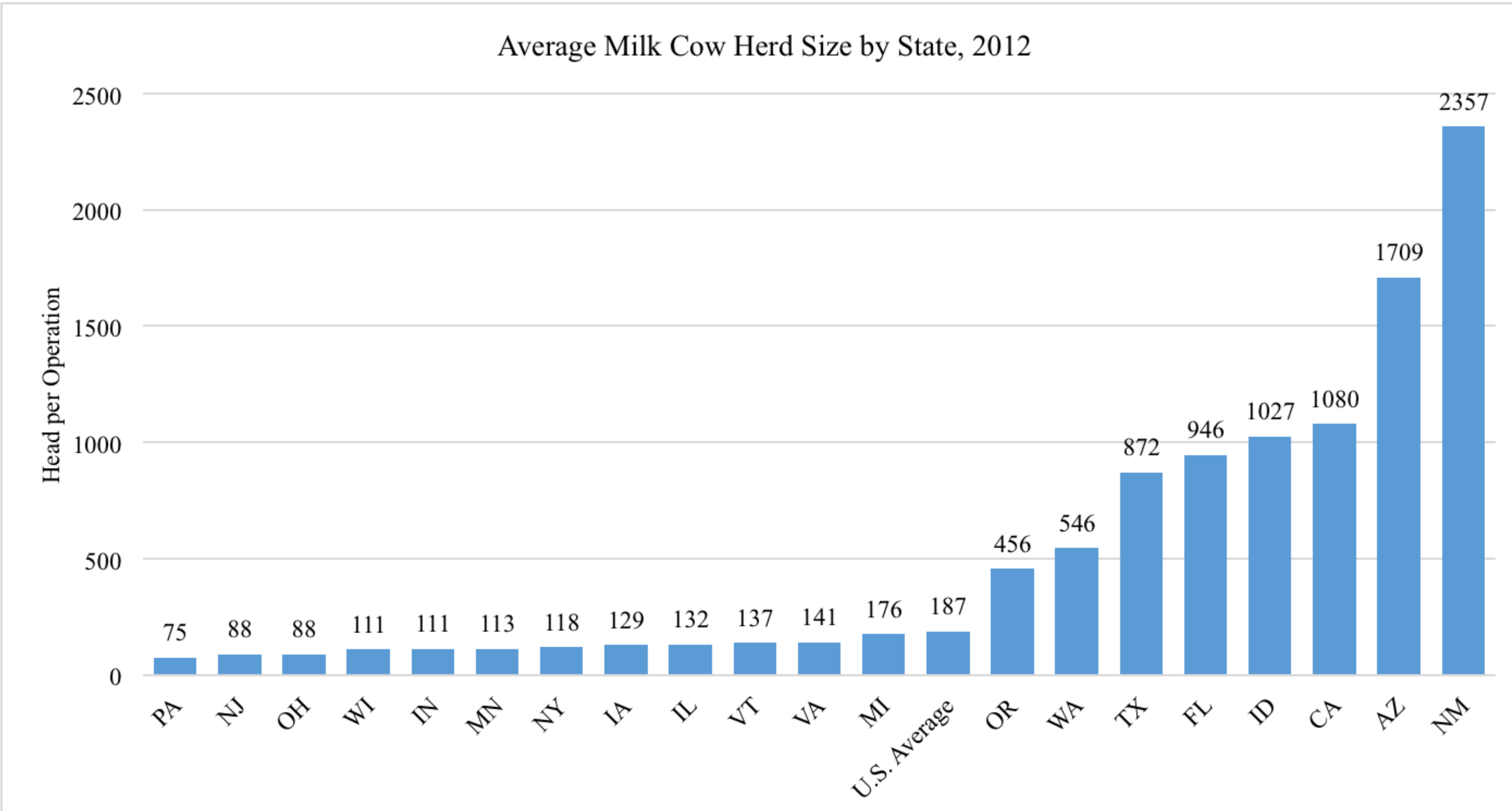

Figure 6. Average Cow Herd Size by State, 2012 National Agricultural Statistics Service (NASS), Milk Production, February 2013, Available online at http://usda.mannlib.cornell.edu/usda/nass/MilkProd//2010s/2013/MilkProd-02-20-2013.pdf

Despite the emergence of new, large players in Western states over the past several decades, other regions of the country are undergoing a renaissance in their own right. For example, the emergence of the yogurt industry in New York State is well-documented (Novakovic and Boynton, 2014). New York has nearly doubled its yogurt (specifically Greek yogurt, which requires 3 times more milk to produce than regular) plants since 2000, and has tripled its yogurt production over the past 6 years to become the nation's largest producer of the protein-rich dairy product. This increase in processing capacity has produced a considerable amount of momentum and pressure for the state's milk production to increase in order to meet the demand, even resulting in Governor Cuomo's *Yogurt Summit* in August 2012 to discuss strategies to meet these challenges. A similar resurgence of the Wisconsin dairy industry has occurred since the early 2000s through efforts by the state's Dairy Business Association and Professional Dairy Producers of Wisconsin as herd sizes have increased and statewide regulations and standards have been passed in the state legislature.

Current Policy

Price support programs in the dairy industry have been in existence since the Agricultural Act of 1949, and although they have been amended many times through the passage of numerous farm bills, their intent has always been the same: to provide price and income support, provide market stability for dairy producers, and enhance risk management. Chief among these programs under the Food, Conservation, and Energy Act of 2008 (the 2008 Farm Bill) include the Dairy Products Price Support Program (DPPSP) and the Milk Income Loss Contract (MILC) Program, both of which rely on simple price triggers (Schnepf, 2012).

The DPSPP was established in 1949 and supports the farm price of fluid milk at $9.90 per hundredweight (cwt.) through government purchases of dairy products at set prices. These purchases are countercyclical. When purchases exceed statutory levels, USDA makes temporary adjustments to avoid accumulation of excess inventories. Since the mid-1990s, milk prices have trended higher than the flat support price, albeit coupled with greater volatility. This volatility has made it difficult for farmers and farm managers to plan in the future, as the low support price increases vulnerability to the costs of feed. Rising feed costs, arising from the emergence of the U.S. ethanol industry since 2006, are of particular concern to dairy producers, as they represent a significant portion of the cost of milk production. At its height of importance in the early 1980s, the DPPSP had financial outlays in of $10.592 billion in FY1981-FY1985, whereas outlays in FY20008-FY2012 hovered around $280 million (Schnepf, 2012).

The Milk Income Loss Contract (MILC) Program provides farm income support to participating dairy farms through government payments whenever the farm price for fluid consumption falls below the target price for fluid milk sold to processors in the Boston market. MILC imposes a limit on milk marketing eligible for payment during any fiscal year ranging from 2.4 to 2.985 million pounds, or approximately the production of 100-150 cows. As a result, large-scale producers can quickly hit their cap in the first couple months of a calendar year. In recent years, the target minimum price of $16.94 per hundredweight is increased if feed prices exceed a base level as determined by the National Average Dairy Feed Cost, based off of national prices.

As a result of differences in dairy farm size and productivity across states, regional distribution of benefits can, and do, differ. Due to the cap on MILC payments, it is generally known and accepted that the program provides disproportionate benefits to states and regions with smaller-sized herds. As a result, many have recognized the need for more capable risk management tools for large-scale dairy operations to utilize to protect themselves from increasingly volatile feed costs and milk prices. This is one of the primary inspirations for the policies which serve as the focus of this study, described in the next section. MILC payment rates historically have been unknown until the end of the month following the month to which they apply, which further delays the payment process. Financial outlays for the MILC program totaled $1.091 billion in FY2008-FY2012 (Schnepf, 2012).

In addition to DPPMP and MILC, there also exists the Dairy Export Incentive Program (DEIP), established in 1985 to subsidize dairy exports by providing per-unit cash payments to exporters. The program was designed to help higher priced U.S. dairy products compete in international markets. The program is rarely used, as the use of dairy export subsidies worldwide has decreased dramatically. In FY2008-FY2012, total outlays associated with DEIP amounted to $28 million (Schnepf, 2012).

The Federal Milk Marketing Orders (FMMOs) are geographically defined fluid milk demand areas. The FMMOs regulate milk marketings across state lines to provide both price support and market stability for dairy producers. FMMOs are permanently authorized and are not subject to reauthorization in farm bills. Delivery to FMMOs are governed by two main principles: classified pricing of milk according to end use, and pooling of receipts within the FMMO with a weighted average price, or blend price. Nine states have their own marketing orders separate from the federal orders, but operate in similar manners. Within each FMMO, processors are required to pay a minimum price for milk based upon its intended end use, known as classified pricing. Fluid milk (Class I) demands the highest prices, followed by manufactured products such as yogurt and ice cream (Class II), cheese (Class III), and finally butter and powdered milk (Class IV). Component prices are determined by the wholesale prices of storable dairy products. The processing costs, or make allowance, is determined from a formula and the yield of milk components in the final products. A fluid milk price is calculated from these and varies by region. Finally, the value of all milk sales in each order is pooled together to provide a uniform average price to farmers delivering milk.

These programs, coupled with smaller dairy support programs, are the main vehicles through which dairy producer price and income support are delivered. Other programs focus on promotion and disaster assistance, but are beyond the scope of this research. In the following paragraphs, the two competing dairy legislation proposals, H.R. 2642 and S. 954, or as they are more commonly known the Dairy Freedom Act (DFA) and the Dairy Security Act (DSA), respectively, are described in detail. The DSA was included in the Senate's 2012 and 2013 Farm Bill, whereas DFA was the policy instrument of choice in the House's 2013 Farm Bill. Both pieces call for the repeal of DPPSP, MILC, and DEIP programs and replace them with margin insurance.

Dairy Producer Margin Protection Program

Variability in the agricultural industry is not a new concept, but the levels in recent years are unprecedented. The U.S. all-milk price in May 2008 was $18.30/

hundredweight; a year later, it dropped to $11.60. This type of variability, coupled with feed prices soaring to record levels amid the nationwide drought of 2012, led to call for the replacement of the dairy programs that rely on simple price triggers and instead focus on measures of profitability that truly matter to a producer's viability in the marketplace.

Both the House and the Senate's dairy provisions contained the Dairy Producer Margin Protection Program (DPMPP). The DPMPP is an income-over-feed costs margin insurance program that pays the difference between the national all-milk price and the national average of feeding dairy animals, which is a weighted formula announced by USDA's National Agricultural Statistics Service (NASS). The formula for the feed cost per cwt. and margin per cwt. are found below, where milk price is in \$/cwt., corn price is \$/bushel, and the soybean meal and alfalfa hay prices are in \$/ton:

$$\begin{aligned} \textit{Feed Cost per cwt.} &= (1.0728 * \textit{corn price}) + (0.00735 * \textit{soybean meal price}) \\ &+ (0.0137 * \textit{alfalfa hay price}) \end{aligned}$$

$$\textit{Margin per cwt.} = (\textit{All Milk Price per cwt.}) - (\textit{Feed Cost per cwt.})$$

The DPMPP included a fully-subsidized option in the Senate and a nearly fully-subsidized version in the House that pays producers when the margin between the bi-monthly U.S. all-milk price and a feed cost formula fall below $4.00 for consecutive two-month periods known as *Basic Margin Protection (BMP).* Once triggered, the BMP pays out on the minimum of 80% of the producer's milk production history (the highest annual production of the past three years prior to implementation) or the actual milk produced in the 2 month period. BMP payments are equal to the following:

$$BMP\ Payment = Margin\ Shortfall * Min(0.8 * \frac{APH}{6}, Actual\ Production)$$

Administrative fees are based upon the previous calendar year milk marketings (lbs.) and are paid at registration:

Table 2. DFA and DSA Administrative Fees

If previous calendar year milk marketings (lbs.) are:					H.R. 2642	S. 954
			<	1 million lbs.	None	$100
≥	1 million lbs.	but	≤	5 million lbs.	None	$250
>	5 million lbs.	but	≤	10 million lbs.	None	$350
>	10 million lbs.	but	≤	40 million lbs.	None	$1,000
>	40 million lbs.				None	$2,500

Producers enrolled in the BMP also have the option to annually decide whether or not to participate in *Supplemental Margin Protection (SMP)*, which allows producers to purchase, at fixed premium rates per cwt., additional insurance of up to an $8.00 margin, on their choice of 25% to 90% of the previous year's milk production. The predetermined premiums vary by coverage/trigger level, as well as overall production per year, but are fixed for the lifetime of the Farm Bill. Again, the election to participate in the DPMPP is voluntary—the decision to participate in BMP is a one-time decision that last for the duration of the Farm Bill, whereas the SMP decision is made on an annual basis.

The DFA and DSA both contain the SMP, albeit with differing producer premiums and coverage options. Both versions include a break in premium rates between the first 4 million pounds of production and production in excess of 4 million pounds, as can be found in Table 3.

Table 3. DSA and DFA DPMPP Premium Rates

Coverage Threshold	H.R. 2642		S. 954	
	1st 4 million pounds	Production > 4 million pounds	1st 4 million pounds	Production > 4 million pounds
$4.00	None	$0.03	None	None
$4.50	$0.01	$0.045	$0.01	$0.02
$5.00	$0.02	$0.066	$0.02	$0.04
$5.50	$0.035	$0.11	$0.035	$0.10
$6.00	$0.045	$0.185	$0.045	$0.15
$6.50	$0.09	$0.29	$0.09	$0.29
$7.00	$0.18	$0.38	$0.40	$0.63
$7.50	$0.60	$0.83	$0.60	$0.83
$8.00	$0.95	$1.06	$0.95	$1.06

Payments under SMP are calculated by the following formula:

$$SMP\ Payment = [Insured\ Margin - Max(Actual\ Margin, \$4.00)] * cov\% * Min(\frac{APH}{6}, Actual\ Production)$$

Unlike the MILC program, the DFA and DSA do not have production caps on payments. Because of this, these programs are thought to appeal to those producers who were large enough to exhaust their MILC payments before the end of the calendar year, as well as those who have different cost or revenue structures than the national level prices used in the calculation of margins. A summarization of past national IOFC margins from 2000-2012 can be found in Figure 7.

It is important to note that this margin is only a rough estimate of the nation’s

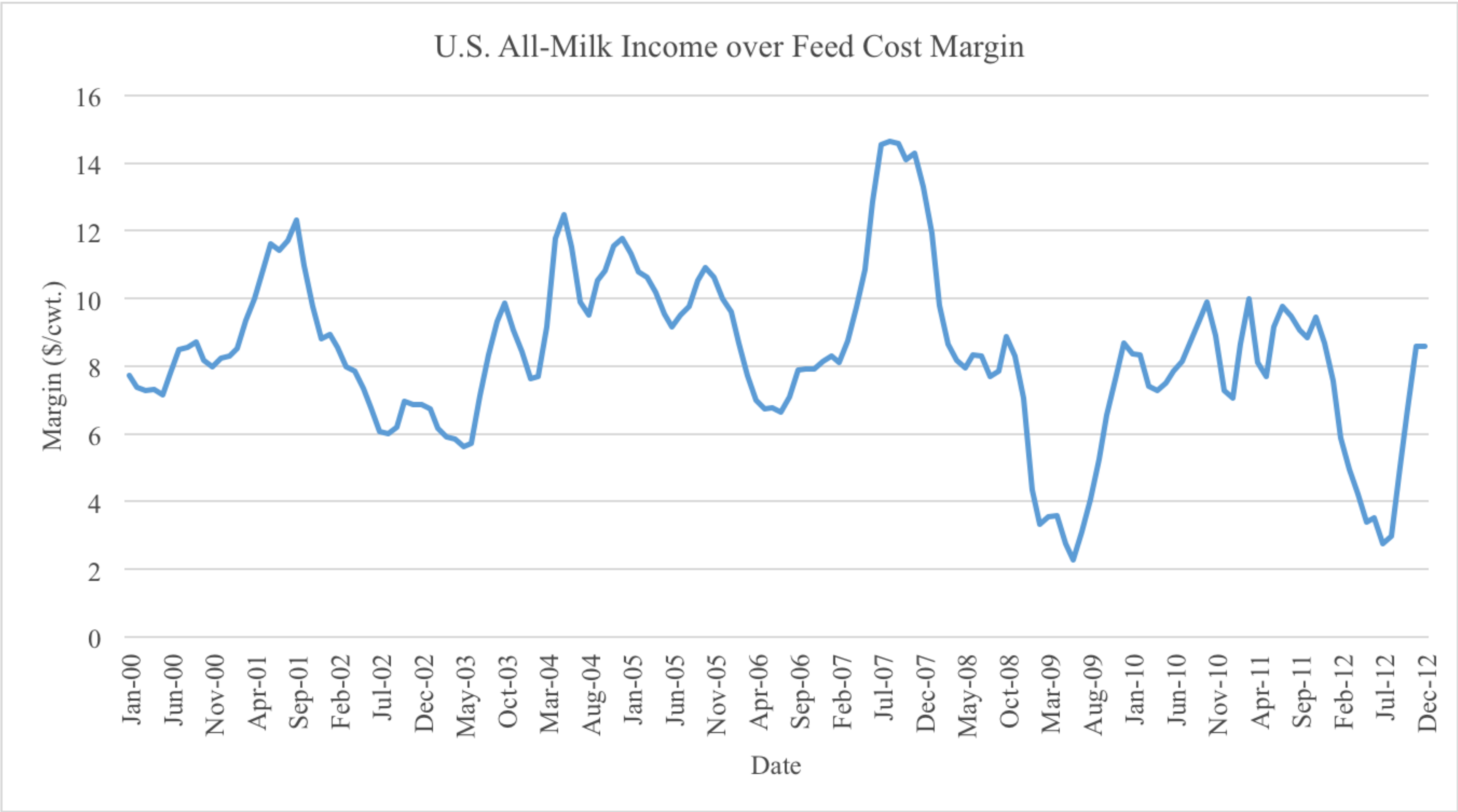

Figure 7. U.S. Monthly Milk Income over Feed Cost Margin, 2000-2012

dairy farmers' prices as a whole, and omits individual heterogeneity or regional differences in milk and feed prices. In addition, no attempt to include other operating costs, such as management or labor, is included. The voluntary participation component presents unique challenges to predicting potential impacts of the legislation, and will be discussed later in this paper.

Dairy Market Stabilization Program

In times of low margin, it is in the collective interest of dairy producers to collectively reduce output to drive prices up toward more desirable levels. Because relying on the market to make these necessary adjustment can at times, it is believed, be slow and inefficient, the DSA contains the *Dairy Market Stabilization Program (DMSP).* Under DSA, producers participating in the DPMPP are required to also participate in the DMSP, which is a supply management-type program designed to enhance milk prices by reducing milk supply by imposing penalties on dairy farmers shipping more milk than their assigned production levels during these periods, in essence decreasing supply. In addition, the forfeited income as a result of overproduction from participating farms would be diverted to the government, at which point the funds would be used to purchase dairy products for school lunch programs, shelters, etc. These actions are thought to increase demand for dairy products, thus allowing the margin to recover quicker than the market would recover on its own.

Each year, dairy producers have the ability to choose how their milk production base is determined under DMSP. The participating dairy operation can elect to use the volume of the average monthly milk marketings for the 3 months immediately preceding the announcement by the Secretary of Agriculture that the stabilization is activated, or the volume of the monthly milk marketings for the same month in the preceding year as the month for which the program is effective. When the rolling 2 month average margin is below $6, producers receive payment for the higher of either 98% of their production base or 94% of the current month's actual marketings. If the national margin is below $5 for two consecutive months, producers receive payment for the higher of 97% of their production base or 93% of the current month's marketings. When the margin is below $4 for a single month, producers receive the higher of 96% of their production base or 94% of the current month's milk marketing.

The stabilization program is suspended after the margin is above $6 for two consecutive months, or when the U.S. cheddar cheese or nonfat dry milk price is equal to or higher than the world price for 2 consecutive months when the margin is less than $6, 5% or more above the world price for 2 consecutive months when the margin is less than $5, or 7% or more above the world price for 2 consecutive months when the margin is less than $4.

According to the Congressional Budget Office (CBO), budgetary outlays for the House and the Senate versions over FY2013-FY2017 are $60 million and $107 million, respectively. By revoking existing policies in place and replacing them with the aforementioned bills, the projected savings are estimated at $141 million under the Senate plan and $181 million under the House plan. However, despite the importance of these types of policy interventions, the welfare implications, regional effects, impacts on producer behavior, and producer preferences and perceptions, although analyzed in number of reports and articles, are not well understood. Because the programs are in their infancy and have yet to be implemented, there are a number of unknown factors surrounding the efficacy and reliability of each.

Virtually all producer groups representing dairy farmers across the country support the DPMPP. The DMSP, on the other hand, received the lion's share of debate and scrutiny surrounding the farm bill debate. In general, states that tend to have larger dairy cow herd sizes, feed costs, and purchased feed as a percent of total feed costs tended to house producer groups which favored the DMSP. In contrast, those states with a higher percentage of smaller herd sizes and those which grew their own feed tended to, on the margin, be home to producer groups which were outspoken against the DMSP. Similarly, food processors, manufacturers, and retailers vehemently opposed the supply controls included in the DMSP. This divide is better understood by taking a fundamental look at the roles of variable and fixed costs. Many states in the West, as described above, and those with Western-style production practices, have been exposed to episodes of very high and volatile feed (variable) costs because they purchase the majority of their inputs. These larger farms also have lower fixed costs per unit, which translates to a lower opportunity cost of idling production compared to their Midwestern and Eastern counterparts. For this reason, it is not surprising the DMSP gained publicly-stated support from the majority of the dairy producer groups in Western-style states.

2014 Farm Bill Dairy Title

The conference report for the Agricultural Act of 2014 was agreed to in the House and Senate in late January and early February 2014, some 6 months after H.R.

2642 first passed. After long and arduous debates in the conference committee over the dairy title, the bill was signed into law on February 7, 2014. In general, the final provisions contain a version of the margin protection program without supply controls. Limits are placed on the amount of milk that can be insured. This value is equal to the highest annual milk marketings by the operation during 2011-2013. Farmers can insure between 25-90% in 5 –percent increments of its production history in 50 cent intervals from $4.00 to $8.00. Annual administrative costs for participating producers of any size is $100. Producer premiums once again have a break at the 4 million pounds of production threshold and are summarized below:

Table 4. 2014 Farm Bill DPMPP Premium Rates

Coverage Threshold	1st 4 million pounds	Production > 4 million pounds
$4.00	None	None
$4.50	$0.010	$0.020
$5.00	$0.025	$0.040
$5.50	$0.040	$0.100
$6.00	$0.055	$0.155
$6.50	$0.090	$0.290
$7.00	$0.217	$0.830
$7.50	$0.300	$1.060
$8.00	$0.475	$1.360

It is important to note that, once again, these margins are based upon national level prices and the premiums do not change over the life of the bill. Despite the fact market conditions change throughout the lifetime of a multi-year piece of legislation, the premium structure is static and could allow for producers to adversely select in and out of different thresholds. A purpose of this research is to focus on whether or not these are actuarially fair and to determine government loss ratios associated with each coverage level.

Literature Review

A wide array of work has been conducted examining price volatility in the dairy industry as well as the effects of both DFA and DSA. Variability is accepted as inherent of the dairy industry, as anyone familiar with the nature of milk and feed price paths over the past decade can contend. The source of this volatility is perhaps less well understood. Nicholson and Fiddaman (2003) contend price volatility increased dramatically for farm milk prices after the removal of price supports as a central feature in dairy markets beginning in 1988. Their model suggests there are a large number of factors affecting price volatility, including supply and demand shocks, behavioral responses of various segments of the industry to price signals, cycles of processing capacity, and cycles of cow numbers. Ultimately, their findings suggest certain regulatory policies may actually unintentionally increase volatility, whereas price supports and trade may decrease this volatility.

A considerable amount of research is focused on assessing legislation's effect on level and variation of all-milk price, the level of IOFC, milk marketed, government expenditures, and net exports of dairy products. Nicholson and Stephenson (2010) analyze the ability of the Foundation for the Future program (which includes what is known today as DSA), to mitigate price volatility in the U.S. dairy industry. Dairy product demand was represented utilizing constant elasticity demand equations, which shift with income and population growth. Focusing specifically on the FFTF program, it was found to reduce cumulative milk production compared to the baseline, reduce cumulative milk production, and reduce government costs for dairy programs. The program also increased average all-milk price both in the absence and presence of shocks.

Nicholson and Stephenson (2011) also attempt to analyze the market impacts, specifically focusing on prices, price volatility, milk marketed, government expenditures, and exports, of the Dairy Security Act and the Dairy Provisions of the Rural Economic Farm and Ranch Sustainability and Hunger Act of 2011. They found DSA reduces variation in the U.S. all-milk price, with reductions increasing with increasing participation. But because the variability is reduced, the average U.S. all-milk price is reduced. Despite the supply controls, total milk marketed per year actually increases. Higher coverage levels also result in larger government costs, and total milk marketed per year on average from 2012-2018 increases a small amount. Ultimately, the degree of reduced variation depends strongly on the participation decisions of farmers. We extend this analysis by looking at not only differing levels of participation of producers, but also differing levels of participation in different states.

DSA and DFA effects on the individual farm level are also analyzed by a number of studies. The DSA is found to lower variance of NFIO, and as a result lower the average NFIO for all farms, although participation is the largest driver of this outcome (Nicholson and Stephenson, 2011). Milk production is found to be virtually unchanged under both DFA and DSA, while DSA has the potential to reduce government outlays, as well (Brown and Madison, 2013; Newton et. al, 2013). It is important to note, however, that once again, these outcomes are more likely with higher participation rates and depend greatly upon future price paths of milk and feed prices. The contributions of this paper hope to build upon the analysis by conducting sensitivity analyses utilizing differing participation rates in different areas of the country and analyzing national level effects on price and quantity.

The supply control components of the DSA result in an unequal diversion of payments and benefits (Woodard and Baker, 2013; Balagtas, 2013). It is understood the biggest winners from a switch from the MILC program to DSA would be large producers, and by and large the large producers in states that tend to have large average herd sizes. Because a number of the states with smaller herd sizes are undergoing significant growth, and because the exact ramifications of the proposed policies are not well-understood in terms of participation levels in certain states' effect on others, the focus of this research is to bridge this gap in understanding. This study aims to grasp the ramifications of the transfers of wealth from region to region and build upon these studies to help understand future states of the world differing policy frameworks.

Previous studies on milk markets tend to exhibit similar shortcomings that could jeopardize their findings. In particular, none of the previously described studies, or any dairy market studies to our knowledge, recognize the simultaneity between price and quantity. Because these studies ignore this endogenous relationship, parameter estimates are biased toward zero and inconsistent. Presumably, patterns exist in both milk production and agricultural prices across the country. Traditional regression approaches ignore relationships among panel members and assume exogenous shocks affect only those states in which they occur, without flowing throughout the system. Approaches to account for these two shortcomings are described in later sections.

This research is inspired by the desire to build on understanding of the available literature on implications of the supply controls in regions of the country and these effects on the national landscape. It is also necessary to improve upon the existing literature to create a monthly, state-level milk model of supply and demand that is both consistent and unbiased to examine regional effects of policies. Once a model is constructed, it is possible to analyze future states of the world through simulations and analyze the legislation's overall impact on both the state and national levels of price, quantity, and economic welfare.

CHAPTER 3

DATA

Data are collected from an array of public sources at varying levels of aggregation. The insights and assumptions contained herein build upon the existing literature on estimating milk supply and demand curves (Chavas, Kraus, and Jesse, 1990; FAPRI, 2004; AMS, 2007; Bozic, Kanter, and Gould, 2012; Weersink and Tauer, 1990; Kaiser, 2000; Schmitt and Kaiser, 2002; Kaiser and Dong, 2006; Kaiser, 2010). Chief among significant found variables in these studies focused on supply include milk price, feed price, and cow slaughter price. Demand shifters are a bit less straightforward, but tend to include both population and disposable income per capita.

It is known that seasonal variation in milk production is inherent, as pastures grow most rapidly in the spring. Cows, as a result, produce the most milk in the spring in May and production tends to bottom out in November. Therefore, it is necessary to control for the peaks and valleys of milk production throughout the year if using a monthly approach. Similarly, consumption of dairy products is assumed to exhibit seasonality if modeled at the monthly level. Furthermore, dairy farmers and those associated with the industry commonly discuss a "3 year cycle", implying approximately every three years, milk prices bottom out and begin to rise again. An attempt to control for both the seasonal and cyclical nature of milk prices and production is also included utilizing sinusoidal waves.

Description of Data

State level monthly milk supply and demand is necessary for this analysis because the margin insurance program is based upon monthly all-milk and feed prices.. Data collected from USDA's National Agricultural Statistics Service (NASS) Quick Stats 2.0 are utilized and interpreted. Due to the disaggregated nature of the data at hand, there exists considerably less data at the state level than annual data. The USDA compiles dairy data for 23 states on a consistent basis, but as production concentration shifts from one state or region to another, so, too, do the states for which the USDA records data. For this reason, monthly state level data from 1998-2012 are utilized from the 19 states for which there exists complete information throughout the time period. These 19 states represent 84.14% to 88.24% of all U.S. milk production during this time period. To account for the remaining production, a 20th "state" is created to account for those states not included in the USDA's data collection process. Milk production (lbs.), milk price received ($/cwt.), and milk cow slaughter price received ($/head) as an estimate of meat price are included. Summary statistics for each can be found in Table 5.

Feed costs are less straightforward. The majority of milk supply literature (Chavas, Kraus, and Jesse, 1990; Bozic, Kanter, and Gould, 2012) use a 16% protein dairy ration as a proxy for feed costs. This data is no longer reported by the USDA on the state level, as it is collected regionally today. Furthermore, this regional data only covers the time period since 2001. The three important components of dairy feed include corn, soybean meal, and alfalfa hay. The USDA calculates a representative feed price index using corn, soybean, and hay prices. The formula for this index is found below:

Table 5. Monthly State Level Supply Shifter Summary Statistics

	Milk Production		Milk Price		Feed Price		Cow Price Received	
State	Mean	SD	Mean	SD	Mean	SD	Mean	SD
AZ	310,184,358	53,661,178	14.99	3.03	7.28	2.66	1,583	243.0
CA	3,070,346,369	368,713,574	14.18	2.85	6.96	2.55	1,495	211.6
FL	187,324,022	25,828,215	18.83	3.40	6.40	2.54	1,644	290.5
ID	834,798,883	210,870,571	14.20	2.95	6.89	2.50	1,575	289.0
IL	165,363,128	10,511,470	15.78	3.28	6.20	2.38	1,510	231.1
IN	251,351,955	41,264,618	16.02	3.19	5.93	2.35	1,494	258.1
IA	339,284,916	24,201,921	15.49	3.15	5.89	2.38	1,491	249.7
MI	579,329,609	96,088,429	15.82	3.14	5.99	2.34	1,587	279.3
MN	732,804,469	47,524,929	15.64	3.23	5.53	2.38	1,464	240.8
MO	151,402,235	27,610,558	15.72	3.20	6.31	2.71	1,361	235.1
NM	564,748,603	104,476,643	14.84	2.86	7.52	2.63	1,549	242.0
NY	1,017,966,480	51,579,207	16.13	3.12	6.99	2.23	1,438	229.7
OH	399,027,933	33,587,121	16.17	3.20	6.85	2.63	1,506	242.5
PA	887,452,514	40,913,333	16.98	3.08	7.46	2.41	1,535	246.1
TX	585,296,089	137,559,370	15.97	2.95	7.04	2.88	1,546	281.7
VT	217,100,559	9,856,895	16.42	3.17	7.03	2.38	1,550	271.1
VA	148,743,017	9,729,539	17.55	3.32	6.67	2.34	1,528	241.4
WA	471,022,346	26,714,251	15.33	3.05	7.05	2.43	1,539	280.4
WI	1,984,882,682	150,105,254	15.60	3.19	5.60	2.30	1,533	249.9
OTHER	1,981,810,056	92,794,673	15.56	3.01	6.28	2.50	1,512	241.5

$$p_{feed} = \left(\left(\frac{p_c}{56}\right) * 50\right) + \left(\left(\frac{p_{sb}}{60}\right) * 8\right) + \left(\left(\frac{p_h}{2000}\right) * 41\right)$$

where p_{feed} is the price of a pound of feed, p_c is price of corn ($/bu.), p_{sb} is price of soybeans ($/bu.), and p_h is the price of hay ($/ton). A number of states have monthly data available through Quick Stats 2.0 on each of the three feed components on a monthly basis. For those states for which monthly data does not exist, annual data is available in nearly every circumstance. The exception to this is the state of Vermont. The assumption that Vermont feed costs were the same as New York's was made. Western states including Arizona, California, New Mexico, and Washington had missing values for soybean price.

The assumption of a constant annual basis is adopted for those states in which monthly feed component prices are missing. For example, Arizona monthly corn prices do not exist in the data set, but annual prices are available. Upon reviewing the difference between annual average prices between Arizona and Illinois corn prices, this basis is used to approximate Arizona monthly prices based on the monthly Illinois price. Missing monthly values for corn, soybean, and hay prices for all states are priced off this type of basis utilizing Illinois as the base. After the missing values are calculated with the process just described, monthly state level 16% protein ration costs for all 19 states are calculated. For the 20th "state", national average prices are used.

Similarly, missing observations exist for the meat price for certain months for certain states. In order to accommodate this missing data, a similar assumption regarding the basis for feed prices is made for meat price, but instead of using Illinois for base calculation, the cow slaughter price in Kansas is used as the base. MILC payments were also collected for each month, when applicable, from the USDA Farm Service Agency (FSA). Average herd sizes were obtained for each state for the years during which the MILC was operating by taking the state's total cow herd size and dividing by the number of licensed dairy operations by state, obtained from the USDA NASS Milk Production reports. MILC payments and average farm size are interacted to examine if this interaction has a significant effect on milk production. Furthermore, dummy variables for the 1996, 2002, and 2008 Farm Bills are included to determine if the policy regime have a significant effect on milk production, as well.

State population and state-level disposable income per capita data are principal components among demand shifters in the literaute. These state-level values are obtained from the U.S. Census Bureau and the U.S. Bureau of Economic Analysis, respsectively, and are found in Table 6.

For the purposes of robustness, the same data are also collected from Quick Stats 2.0 on the annual state level, national monthly level, and national annual level over the same time period. Data at these less aggregated levels are much more plentiful, and fewer assumptions are necessary to create the complete dataset. The summary statistics for these different levels of aggregation inculding annual state, monthly national, and annual national levels are found in Tables 7, 8, and 9, respectively.

From the monthly state summary statistics included herein, it is clear large differences in the level data from one state to the next exist for nearly every variable. Consider the case of viewing the milk production in California and production in Virginia. Large disparities exist between the sheer sizes of the two industries—an

Table 6. Monthly State Level Demand Shifter Summary Statistics

	Personal Disposable Income		State Population	
State	Mean	SD	Mean	SD
AZ	29,034.92	2,986.56	5,803,261	544,975
CA	35,135.87	3,198.45	35,701,626	1,458,945
FL	32,503.55	3,377.29	17,579,440	1,222,749
ID	27,300.21	2,653.86	1,433,056	115,896
IL	34,898.89	3,206.33	12,620,871	177,207
IN	29,232.04	2,473.50	6,285,700	172,181
IA	31,423.18	4,543.54	2,979,894	54,205
MI	30,347.67	2,005.43	9,959,392	70,281
MN	34,775.17	3,350.29	5,122,554	168,332
MO	30,365.41	2,959.16	5,794,155	163,319
NM	26,967.42	3,618.15	1,937,231	99,626
NY	37,815.42	4,486.38	19,161,047	196,910
OH	30,373.78	2,675.14	11,454,286	74,623
PA	33,420.23	3,822.45	12,482,836	177,432
TX	31,523.96	3,974.95	23,016,696	1,838,792
VT	32,399.95	4,406.14	618,437	7,868
VA	35,765.70	4,269.39	7,562,826	394,499
WA	35,556.28	3,884.51	6,310,176	355,789
WI	31,859.18	3,187.54	5,535,833	135,857
OTHER	31,665.87	4,843.35	104,309,790	4,449,874

external shock to the system certainly affects the production in both states, but the actual amount of milk production increase or decrease will almost certainly be different in the two states. Because of the discrepancies between the sizes of states' dairy industries, the percentage change in milk production in response to percentage change in milk price, feed costs, and cow slaughter costs are most relevant to the purposes of this study. Likewise, a 1% change in milk production in California is likely to affect the national landscape more than the same 1% change in milk production in Virginia. For this reason, and due to the large disparity in terms of

Table 7. State Annual Level Supply Shifter Summary Statistics

	Milk Production		Milk Price		Feed Price		Cow Price Received	
State	Mean	SD	Mean	SD	Mean	SD	Mean	SD
AZ	3,717,133,333	585,452,068	14.94	2.66	7.46	2.79	1580.67	241.29
CA	36,795,533,333	4,386,318,646	14.17	2.51	7.03	2.58	1494.67	204.62
FL	1,427,600,000	40,598,733	18.78	2.93	6.51	2.50	1642.00	283.60
ID	9,992,866,667	2,580,116,439	14.21	2.62	7.08	2.64	1577.33	281.64
IL	1,985,466,667	71,984,985	15.75	2.98	6.24	2.44	1508.67	229.72
IN	3,011,800,000	497,182,806	15.97	2.85	6.54	2.68	1492.67	254.09
IA	4,070,400,000	256,190,443	15.44	2.84	6.06	2.58	1488.67	245.09
MI	6,942,733,333	1,167,847,377	15.81	2.82	6.05	2.43	1586.00	281.34
MN	8,797,333,333	451,748,929	15.66	2.92	5.68	2.60	1462.67	237.86
MO	1,820,200,000	308,448,468	15.66	2.79	5.66	2.30	1360.67	229.27
NM	6,761,066,667	1,272,113,285	14.83	2.53	11.14	4.11	1548.00	239.89
NY	12,212,133,333	434,850,691	16.11	2.79	6.76	2.19	1436.67	222.09
OH	4,787,000,000	364,251,679	16.15	2.92	6.50	2.49	1504.67	240.47
PA	10,652,533,333	262,048,760	16.98	2.76	7.20	2.31	1536.67	239.30
TX	7,017,400,000	1,633,965,020	15.93	2.59	6.35	2.45	1544.00	271.60
VT	2,605,533,333	72,256,356	16.41	2.86	7.11	2.45	1549.33	271.59
VA	208,200,000	43,819,761	17.54	2.97	6.49	2.57	1526.67	237.81
WA	5,649,933,333	258,337,948	15.37	2.75	7.31	2.61	1538.00	271.43
WI	23,811,200,000	1,648,135,145	15.59	2.84	5.65	2.37	1531.33	245.44
OTHER	23,789,726,667	466,511,720	15.40	2.65	5.74	2.58	1507.33	231.32

Table 8. Monthly National Level Summary Statistics

Variable	Mean	SD
Milk production, in lbs.	14,881,061,453	1,200,085,901
Milk price received, in $/cwt.	15.41	2.98
Corn price received, in $/cwt.	3.16	1.55
Soybean price received, in $/bu.	7.70	3.13
Hay price received, in $/ton	118.55	36.59
Milk cow price received, in $/head	1,512	242
Feed costs, in $/cwt. Milk	6.28	2.50
Disposable personal income, in $	31,666	4,843
National population	295,669,107	11,734,546

Table 9. Annual National Level Summary Statistics

Variable	Mean	SD
Milk production, in lbs.	176,055,793,333	13,460,456,336
Milk price received, in $/cwt.	15.40	2.65
Corn price received, in $/cwt.	3.32	1.72
Soybean price received, in $/bu.	7.80	3.23
Hay price received, in $/ton	113	35
Milk cow price received, in $/head	1,507	231
Feed costs, in $/cwt. Milk	5.74	2.58
Disposable personal income, in $	31,621	5,024
National population	295,559,024	12,174,568

the sheer sizes of state milk productions, all values are converted into logarithmic form. Instead of the model implying identical changes in actual milk production across all states due to the same shock, the model instead implies identical percentage change in milk production as a result of the same shock. This strict assumption is relaxed to an extent with the inclusion of a spatial network model described in the following section. This double log functional form also offers simplicity for interpreting coefficients, as the slope parameter can be viewed as a direct measure of elasticity.

From economic theory and a solid understanding of milk production, it is possible to hypothesize the sign of the coefficients for the various variables included in the supply model. For example, logged value of milk should be positively related with the logged lagged value of milk production, or the logged lagged milk production value. Basic economic theory implies the coefficient on logged milk price should be positive, as producers are willing to supply more milk at higher prices. Likewise, logged feed and logged cow slaughter prices should have negative coefficients. As feed prices increase, farmers could feed less to their cows, and as a result decrease overall milk production. Similarly, as the value of cull cows increases, producers may increase their culling rate to receive a higher price for their cows. If this is the case, it is possible that overall milk production may decrease as a result. Finally, the MILC payments are expected to be positively-related to milk production, whereas MILC payments interacted with the average farm size is expected to be negatively related to milk production.

CHAPTER 4

METHODS AND MODELS

The following section is composed of two discussions first focusing on milk supply, followed by a discussion focusing on milk demand. First, replications of previous supply models are attempted. After, a discussion on the necessity of instrumental variables and a spatial filter follows for the supply models. Finally, an overview of the framework for the state-level milk supply model is discussed. Following the discussion on the supply side model, a summary of the framework for the demand model estimation is described. A similar approach is taken for the demand side as the supply side, and specification and statistical tests are also provided for both sides of the market.

Replication of Previous Supply Models

Attempts are made to replicate a number of the previous econometrics models of milk supply, but to little avail. Proprietary information appears to be one of the main drivers of this phenomenon, but it is clear there are other issues at play that make replication so difficult. The AMS (2007) study, however, utilizes strictly public data and is straightforward in its structure. An attempt to recreate this model is made, and although results are not identical, the statistical significance of parameters and the signs of these parameters are similar for the time period the study covers from 1980-2005. Once data are included beyond the years included in the study, the model becomes unstable and coefficients do not make theoretical sense. This model specification does not make sense to use, given the annual nature of its structure and the volatility introduced into the industry since 2005. Results from the replication are displayed below, next to parameters from the study and parameters resulting from the introduction of additional years into the model.

Although the replication using what should be identical data is not exactly the same from 1980-2005, the significant variables in the number of cows equation are the same and similar in magnitude. In the year over year change in milk per cow equation, results are less similar in magnitude but similar in sign. For example, the coefficients on the lagged values of the logged total cow herd size, dummy variable for 1984, and dummy variable for 1987 are all statistically significant in the original study as well as the replication. Similarly, the coefficients in the year-on-year change in milk per cow are statistically significant for lagged milk price divided by the all product CPI and the feed price divided by the all product CPI. In the replication, the coefficient on the dummy variable for 1984 is also significant. It is troubling to see such a decrease in the R-squared value between the original study and the replication for the change in milk per cow equation, although these values are more similar in the logged total cow equation above.

It is easy to see as the sample period increases to include the years 1980-2012, subtle changes begin to develop. Although the signs on the coefficients remain the same as those in the original replication displayed in model (2), the R-squared value in model (3) decreases in both equations as a result of losing statistical significance on the 1984 dummy variable in the first equation and half the variables in the second equation. This phenomenon is likely related to the increased volatility in feed prices, as well as the changing structure of the United States dairy industry over

Table 10. AMS 2007 Replication, Annual Milk Production by State

Variable	(1) AMS log(cow_tot)		(2) 1980-2005 Rep log(cow_tot)		(3) 1980-2012 Rep log(cow_tot)		(4) 1998-2012 Rep log(cow_tot)	
Intercept	0.666		-0.670051		0.365049		10.788677	***
	(0.73)		(-0.45)		(0.25)		(2.35)	
log(milk_p/feed)	0.03		0.019175		-0.013198		-0.032396	
	(1.46)		(1.23)		(-1.30)		(-1.83)	
log(trend: year-1979)	-0.013		-0.005343		-0.005697		-0.02829	
	(-1.5)		(-0.95)		(-0.97)		(-0.99)	
lag(log(cow_tot))	0.929	***	1.03422	***	0.974657	***	0.332204	
	(9.61)		(11.78)		(11.27)		(1.18)	
log(cow_sl/milk_p)	-0.013		0.024109		0.01528		0.008521	
	(-1.04)		(1.16)		(0.94)		(0.61)	
Dummy: 1984	-0.021	***	-0.022153	***	-0.019456			
	(-2.11)		(-2.22)		(-1.72)			
Dummy: 1986	-0.02		-0.020188		-0.008218			
	(-1.59)		(-1.723)		(-0.66)			
Dummy: 1987	-0.043	***	-0.041322	***	-0.035304	***		
	(-3.47)		(-4.02)		(-3.05)			
Dummy: 1998	-0.013		-0.002519		-0.000851		0.00137	
	(-1.32)		(-0.22)		(-0.07)		(0.13)	
R-squared	0.9993		0.9907		0.9855		0.5199	

Variable	(1) AMS Δ milk_cow		(2) 1980-2005 Rep Δ milk_cow		(3) 1980-2012 Rep Δ milk_cow		(4) 1998-2012 Rep Δ milk_cow
Intercept	333	***	198.37		306.421245	***	51.87484
	(2.29)		(1.36)		(2.35)		(0.12)
lag(milk_p/cpi_all)	6393	***	5332.415819	***	1301.52271		4036.386887
	(2.44)		(1.97)		(0.82)		(0.84)
feed/cpi_all	-19203	***	-11713.83991	***	-3035.054453		-1343.33866
	(-2.63)		(-1.91)		(-0.08)		(-0.25)
Dummy: 1984	-297		-447.571439	***	-420.532632	***	
	(-1.67)		(-2.55)		(-2.37)		
R-squared	0.9952		0.3088		0.1806		0.063

this time period. This phenomenon is further exemplified in the model containing only years 1998-2012, as R-squared values decrease dramatically and little, if any, useful information is obtained from the results. Statistical significance of the parameters is all but lost as it is clear other factors are at play in determining the supply of milk other than the data included in the 2007 study.

A monthly state level milk supply model with a simple OLS regression with state level fixed effects is estimated as a first step toward modeling milk supply. First, logged state level milk price was included as a variable. After, logged state level milk price plus MILC payments, if applicable, are included. Results are found in Table 11.

Despite high goodness of fit measures, the model is troubling for a number of reasons, particularly when looking at the price elasticity of milk supply. Previous studies find a national level elasticity of milk supply in in the range of 0.06-0.08. It is plausible to expect level elasticities to be higher at the state level as a result of the mobility of both milk and heifers across state lines. Furthermore, parameter estimates on logged feed and logged cow slaughter prices are expected to be negative, but in these models they are positive. For these reasons, it is necessary to employ alternative estimation techniques.

Fixed versus Random Effects

Due to the nature of the data, a model with fixed effects is assumed to be appropriate. Time-invariant, unobserved heterogeneity of states is assumed to exist, and must be accounted for. This is qualified by a Hausman test on the data, which produces a resounding rejection of the random-effects model.

Table 11. State Monthly OLS Parameter Estimates

	Dependent variable is:			
	(1)		(2)	
Variable	Logged milk production		Logged milk production	
Logged milk price	0.017994	***		
	(2.16)			
Logged milk price plus MILC			0.023022	***
			(2.27)	
Logged lagged milk production	0.904762	***	0.904861	***
	(128.76)		(128.76)	
Logged feed price	0.007441		0.005738	
	(1.79)		(1.24)	
Logged cow price	0.001828		0.001475	
	(0.33)		(0.27)	
Cosine seasonal trend	0.013342	***	0.013444	***
	(10.54)		(10.72)	
Sin seasonal trend	0.019231	***	0.019392	***
	(14.90)		(14.82)	
Cosine cyclical trend	-0.000193		-0.000119	
	(-0.15)		(-0.094)	
Sin cyclical trend	-0.002826		-0.002798	
	(-1.71)		(-1.75)	
R-squared	0.9967		0.9967	
# observations	3580		3580	
# variables	28		28	

Table 12. Hausman Test Results

Fixed versus Random Effects			
Hausman Specification Test			
Test: Ho: difference in coefficients not systematic			
	chi2(6)	=	99.49
	Prob>chi2	=	0.0000

Due to the results of the test above, individual-level effects are best modeled through the fixed-effects specification. The use of fixed effects is in line with the hypothesis there may exist time-invariant effects in the sample; that is, each state could have its own intercept due to regulatory conditions, weather patterns, and other unobservable characteristics of each state.

Instrumental Variables

A number of assumptions must hold to implement a linear regression model. Included in these assumptions is the zero-conditional mean assumption, implying the mean of the error terms, given a clue of the independent variable x_i, is zero. Written algebraically, this implies the following:

$$E(\varepsilon_i | X_i) = 0$$

One instance in which this assumption does not hold is the case of endogenous variables. Market supply is established by aggregating individual supply schedules from all players in the market. Supply functions are rarely, if ever, actually observed in the marketplace. Rather, equilibrium prices and quantities are easily visible, where quantity supplied equals quantity demanded to discover the market-clearing price. A change from one period to the next in equilibrium price or quantity does not necessarily provide insight into the actual shape of the supply or demand curves, rather, it provides differing equilibrium points. An ordinary least squares regression of quantities on prices fails to identify the supply relationship (Baum, 2006). This is known as the identification problem. It is necessary to utilize instruments to identify the curve, which are factors determined outside the economic model, but factors that have an effect on the endogenous variable.

In the case of endogenous variables, consistent estimates are only obtained when instrumental variables satisfy two conditions: the instrument is uncorrelated with the error term but highly correlated with the endogenous variable(s) (Baum, 2006). The second assumption is easily testable. For this reason, it is necessary to utilize exogenous observable variables to help construct parameters for supply in order to properly model the system at hand. This is typically accomplished by the use of a two-stage least squares (2SLS) estimator, which is consistent, but not unbiased (Angrist and Krueger, 2001). In a 2SLS model, multiple instruments are combined into one optimal instrument to generate predicted values of the endogenous variable, in this case milk price. These predicted values of the endogenous variable are the optimal linear combinations of the information contained in the instruments. The "second stage" of the regression then calls for regressing the dependent variable on the predicted values of the endogenous variable and all other exogenous variables. This is a consistent estimate of parameters in a model where some of the regressors in X are correlated with the disturbance process.

According to Baum (2006), "the parameters in an equation are said to be identified when we have sufficient valid instruments so that the 2SLS estimator produces unique estimates". Consider instruments matrix Z. Coefficients from 2SLS are unique if $(Z'Z)$ is nonsingular and $(Z'X)$ has full rank k, known as the rank condition. In other words, there must be enough correlation between the endogenous variables and the instruments to produce unique estimates. The order condition requires, essentially, that there be at least as many instruments as endogenous variables. If the rank condition fails, the equation is underidentified. If the rank of

(Z’X) is k, the equation is exactly identified, and if (Z’K) is greater than k, the equation is overidentified (Baum, 2006). Instruments that meet the rank condition but are not sufficiently correlated with the endogenous variables are known as weak instruments. It is important to note, however, that weak is a relative term.

In order to build upon the instrumental variable approach put forth by Wright (1928) to instrument for milk price in the supply model, we instrument for milk price in the supply model with demand shifters (state population and disposable income per capita), and instrument for milk price in the demand model with supply shifters (lagged milk production, feed costs, and cow slaughter prices).

Utilizing a 2SLS framework, the previous model was re-estimated using the demand shifters as instruments, and the results are summarized in Table 13. As expected, the elasticity of milk supply with respect to milk price increases dramatically when instruments are used. While it appears to be too large at this point, it is also interesting to note the signs on the coefficients for feed and cow slaughter price also switched from positive to negative, which falls more closely in line with what we would expect. We must attempt to ensure the instruments utilized to instrument for milk price meet the rank and order conditions. The order condition, which is necessary but not sufficient, is satisfied, as two instruments are used to account for the single endogenous regressor in the case of the supply model, and three instruments are used in the demand model. Results from the first stage can be found in Table 14.

A Shea’s partial R-squared of 0.02 and an F-statistic of 36.27 relate the statistical strength of the instruments. Staiger and Stock (1997) proposed the notion that when only one endogenous variable exists on the right hand side of the equation, as we have in this case, an F-statistic of greater than ten implies the instruments are

Table 13. Monthly State 2SLS Parameter Estimates

	Dependent variable is:	
Variable	Logged milk production	
Logged milk price	0.544055	***
	(4.76)	
Logged milk price plus MILC		
Logged lagged milk production	0.941936	***
	(85.89)	
Logged feed price	-0.190102	***
	(-4.41)	
Logged cow price	-0.063461	***
	(-3.91)	
Cosine seasonal trend	-0.004584	***
	(-1.07)	
Sin seasonal trend	0.047427	***
	(7.44)	
Cosine cyclical trend	0.017797	***
	(4.14)	
Sin cyclical trend	-0.073114	***
	(-4.76)	
R-squared	0.9929	
# observations	3580	
# variables	28	

strong. In our case, an F-statistic of 36.27, coupled with theory described above, leads us to believe our instruments are not weak.

Testing the relevance of instruments can also be conducted through a number of methods. We begin the examination of instrument relevance with the approach put forth from Anderson (1984). All of the canonical correlations between the *X* and *Z* matrices must be significantly different from zero if an equation estimated with IVs is identified from a numerical standpoint, and failure to reject the null hypothesis calls

Table 14. Monthly State 2SLS Stage 1 Results

	Dependent variable is:	
Variable	Logged milk price	
Logged lagged milk production	-0.0535663	***
	(-2.83)	
Logged feed price	0.4475495	***
	(39.40)	
Logged cow price	0.2446355	***
	(16.98)	
Cosine seasonal trend	0.0358878	***
	(11.60)	
Cosine cyclical trend	-0.0990716	***
	(-32.71)	
Logged state population	-0.247842	***
	(-6.18)	
Logged disposable income	-0.1656473	***
	(-2.07)	
First-stage F-statistic	36.27	
Partial R-squared	0.020	

the identification of the estimated equation into question. Results from the underidentification test for both supply and demand can be found below, which led to a sound rejection of the null hypothesis.

Table 15. Monthly State 2SLS Underidentification Test

Underidentification Test		
Anderson canon. Corr. LM stat	=	71.221
Chi-sq(2) P-val	=	0.0000

In order to test for over-identifying restrictions, it is common to use the Sargan test, summarized in Table 16 below.

Table 16. Monthly State 2SLS Sargan Test

Sargan Test		
Sargan stat	=	14.730
Chi-sq(1) P-val	=	0.0001

The test results instruct to reject the null hypothesis that overidentifying restrictions are valid. While this appears potentially troubling at first, it is important to note the Sargan statistic is primarily utilized for models estimating IVs with time series or cross-sectional data. In instances where panel data are available, testing of over-identifying restrictions is not nearly as important, as these restrictions are often automatically built in to the models estimated using panel data. While it is possible "better" instruments exist, the instruments utilized operate sufficiently, and, coupled with the strategies described in the spatial discussion to follow, sufficiently serve the purpose of this research. Therefore, the variables included in the first stage to instrument for logged milk price are appropriate for both the supply and demand models.

Arellano-Bond Estimator

At this point, the Arellano-Bond GMM estimator may be appropriate. The data contains an endogenous variable, fixed effects are appropriate, and a lagged dependent variable is included as an explanatory variable, all of which are important components of a successful Arellano-Bond model (Arellano and Bond, 1991). Below are the results for the Arellano-Bond estimator for the supply model with different specifications.

In the first model, the logged milk price is instrumented with the logged values

Table 17. Arellano-Bond Dynamic Panel GMM Estimator Parameters

	Dependent variable is:							
Variable	(1) Logged milk production		(2) Logged milk production		(3) Logged milk production		(4) Logged milk production	
Logged milk price	-0.0118		-0.0644	***	-0.0108		-0.00992	
	(-1.54)		(-9.69)		(-1.42)		(-1.29)	
Logged lagged milk production	0.998	***	0.434	***	0.997	***	0.998	
	(597.62)		(23.36)		(660.08)		(596.28)	
Logged feed price	0.00534		0.109	***	0.00495		0.00467	
	(1.35)		(22.73)		(1.26)		(1.18)	
Logged cow price	0.00463		0.0567	***	0.00417		0.00423	
	(0.70)		(10.25)		(0.64)		(0.64)	
Cosine cyclical trend	0.0178	***	-0.000822		0.0177	***	0.0177	
	(11.90)		(-0.64)		(11.87)		(11.85)	
Sin cyclical trend	-0.0013		-0.00168		-0.00117		-0.00109	
	(-0.78)		(-1.30)		(-0.71)		(-0.66)	
Constant	0.0302				0.0427		0.0345	
	(0.53)				(0.77)		(0.60)	

of the state's population and disposable income per capita with the system GMM estimator, whereas the second model is the same except the difference GMM estimator is utilized. In both cases, the coefficient on logged milk price is opposite of expectations in a model of supply, as are the coefficients on logged feed price and logged cow price. Both models contain positive and statistically significant parameters for logged lagged milk production, but overall model 2 appears to have higher more significant coefficients.

In model 3, lagged levels from lag=3 to lag=4 are included in the model, whereas model 4 includes only lags from t=3. Results for parameters are both similar, although model 3 has more significant parameters than model 4. Both models also result in statistically insignificant negative coefficients for logged milk price, which is unfortunate but not surprising. Arellano-Bond estimators are appropriate for the aforementioned reasons, as well as cases in which there are a large number of panel members over a relatively short time period. The data included in this study, however, contain a relatively small number of states (n=20) over a relatively longer time dimension (t=179). For this reason, more appropriate models must be examined and analyzed. It is also important to note there may be more complex issues at play in the market and must be accounted for before a plausible model can be constructed.

Spatial Dependence

Spatial autocorrelation and dependence in supply and demand across states leads to violations of the standard OLS regression model. Major milk production areas in the United States historically have been centered near the population centers of the country, due in no small part to the perishability of milk and the lack of refrigeration technologies and transportation systems during the beginning of the Twentieth Century. Class I differentials are the constant factors added to the Class I price mover to determine Class I milk price in any given month in federal milk marketing orders.

The differential varies by location, and tends to be lowest in areas with high milk supplies and low populations and highest in areas of moderate milk supplies and high populations. For example, the Class I differential in the Upper Midwest FMMO is highest near Chicago, and decreases as one moves northwest toward North Dakota. This differential, or spatial difference in price, reflects the cost of transporting milk to more populated areas. Spatial regression methods allow us to account for dependence between observations, oftentimes from observations located in space (LeSage, 2008).

Spatial autoregressive models can be employed when spatial autocorrelation or dependence is present (LeSage, 2008). Dependence between observations often arises when data are collected from various points across space. This phenomenon is referred to as spatial dependence. Most are generally more familiar with time dependence in time series literature, which often arise as the result of costly adjustment costs, behavioral frictions, or biological response lags, indicating a dependence from one time period to the next. Ertur and Koch (2007) used the notion of “spatial diffusion with friction” to describe the need for a spatial lag, which takes the form of an average of neighboring regions. Furthermore, latent influences such as infrastructure and culture can be accounted for by taking into account the dependent variables of neighboring units. The standard cross-sectional spatial lag model is as follows:

$$y_{nx1} = \rho W y + X\beta + \varepsilon$$

In the standard model above, ρ is the spatial lag coefficient with a value between -1 and 1, **W** is a sparse spatial weight matrix where $W_{i,j}$ >0 if *i* and *j* are contiguous, and **W** is row-standardized such that the sum of each row is equal to 1.

The term **W**y is a spatially weighted average of an observation's neighbors. The data-generating process can be re-written as follows:

$$y = (I - \rho W)^{-1}(X\beta + \varepsilon)$$

Due to the $(I - \rho W)^{-1}$ component, and because it is non-sparse, every observation is a function of not only its own exogenous variables and error, but also of its neighbors, the neighbors of its neighbors, etc. with distance decay. The magnitude of this effect is determined by the value of the spatial lag coefficient. This model allows for spatial feedback effects and spatial autocorrelation.

In the panel data case, the model can be expressed as follows:

$$y_{TNx1} = \rho(I_T \otimes W_N)y + X\beta + \varepsilon$$

Again, the model can be re-written as the following:

$$y = (I_T \otimes I_N - \rho(I_T \otimes W_N))^{-1}(X\beta + \varepsilon)$$

A spatial autoregressive (SAR) model is implemented without the use of instruments, and the results are below. In general, the signs on the coefficients are as expected, although because instruments are ignored, the elasticity of supply with respect to milk price is very low. Of course, an elasticity of supply with respect to milk price of 0.0218 is The model produces a positive and statistically significant parameter estimate for ρ, as expected.

It is possible to test for correlation in the dependent variables and the residuals of a model to ensure a spatial network model is appropriate. Here, and LM statistic of greater than 6.635 calls for the rejection of the null hypothesis of no spatial correlation. Similarly, a Moran's I-statistic for spatial correlation in the residuals of a regression model of greater than 1.96 rejects the null hypothesis of no spatial correlation. It is clear form a statistical standpoint, and given knowledge of the dairy industry, an accurate model of milk supply simply cannot ignore spatial relationships. Therefore, a SAR model is appropriate for this study.

Table 18. Monthly State SAR Parameter Estimates

	Dependent variable is:	
Variable	Logged milk production	
Logged milk price	0.0218	***
	(2.88)	
Logged lagged milk production	0.850106	***
	(118.38)	
Logged feed price	-0.03491	***
	(-8.82)	
Logged cow price	-0.010199	***
	(-2.03)	
Cosine seasonal trend	0.016504	***
	(14.39)	
Sin seasonal trend	0.010735	***
	(8.92)	
Cosine cyclical trend	-0.000818	
	(-0.72)	
Sin cyclical trend	-0.000501	
	(-0.33)	
Rho	0.298984	***
	(28.11)	
R-squared	0.9972	
# observations	3580	
# variables	29	

Table 19. Monthly State Spatial Tests

LM Lag Statistic for Panel Regression Model		
LM	=	647.4915
chi1	=	6.6400
LM Error Statistic for Panel Regression Model		

LM	=	5456.6
chi1	=	6.6400
Moran's I-statistic for Spatial Correlation in Residuals		
morani	=	0.7934
istat	=	74.0215

Spatial Autoregressive Model with Instrumental Variables

The next step is to combine these two approaches to develop a SAR model utilizing instrumental variables. Again, the demand shifters (state population and disposable income per capita) are used to instrument for milk price. Rather than include the actual logged milk price in the SAR model, a fitted value of logged milk price is generated via the OLS regression of milk price on all exogenous variables including the demand shifters in the first stage and included in the second stage. After these fitted milk prices are obtained, they are inserted into the SAR panel model described earlier and the model is estimated. Attempts at utilizing logged milk price, logged milk price plus MILC payments, and including dummy variables for Farm Bills are all conducted and are summarized in Table 20.

A cursory look at the results are promising. Signs of the coefficients in each case are as we expect, and elasticity with respect to milk price are higher than those found in previous studies, but not so high as to cause alarm. The spatial autoregressive parameter is positive and statistically significant in every instance. The first model reported in Table 20 appears to be the most plausible and has high goodness of fit and statistical significance. We will focus on this model throughout the rest of the study.

Because the process of instrumenting was broken apart from the rest of the estimation, it is necessary to bootstrap the standard errors, because otherwise they are biased. Bootstrapped standard errors are reported with the parameter estimates. It is also believed that a spatial approach will also aid in the instrumentation that takes place in the first stage. By incorporating spatially-lagged information and

Table 20. Monthly State SAR Panel Model with IVs

	Dependent variable is:					
Variable	Logged milk production		Logged milk production		Logged milk production	
Logged milk price	0.157139	***			0.113264	***
	(5.87)				(4.42)	
Logged milk price plus MILC			0.20852	***		
			(7.32)			
Logged lagged milk production	0.851848	***	0.853463	***	0.853617	***
	(119.13)		(119.66)		(118.32)	
Logged feed price	-0.072235	***	-0.104444	***	-0.68259	***
	(-8.20)		(-9.50)		(-5.245)	
Logged cow price	-0.027421	***	-0.031229	***	-0.010654	
	(-4.60)		(-5.35)		(-1.66)	
Cosine seasonal trend	0.012013	***	0.012711	***	0.015925	***
	(8.38)		10		(13.22)	
Sin seasonal trend	0.017669	***	0.019521	***	0.014353	***
	(9.90)		11.09		(8.17)	
Cosine cyclical trend	0.003782	***	0.004665	***	0.001585	
	(2.64)		3.36		(1.22)	
Sin cyclical trend	-0.01848	***	-0.019037	***	-0.007221	***
	(-4.96)		(-6.09)		(-3.02)	
Rho	0.309973	***	0.306964	***	0.305977	***
	(28.58)		28.61		(28.86)	
Dummy variable: 1996 Farm Bill					0.004423	
					(1.03)	
Dummy Variable: 2002 Farm Bill					-0.002243	
					(-0.49)	
MILC payments					0.015499	***
					(4.15)	
MILC payments*average					-0.000002	

farm size			
			(-0.81)
R-squared	0.9973	0.9973	0.9972
# observations	3580	3580	3580
# variables	29	29	33

instrumenting logged milk price on the new information, it is believed the instruments will increase in strength and serve our purposes better. Results from the first stage are found Table 21.

Table 21. Monthly State SAR 1st Stage Results

Variable	*Dependent variable is:* Logged milk price	
Logged lagged milk production	-0.0216787	
	(-1.11)	
Logged feed price	0.0524019	
	(1.74)	
Logged cow price	0.0423793	
	(1.08)	
Cosine seasonal trend	0.0293809	***
	(9.25)	
Cosine cyclical trend	-0.0974187	***
	(-33.2)	
Logged state population	-0.0053752	
	(-0.07)	
Logged disposable income	-0.4496647	***
	(-10.27)	
Spatial lagged logged milk production	-0.2403325	***
	(-6.43)	
Spatial lagged logged feed price	0.4730368	***
	(14.49)	
Spatial lagged logged cow price	0.248224	***
	(6.05)	

First-stage F-statistic	68.883
Partial R-squared	0.0884

Both the partial R-squared and the first stage F-statistic increase in the supply framework with the introduction of spatial components. Furthermore, the decisions resulting from tests discussed in the previous section do not change, indicating the additional information does not harm, but more than likely aids, in explaining the variation in logged milk price. The results of these tests are summarized in Tables 22 and 23.

Table 22. Monthly State SAR Underidentification Test

Underidentification Test		
Anderson canon. Corr. LM stat	=	314.839
Chi-sq(2) P-val	=	0.0000

Table 23. Monthly State SAR Sargan Test

Sargan Test		
Sargan stat	=	212.045
Chi-sq(1) P-val	=	0.0000

Monthly Milk Demand

A similar approach is taken to develop a demand model to interact with the estimated supply curve to produce equilibrium price and quantity. Rather than instrument utilizing demand shifters, however, the all-milk price is instrumented with the supply shifters. Supply shifters include the logged lagged milk production, logged feed price, and logged cow slaughter price. It is believed that these items have a significant impact on actual milk supply, but are unlikely to affect demand.

Signs of coefficients in the demand model may again be hypothesized borrowing from economic theory. The coefficient on the logged milk price is expected to be negative, which implies a downward sloping demand curve. Kaiser (2010) explains this coefficient is small, consistent with previous studies due to the importance of milk as a staple in the American diet. The coefficient on logged personal disposable income is perhaps less straightforward. Previous studies (Kaiser, 2000; Schmitt and Kaiser, 2002; Kaiser and Dong, 2006; Kaiser, 2010; AMS, 2007) find a positive coefficient on the logged personal disposable income. Kaiser (2010) also investigates the role of the percentage of food eaten away from home (FAFH), and determines the availability of milk substitutes away from cause this measure to be negatively correlated with per capita fluid milk consumption, whereas it could increase other areas of dairy consumption, such as cheese. Furthermore, French, Wall, and Mitchell (2010) determined higher income household spend a higher percentage of food expenditures away from home compared to those households with lower incomes. Given these findings, it is unclear what sign we expect the coefficient on disposable income to have. The logged state population coefficient is expected to be positive, as a higher population, in general, is expected to demand a higher quantity of dairy products. Seasonality is also vital to include in the monthly demand model, thus seasonal variables are included in the models to capture the cyclical dairy demand throughout the year, as well as a time variable to capture the overall trend in dairy consumption throughout the time period.

Once again, a basic OLS model without the use of instrumental variables or spatial networks is first estimated. The results are summarized in Table 24. The coefficient on logged milk price is positive, which is troubling and goes against economic theory. For the reasons mentioned above, it is also clear that when using a linear regression model and ignoring the endogeneity inherit in the relationship between price and quantity, the model suffers from being biased and inconsistent. Again, it is necessary to instrument for milk price to account for these shortcomings.

.Results from a 2SLS approach using supply shifters as instruments are found in Table 25.

Table 24. Monthly State OLS Demand Parameter Estimates

Variable	*Dependent variable is:* Logged milk quantity	
Logged milk price	0.0178	
	(1.52)	
Logged disposable income	-0.0131118	***
	(-3.46)	
Logged state population	1.544963	***
	(23.32)	
Cosine seasonal trend	-0.021901	***
	(-8.20)	
Sin seasonal trend	0.038355	***
	(13.99)	
Trend	0.12992	***
	(3.41)	
R-squared	0.984	
# observations	3580	
# variables	26	

Table 25. Monthly State 2SLS Demand Parameter Estimates

Variable	*Dependent variable is:* Logged milk quantity	
Logged milk price	-0.005524	
	(-0.25)	
Logged disposable income	-0.102794	***
	(-2.32)	
Logged state population	1.550079	***
	(23.34)	
Cosine seasonal trend	-0.021146	***
	(-7.71)	
Sin seasonal trend	0.037028	***
	(12.56)	
Trend	0.011604	***
	(2.92)	

R-squared	0.984
# observations	3580
# variables	26

Results are similar for the 2SLS compared to the OLS approach, although the coefficient on logged milk price becomes negative. It is once again possible to examine the results from the first stage to examine strength and validity of the included instruments. A high value for the Shea partial R-squared and a Cragg-Donald Wald F-statistic suggest our instruments are not weak, and interpretations from the underidentification test suggest from a statistical standpoint, the model is not underidentified. Results from this first stage are also summarized in Table 26, and summaries of the instrument tests are found in Tables 27 and 28.

Table 26. Monthly State 2SLS 1st Stage Parameter Estimates

	Dependent variable is:	
Variable	Logged milk price	
Logged state population	-0.0471064	
	(-0.5)	
Logged disposable income	-0.1739228	***
	(-2.77)	
Cosine seasonal trend	0.0345296	***
	(9.77)	
Time Trend	-0.0004207	***
	(-2.65)	
Logged lagged milk production	-0.0857558	***
	(-3.98)	
Logged feed price	0.4472637	***
	(29.88)	
Logged cow price	0.2319894	***
	(14.10)	
First-stage F-statistic	318.47	
Partial R-squared	0.212	

Table 27. Monthly State 2SLS Demand Underidentification Test

Underidentification Test		
Anderson canon. Corr. LM stat	=	754.426
Chi-sq(2) P-val	=	0.0000

Table 28. Monthly State 2SLS Demand Sargan Test

Sargan Test		
Sargan stat	=	2766.879
Chi-sq(1) P-val	=	0.0000

Much like the supply model, a spatial approach to account for spatial patterns and dependencies and instrument for milk price is implemented. Results using logged milk price and logged milk price plus MILC payments are summarized below.

Table 29. Monthly State Demand SAR IV Parameter Estimates

	Dependent variable is:			
Variable	Logged milk quantity		Logged milk quantity	
Logged milk price	-0.00965			
	(-0.46)			
Logged milk price plus MILC			-0.017462	
			(-0.77)	
Logged disposable income	-0.143407	***	-0.0136755	***
	(-3.41)		(3.31)	
Logged state population	1.202646	***	1.202385	***
	(18.42)		(18.42)	
Cosine seasonal trend	-0.013816	***	-0.013742	***
	(-5.23)		(-5.30)	
Sin seasonal trend	0.024526	***	0.024131	***
	(8.40)		(8.34)	
Trend	0.006528		0.006424	
	(1.72)		(1.74)	
Rho	0.34997	***	0.351994	***
	(17.00)		(17.13)	
R-squared	0.9855		0.9855	
# observations	3580		3580	
# variables	27		27	

Both models exhibit similar parameter estimates. Because the supply model we decided to use in the previous section employs logged milk price as opposed to logged milk price plus MILC payments, we will focus on this model for tests on the instruments. Much like the supply model, utilizing spatial lags of exogenous variables as instruments employs more information in the model and aids in the instrumentation of logged milk price. The first stage results are found in Table 30.

Results for tests on the instruments in the demand equation with spatial components are reported in Tables 31 and 32. Again, results suggest the model is not underidentified, and the instruments are not too weak to move forward.

Table 30. Monthly State Demand SAR IV 1st Stage Parameter Estimates

	Dependent variable is:	
Variable	Logged milk price	
Logged state population	0.1944068	
	(1.55)	
Logged disposable income	-0.0024171	
	(-0.03)	
Cosine seasonal trend	0.0344436	***
	(9.76)	
Time Trend	0.0000215	
	(0.11)	
Logged lagged milk production	-0.0804759	***
	(-3.72)	
Logged feed price	0.4537807	***
	(29.76)	
Logged cow price	0.2405056	***
	(14.29)	
Lagged logged disposable income	-0.3316108	
	(-3.06)	
Lagged logged state population	-0.4794066	
	(-2.54)	
First-stage F-statistic	195.01	
Partial R-squared	0.215	

Table 31. Monthly State Demand SAR IV Underidentification Test

Underidentification Test		
Anderson canon. Corr. LM stat	=	766.939
Chi-sq(2) P-val	=	0.0000

Table 32. Monthly State Demand SAR IV Sargan Test

Sargan Test		
Sargan stat	=	2767.599
Chi-sq(1) P-val	=	0.0000

A SAR model is the correct model specification to model demand as is evident from the statistical tests reported. Therefore, is necessary to, again, instrument for the endogenous variable, milk price. All variables are logged in order to allow for state elasticities to be constant across states, such that percent changes are the same from one state to another given a shock, as opposed to the actual magnitudes of changes. Keep in mind, however, the spatial filter applied allows for the actual elasticities of a state to depend on the environments in neighboring states, thus actual elasticities from one state to the next can differ given what is happening in its own borders and those states with which borders are shared.

CHAPTER 5

MODEL COMPARISONS

Supply Models

Due to the nature of the margin insurance programs, it is necessary to have a monthly model of milk supply in the United States. For the sake of robustness, models are estimated at various levels of spatial and temporal aggregation. The results are briefly summarized in the following section.

In addition to the expected signs of the coefficients discussed in the previous section, particular attention is given to the elasticity of supply with respect to milk price, which is equal to the value of the coefficient on milk price due to the double log structure of the models. Previous studies determined an own-price elasticity of supply to be equal to 0.076 and 0.068 (Bozic, Kanter and Gould, 2012; AMS, 2007). Again, these values are based on national level models. State level models should have higher own-price elasticities of supply due to the mobility of heifers and cows than those at the national level, ceteris paribus. Discussion past the interpretation of parameter estimates of the more aggregated models, although interesting and potentially useful in future research on milk supply, is beyond the scope of this study.

National Monthly Supply Models

The monthly national models are created utilizing the same variables as the state level in previous section, but without the spatial components. Model (1) is estimated with simple OLS, excluding the instruments. The only significant variables in this case are the logged lagged milk production and a portion of the seasonal component. All of the signs on the coefficients are in line with theory and those obtained from the state level model, except for the logged cow price.

Moving on to model (2), 2SLS is used to estimate and instrument for the logged milk price. Much like the state level results, the elasticity of milk price increases as a result of instrumentation, albeit remains insignificant. Results are quite similar to model (1), although the coefficient on the logged cow price switches signs to become negative. Note, however, this variable does not gain significance. As expected, the elasticity of supply is more inelastic in these two models at the national level than at the state level. R-squared values are quite comparable between the two models, as well.

Model (3) incorporates and instruments for the value of milk price plus the MILC payments for the month, if applicable. Instruments used are national level data on population and personal disposable income per capita. The model experiences an increase the number of significant parameters, but loses ground on the previous models when it comes to goodness of fit. Again, the signs on the coefficients are in line with expectations. Model (4) is similar to (2), except the MILC payments are included as a regressor, as are dummy variables to capture the three farm bills throughout the sample period. Estimated parameters change dramatically in model (4), and they become implausible. For example, an elasticity of supply of 6.120434 would suggest the milk supply in the United States is extremely inelastic, which simply is not the case.

Table 33. Monthly National Level Supply Parameter Estimates

	Dependent variable is:							
Variable	(1) Logged milk production		(2) Logged milk production		(3) Logged milk production		(4) Logged milk production	
Logged milk price	0.031498		0.082367				6.120434	***
	(0.87)		(0.67)				(3.36)	
Logged milk price plus MILC					0.482287	***		
					(-2.41)			
Logged lagged milk production	0.997016	***	0.994662	***	0.971306	***	0.052715	***
	(131.07)		(105.75)		(66.61)		(3.22)	
Logged feed price	-0.009634		-0.027371		-0.162951	***	-3.158427	***
	(-0.59)		(0.62)		(2.35)		(3.29)	
Logged cow price	0.000441		-0.006628		-0.049307		0.055609	
	(0.02)		(0.23)		(1.33)		(0.20)	
Cosine seasonal trend	0.009429		0.007331		-0.003159		-0.129078	***
	(1.82)		(1.03)		(0.04)		(2.07)	
Sin seasonal trend	0.017786	***	0.020386	***	0.038528	***	0.318039	***
	(3.36)		(2.53)		(3.46)		(3.16)	
Cosine cyclical trend	0.000964		0.002627		0.013894		0.156425	***
	(0.19)		(0.40)		(1.62)		(2.39)	
Sin cyclical trend	-0.002976		-0.009855		-0.04917	***	-0.4642	***
	(0.42)		(0.56)		(2.25)		(3.14)	
Dummy variable: 1996 Farm Bill							-0.964801	***
							(2.90)	
Dummy Variable: 2002 Farm Bill							-0.888136	***
							(2.97)	
MILC payments							0.776749	***
							(3.21)	
R-squared	0.6772		0.6734		0.4989		-24.7264	
Adjusted R-sq	0.6639		0.6601		0.4784		-26.2958	
# observations	179		179		179		179	
# variables	8		8		8		11	

State Annual Supply Models

Annual state models are summarized in Table 34, and are constructed in very similar fashion to the monthly models. The main exception is the exclusion of the seasonal sinusoidal wave variables. These are included in the monthly models to capture seasonality within a year, but unnecessary when looking at annual data.

Again, model (1) is a SAR model without instrumentation, and despite a high goodness of fit measure, the parameters do not have what we expect in terms of signs on the coefficients. For example, the logged milk price in (1) has a negative coefficient, albeit insignificant. The same is also true for the logged feed and logged cow prices. Looking at model (2), the logged milk price is instrumented with the population and disposable income variables, and the coefficients fall closer into line with what we expect. Despite this, only logged lagged milk production and one of the variables used to capture the cyclical trend are statistically significant.

Model (3) is constructed in similar fashion to (2), except the value of the MILC payment added to the milk price is an average of all MILC payments per hundredweight over the course of the calendar year. Results are very similar to those in found in (2) in terms of both signs of the coefficients, magnitude of the coefficients, and statistical significance. Finally, model (4) is and extension of (2) to include the dummy variables for Farm Bills and MILC payments, as well. The parameter for logged feed price switches to positive in (4), which contradicts expectations. Overall, although these models have high R-squared values and seemingly plausible supply elasticities, they lack significance in regards to these elasticities and produce negative spatial weight matrix parameters.

Table 34. Annual State Level Supply Parameter Estimates

	Dependent variable is:							
Variable	(1) Logged milk production		(2) Logged milk production		(3) Logged milk production		(4) Logged milk production	
Logged milk price	-0.011087		0.087534				0.033123	
	(0.52)		(1.30)				(0.48)	
Logged milk price plus MILC					0.090823			
					(1.32)			
Logged lagged milk production	0.935242	***	0.936561	***	0.936322	***	0.938781	***
	(61.67)		(61.80)		(61.82)		(63.24)	
Logged feed price	0.017047		-0.019941		-0.020381		0.018045	
	(1.65)		(-0.76)		(-0.78)		(0.57)	
Logged cow price	0.011433		0.004001		0.003137		-0.014258	
	(0.97)		(0.31)		(0.24)		(-0.87)	
Cosine cyclical trend	-0.010544	***	-0.019275	***	-0.017599	***	-0.018365	***
	(-3.40)		(-2.99)		(-3.37)		(-4.31)	
Sin cyclical trend	0.003799		-0.004745		-0.003158		-0.001137	
	(1.22)		(-0.75)		(-0.60)		(-0.25)	
Rho	-0.024984		-0.014979		-0.015987		-0.026964	
	(-0.83)		(-0.49)		(-0.52)		(-0.89)	
Dummy variable: 1996 Farm Bill							0.010499	
							(0.92)	
Dummy Variable: 2002 Farm Bill							0.018982	***
							(2.51)	
MILC payments							-0.00889	
							(0.82)	
R-squared	0.9993		0.9993		0.9993		0.9994	
# observations	300		300		300		300	
# variables	27		27		27		30	

National Annual Supply Models

Finally, a similar approach is taken with annual national data as the approaches described for the annual state data. Once again, results are not as promising as the results derived from the monthly state level models. Model (1) is an OLS estimations without the use of instruments. Coefficients on both feed and logged lagged milk production are statistically significant, but the rest of the parameters are not. Goodness of fit is very high for this model, due primarily to the inclusion of the lagged dependent variable as a regressor

Models (2) and (3) use 2SLS to instruments for logged milk price and the logged value of milk price and MILC payments, respectively. The parameter estimates from these two models, although not identical, are similar. Both lose significance in the logged feed price when compared to (1), and both imply milk supply in the United States is elastic. Although the signs for the coefficients on the logged feed and logged cow prices are negative for (2) and (3), they are statistically insignificant and not of much use for the purposes of this study.

Table 35. Annual National Level Supply Parameter Estimates

	Dependent variable is:					
	(1)		(2)		(3)	
Variable	Logged milk production		Logged milk production		Logged milk production	
Logged milk price	0.007744		1.018221			
	(1.30)		(0.74)			
Logged milk price plus MILC					1.189942	
					(0.87)	
Logged lagged milk production	0.999876	***	0.925074	***	0.912506	***
	(939.47)		(7.99)		(8.10)	
Logged feed price	-0.005968	***	-0.33413		-0.381206	
	(-2.56)		(-0.74)		(-0.87)	
Logged cow price	0.000879		-0.031222		-0.043443	
	(0.25)		(-0.16)		(-0.23)	
Cosine cyclical trend	-0.001523		-0.093619		-0.082603	
	(-1.78)		(-0.72)		(-0.83)	
Sin cyclical trend	-0.000919		-0.093121		-0.083607	
	(-1.05)		(-0.71)		(-0.82)	
R-squared	0.9996		-0.1687		0.0111	
Adjusted R-sq	0.9994		-0.818		-0.5383	
# observations	15		15		15	
# variables	6		6		6	

CHAPTER 6

SIMULATIONS

Data is manipulated to represent logged values in order to impose similar coefficients, and as a result, similar elasticities across states in both the SAR supply and demand models. The simulation requires the supply and demand system to be solved for state level prices, followed by a calibration of the intercepts and error terms in these models to generate milk futures prices with volatility similar to those in the futures markets. After, correlated corn, soybean, soybean meal, and live cattle futures are generated based upon these milk prices. From state level, commodity-specific characteristic regressions on futures prices, state level input prices are generated. From the supply and demand models described in the previous section, state level prices and quantities are simulated, which aggregate to the national level to be relevant for margin insurance policy discussions. This is believed to be the first study of its kind to simultaneously simulate a spatial supply and demand system.

Solving the System

We observe market equilibriums where quantity supplied and quantity demanded meet to simultaneously determine equilibrium price, thus it is possible to utilize the supply and demand models to solve for state level milk price. For example, it is known:

$$Q_{it} = (I - \rho_{it} W)^{-1}(P\gamma_{it} + X_{it}\beta_{it} + \varepsilon_{it})$$

In the demand model above, Q_{it} is the logged milk production in state *i* during time period *t*, *I* is a 20x20 identity matrix, ρ_{it} is the spatial lag parameter, *W* is a 20x20 spatial weight matrix, P is the logged state level milk price, γ_D is the estimated elasticity of demand with respect to milk price, X_D is a Nx25 matrix of regressors including state dummy variables, logged state level disposable income, logged state population, two variables to capture seasonality, and a logged trend value. β_D is a 25x1 vector of estimated coefficients obtained from the SAR panel regression after instrumenting for logged milk price in the first step, and ε_D is the error term.

Similarly, the supply model for each period can be summarized as the following:

$$Q_S = (I - \rho_S W)^{-1}(P\gamma_S + X_S\beta_S + \varepsilon_S)$$

In the supply model, Q_S is the logged milk production in state *i* during time period *t*, *I* is a 20x20 identity matrix, ρ_S is the spatial lag parameter, *W* is a 20x20 spatial weight matrix, *P* is the logged state level milk price, γ_S is the coefficient on milk price. This can also be interpreted as the estimated elasticity of supply with respect to milk price. The variable X_S is an Nx27 matrix of explanatory exogenous variables, including state dummy variables for all 20 states, lagged logged milk production, logged feed cost, logged cow slaughter price, two variables to capture seasonality within a calendar year, and two variables to capture the cyclical nature of milk production and prices that occurs over the course of 3 years. Finally, ε_S is the error term.

Equipped with both a supply and a demand model, it is possible to solve for the solution of the system in order to simulate. To simulate forward, calculations to determine equilibrium prices and quantities must be made for each period we wish to simulate. A lagged dependent variable is included as a regressor, which means once the system is solved for a given time period, the dependent variable must be plugged in as a regressor in the next period. To begin, it is necessary to note:

$$Q_D = Q_S$$

The state and national level market-clearing condition that quantity demanded must equal quantity supplied indicates market equilibrium, at which point price is discovered. Therefore, it is possible to solve the above equations for state level equilibrium price, P*, as follows:

$$P^* = [(I - \rho_D W)^{-1}\gamma_D - (I - \rho_S W)^{-1}\gamma_S]^{-1}[(I - \rho_S W)^{-1}(X_S\beta_S + \varepsilon_S) - (I - \rho_D W)^{-1}(X_D\beta_D + \varepsilon_D)]$$

This is the solution to our state level system of supply and demand. The simulation approach conducted herein necessitates a number of steps to ensure future price paths are plausible, correlation among these price paths exists, and prices and quantities aggregate up to the national level to produce meaningful results in light of the margin insurance program(s).

To continue moving toward simulations, it is first necessary to run characteristic regressions for the various prices included in the supply and demand models. These regressions allows us to back out state level prices once we obtain futures prices for given commodities in later steps. First, it is necessary to regress milk futures on U.S. all-milk price and lagged future values:

$$y_{milkf} = X_{milkf}\beta_{milkf} + \varepsilon_{milkf}$$

In this case, a simple OLS regression is run of logged Class III milk futures prices, or y_{milkf} on X_{milkf}, which includes a constant, lagged logged Class III milk futures prices, and the monthly U.S. all-milk price.

The logged state level cow slaughter prices, or *y*, are regressed using a SAR panel method on *X*, which includes state dummy variables, lagged logged state level cow slaughter prices, logged live cattle future price, and logged state level milk price. Again, *I* is a 20x20 identity matrix, ρ is the estimated spatial lag parameter, and *W* is the 20x20 weight matrix.

$$y_{cow\_st} = \left(I - \rho_{cow\_st} W\right)^{-1} (X_{cow\_st}\beta_{cow\_st} + \varepsilon_{cow\_st})$$

As a result, the $\left(I - \rho_{cow\_st} W\right)^{-1}$ is able to be pre-generated for utilization in later steps to recover state prices in the spatial framework. After live cattle futures prices and state level milk prices are obtained, state level cow slaughter prices are easily recovered.

Similarly, a SAR panel regression is run for logged state level corn price, in this case *y*, on *X*, which includes state dummy variables, lagged logged state level corn price, and logged corn futures price. The matrices *I* and *W* are the same as before, β_{corn} is the vector of coefficient obtained from the regression, and ε_{corn} is the vector of residuals.

$$y_{corn} = (I - \rho_{corn} W)^{-1}(X_{corn}\beta_{corn} + \varepsilon_{corn})$$

The same SAR process is followed for soybeans such that *y* is logged state level soybean prices, the matrix *X* contains state dummy variables, lagged logged state level soybean prices, and futures soybean prices. Again, the $\left(I - \rho_{soybean} W\right)^{-1}$ is pre-generated for later use.

$$y_{soybean} = \left(I - \rho_{soybean} W\right)^{-1}(X_{soybean}\beta_{soybean} + \varepsilon_{soybean})$$

A SAR panel method is utilized for logged state level alfalfa price, as well, although regressors in this case differ a bit due to the lack of a futures market for alfalfa hay. Instead, *y* includes state level alfalfa hay prices, whereas *X* includes state level dummy variables, lagged logged state level alfalfa hay price, and logged futures corn prices.

$$y_{alf} = \left(I - \rho_{alf} W\right)^{-1} (X_{alf}\beta_{alf} + \varepsilon_{alf})$$

Finally, the logged state level feed prices are regressed on the lagged logged state level feed price, logged state level corn price, logged state level soybean price, and logged state level alfalfa hay price in a SAR panel regression framework.

$$y_{feed} = \left(I - \rho_{feed} W\right)^{-1} (X_{feed}\beta_{feed} + \varepsilon_{feed})$$

National level corn, soybean meal, and alfalfa hay prices are estimated utilizing OLS regressions of logged national cash prices on lagged logged national cash prices and logged futures prices of corn, soybean meal, and corn, respectively.

In all instances to follow, it is first necessary to simulate future price paths of milk futures. Equipped with milk futures prices, it is possible to generate correlated uniform random variables for the other futures contracts and draw out of their price paths, described below. After these futures prices are obtained, it is possible to plug their values into the equations above to recover state level prices utilizing the estimated coefficients from the SAR regressions and national prices utilizing the estimated parameters from the OLS regressions.

Calibrating Coefficients

To begin, it is necessary to calibrate for initial milk price by state. This is accomplished by setting the initial price and quantities equal to the last values in the dataset, or by setting them to current market values. After this step is completed, it is necessary to "burn-in" the model to obtain beta shifts such that we minimize the residual at the starting period between the predicted value and the actual value. Otherwise, the first iteration in the simulation will jump well above or below plausible values. It is necessary to account for discrepancies in initial actual values versus initial predicated values by "burning-in" these beta shifters with 36 iterations, as one complete cycle in the supply model lasts 3 years, or 36 months. The objective here is to minimize the following:

$$minimize \sum (state\_sim - state\_p)^2 + (US\_p - US\_sim)^2 + (log\_sim\_state\_q - log\_state\_q)^2$$

In the above objective equation, *state_sim* is the simulated state level milk price at the end of the 36 iterations, *state_p* is the actual state level milk price at this time, *US_p* is the actual U.S. all-milk price, *US_sim* is the resulting U.S. all-milk price from the simulation, *log_sim_state_q* is the logged value of the simulated state level milk production, and *log_state_q* is the logged value of actual state milk production, all at the end of the burn-in period. Changing the factor by which the state level intercepts are multiplied minimizes this sum. The vectors *betaS* and *betaD* contain supply and demand coefficients, respectively. Multiplying the 20 state level fixed effects contained in each by a factor yields the following:

$$\beta_S(1{:}20{,}1) = \beta_S(1{:}20{,}1) + calibBeta(1{:}20{,}1)$$

$$\beta_D(1{:}20{,}1) = \beta_D(1{:}20{,}1) + calibBeta(21{:}40{,}1)$$

It is possible to minimize the aforementioned objective function by changing the factor by which we shift the coefficients state fixed effects. Because all data is in logged form, these optimal levels of the elements *calibBeta*, when added to the existing intercepts allow for the state level intercepts to be shifted up or down to more accurately accommodate and achieve equilibrium within the initial system with current quantities and prices before future price paths are created to disrupt the system. These new shifted intercepts are utilized throughout the rest of the analysis to avoid large jumps in estimates away from initial values, particularly in the first iteration of the system. These coefficients are utilized to simulate one path for the 36 months leading up to the initial period of the projected simulation, which produces the initial calibrated quantity values such that:

$$P^1 = [(I - \rho_D W)^{-1}\gamma_D - (I - \rho_S W)^{-1}\gamma_S]^{-1}[(I - \rho_S W)^{-1}(X_S\beta_S^1 + \varepsilon_S) - (I - \rho_D W)^{-1}(X_D\beta_D^1 + \varepsilon_D)]$$

In the above equation, β_S^1 andβ_D^1 are calibrated with the state fixed effects found in the previous step. Because we know that:

$$Q_S = (I - \rho_S W)^{-1}(P\gamma_S + X_S\beta_S^1 + \varepsilon_S)$$

It is possible to obtain the quantity supplied in time period 36, and allow for this value to be the lagged quantity value for the simulations moving forward. Utilizing the calibrated coefficients, we obtain ε_S and ε_D, and can generate the standard deviations of each. It is also necessary to create 20x20 correlation matrices of state residuals the supply and demand models.

From the supply and demand models, we obtain both state level price as well as quantity. Because we know the U.S. all-milk price is a weighted average of milk produced throughout the nation, it is possible to obtain an estimate of U.S. all-milk price from the models by multiplying each state's output by price, summing together, and dividing by total milk production. As a result of this U.S. all-milk price, and because we know the lagged value of Class III milk futures, it is possible to obtain an estimate of the simulated Class III milk futures price by pugging these values into the milk futures characteristic regression described above.

Calibrating System Volatility

In order to construct a plausible system, the milk futures prices produced from the interacting supply and demand models must have the same properties, or risk, as those futures contracts in the actual marketplace. The next calibration which must take place is one such that the standard deviation of predicted milk futures prices is equal to that which we observe in the options market. That is, we must calibrate our system by changing the standard deviation on the errors from the supply and demand models in order to produce milk futures price paths that exhibit volatility similarly to the actual volatility of milk futures prices. The objective of obtaining simulated milk futures price paths with volatility equal to 0.22 and $\varepsilon \sim N(0,1)$ is achieved by optimizing the standard deviation of the residuals from the supply and demand. After the system is correctly calibrated, it is possible to begin simulating future price paths and scenarios.

First, let us examine the nature of futures price paths. Here, we utilize a Euler approximation for a random walk. The Euler method indicates for a price path x,

$$x_{t+1} = x_t(\sqrt{\Delta t} + \varepsilon + \sigma)$$

where Δt is the time step, in our case 1/12 because of the monthly data, σ is the implied volatility, and ε is ~N(0,1). The value of σ for a given commodity is obtained using Black-Scholes to recover the annualized implied volatility. Because all data is in logs, it is possible to rewrite this as:

$$\frac{e^{(x_{t+1} - x_t - 1)}}{\sqrt{\Delta t} * \sigma} = \varepsilon \sim N(0,1)$$

This is useful for our purposes that the error term is normally distributed, as it can be leveraged when generating correlated random variables for the other prices in the analysis.

Initial values for milk, corn, soybean, soybean meal, and live cattle futures are set to the ending values of the data, and initial state level cash prices for corn, soybean, cow slaughter, alfalfa hay, and feed are also set. These serve as the x_t portion of the equation above when attempting to calculate the x_{t+1}.

Volatilities for the futures contracts are obtained using Black-Scholes and initialized. Furthermore, a 5x5 correlation matrix between historical logged futures prices for milk, corn, soybean, soybean meal, and live cattle prices is produced. A correlation matrix of logged historical futures prices is created between milk, corn, soybean, soybean meal, and live cattle futures, with logged milk futures in the first column.

By changing the standard deviations of ε_S and ε_D in the supply and demand models, respectively, different Class III milk futures prices are obtained. The objective is to find the optimal standard deviations of ε_S and ε_D such that milk futures prices are obtained with volatility equal to the standard deviation of milk futures prices in the futures market, or 0.22. it is known that ε~N(0,1). These calibrated supply and demand standard deviations are obtained through an optimization procedure and are utilized form this point forward.

Simulating Runs

Equipped with calibrated state intercepts and supply and demand model volatilities, which in turn produce plausible milk futures prices, it is possible to simulate many runs and evaluate the future states of the world. First, initial futures prices are set. Correlated uniform random variables for all futures contracts are generated based upon historical correlations utilizing the Iman-Conover method. After, correlated supply and demand residuals ε_s and ε_d are generated in 20x20 block matrices. These variables are distributed normally with mean zero and standard deviation equal to the optimal levels found in the above calibration.

The iterations, or months, are looped through to generate one path. From this path, state price and quantities are obtained, which lead to the recovery of the U.S. all-milk price. As a result of the previous characteristic regression, and equipped with the lagged value of milk futures, the Class III milk futures price is obtained. Because we know the following from the Euler technique:

$$\frac{e^{(x_{t+1} - x_t - 1)}}{\sqrt{\Delta t} * \sigma} = \varepsilon \sim N(0,1)$$

From the equation above, it is possible to recover ε, or the implied epsilon. Because $\varepsilon \sim N(0,1)$, it is possible to pass the implied ε through a normal CDF. The resulting value becomes the first column for a Cholesky decomposition. Taking the previously generated correlated uniform random variables from the Iman-Conover method, it is possible to obtain values of ε for all futures contract price paths. Equipped with these values, coupled with initial price values, implied volatilities from the futures markets, and a constant time step, it is possible to generate price paths for the corn, soybean, soybean meal, and live cattle futures with the Euler method.

From the generated price paths, these values are plugged back into the characteristic regressions from the beginning of the simulation process to recover state level corn, soybean, alfalfa, and cow slaughter prices, as well as national level corn, soybean meal, and alfalfa prices. Equipped with these values for the number of iterations of each simulation, it is possible to utilize the estimated model parameters from above to generate state milk supply and demand. Relationships between milk, cow slaughter, and feed component prices are maintained with historically correct correlations to one another, although the state level errors allow for the exact basis in each instance to vary slightly. In addition, the variables to capture seasonal and cyclical effects are pre-generated. Demand is assumed to be constant, except for the trend and seasonal components.

Simulation Considerations

During the simulations, it is necessary to collect data not only on prices and quantities, but also to collect data for use in estimating the efficacy of the policy instruments based upon participation rates in various regions of the country. Chief among these considerations are welfare effects and expected payments. Both consumer and producer surplus are calculated for each simulation. Consumer surplus is estimated by integrating the area under the demand curve between a maximum price and the equilibrium price, or *psim*, which is different between different states. Consumer surplus is calculated by integrating over a number s=0:1 by doing change of variables such that:

$$u = (psim + (pmax - psim) * s)$$

In the equation above, *pmax* is set to a very high number, such as 100, and *psim* is the logged price because demand is very inelastic in the short run. The demand equation must be multiplied by *(pmax-exp(psim))* to obtain consumer surplus. After consumer surplus is obtained in simulations without supply controls, the calculations are repeated in the event of supply controls to obtain consumer welfare changes as a result of DMSP.

Producer surplus for a given scenario is the area between the equilibrium price, and supply curve where quantity is equal to zero. Again, producer surplus is calculated by integrating over a number s=0:1. After, it is necessary to conduct change of variables in order to integrate from 0 percent to 100 percent of the equilibrium price, such that Ultimately, it is necessary to multiply the supply equation by the *exp(psim)* and sum across all iterations to obtain producer surplus resulting from the integral from zero to *psim*.

It is important to note that for the consumer and producer surplus calculations, the sheer magnitude of these calculations are less important than the change in values from one scenario to the next. By evaluating the relative changes in producer and consumer surplus from differing levels of participation in various programs, it is possible to examine the sources of deadweight loss or welfare gain for the economy at large.

For the DFA and the 2014 Farm Bill, expected payments are relatively straightforward, as simulated price paths are generated and payments are based upon the margins in each 2 month block from the simulations. For the DSA, however, expected payments are more complex due to the importance of participation in the program and its mandatory supply controls.

Margins are calculated in the simulation, and if necessary, supply controls kick in, but only directly restrict the production for those participation in the program. This is important because of the lagged dependent variable in the supply model, thus the supply control effects reverberate in the system. Provisions of S. 954 are included directly into the simulation procedure. Because of the nature of the models at hand,price and quantity effects at the state and national levels as a result of these controls are collected and analyzed. In addition, it is possible to examine expected payments at different coverage levels. After comparing these expected payments to the static premiums in the 2014 Farm Bill, government loss ratios are estimated.

CHAPTER 7

RESULTS

Coupled with the novel approach to modeling milk supply and demand, as well as the new methods developed for simulating a spatial supply and demand system described in the previous section, a multitude of results may be gleaned. Particular attention is paid to three main takeaways: the dollar impact of supply controls in terms of consumer surplus, producer surplus, and milk price, expected indemnities at the various levels of coverage available, and the loss ratios facing the government at each of these coverage thresholds given static premium rates. When examining the effect of supply controls on the state and national markets, the assumption is made that 100 percent of the milk produced in the U.S. is enrolled in the program and, as a result, subject to supply controls.

Impact of Supply Controls

A priori, we expect supply controls to increase the U.S. all-milk price because of its production restricting provisions and to increase producer surplus at the expense of consumer surplus and the economy at large. Again, the claim that supply control impact is trivial on the milk market does not seem to be credible—either the supply controls have an effect and it can be measured, or there would not have been a point in including them in the DSA to begin with.

In order to estimate the impact of supply controls as outlined in the DSA and put a dollar value on this shift in wealth from consumers to producers, it is necessary to run a baseline scenario in the simulation without policy layered on top. A 48-month simulation is conducted beginning with the end of our data set, December 2012, as the starting values and calibrated to produce futures volatilities equal to those in the options markets as traded on the Chicago Mercantile Exchange. This simulation is repeated 1000 times and results are compiled and analyzed.

When simulated for 4 years without supply controls in place, the average monthly U.S. all-milk price is $22.18/cwt., and milk production is 17,366,064,073 pounds per month. As a result, the average producer revenue from milk sales across all simulations and iterations is equal to $3,838,837,892.20/month. Summing the values of consumer surplus and producer surplus provide a total welfare equal to approximately $23,324,454,408.50 per month.

The assumption is made that all dairy producers in the U.S. participate in a margin insurance program that requires adherence to supply controls similar to those found in the DSA. The simulation is run again, but this time the national margin is calculated after each month. If the margin for a single month is below $4.00 or for a consecutive two-month period is below $6.00, as outlined in S. 954, reductions in production during the following month are made. After margins rise above threshold values, milk production is allowed to continue along unabated until the next period of low margins. The simulation is run over the same 4-year period as the baseline scenario with the same initial starting values and calibrated to the same volatilities as the baseline scenario, but 100% of the milk produced in the U.S. is subject to the supply controls. Presumably, changes that occur small on the surface in terms of price or quantity on a monthly basis will lead to large changes in welfare due to the size of the U.S. milk market.

After 1000 simulations, results are compiled and expected prices and quantities are gathered. The U.S. all-milk price increases by $0.77 to $22.95/cwt. Likewise, and as expected, milk production decreases by nearly 40 million pounds per month. Because of the inelasticity of milk supply and demand, overall producer revenue from milk sales actually increases by $124,241,272.68 per month. Producer surplus increases by $30,080,614 per month, while consumer surplus decreases by over $134B per month when compared to the baseline without supply controls. Overall, supply controls with 100% producer participation costs the U.S. economy $104,596,465 per month over the course of the next 4 years in deadweight loss. Results are summarized below.

Table 36. Welfare Analysis-Simulation Results (Monthly Expected Values)

	No Supply Controls	100% Participation	Difference
CS	$20,189,490,000.40	$20,054,812,920.39	$(134,677,080.01)
PS	$3,134,964,408.10	$3,165,045,022.64	$30,080,614.54
Rev	$3,838,837,892.20	$3,963,079,164.88	$124,241,272.68
US-Q (Pounds)	17,366,064,073.67	17,325,186,527.14	(40,877,546.52)
US-P($/cwt.)	$22.18	$22.95	$0.77
Total Welfare	$23,324,454,408.50	$23,219,857,943.02	$(104,596,465.48)

Certainly producer participation decisions drive these conclusions, and future research utilizing the spatial supply and demand system developed in this study can be utilized to analyze spatial impacts of regional participation levels, and what this means on a national scale. When looking at the state level, interesting patterns emerge when examining state level prices and quantities. The monthly expected value for the U.S. all-milk price increases by 3.472% with the introduction of supply controls.

Table 37 compiles the simulated expected state level milk prices both without supply controls and with supply controls and 100% participation over the same four y ear period. In addition to the simulated expected milk prices, the 10^{th} and 90^{th} percentile for all 20 states.

Table 37. Expected State Level Monthly Milk Price ($/cwt.)

	No Supply Controls			100% Participation		
State	10th Percentile	Expected Value	90th Percentile	10th Percentile	Expected Value	90th Percentile
AZ	$20.36	$22.78	$25.43	$20.52	$23.54	$26.96
CA	$18.66	$20.91	$23.41	$18.86	$21.62	$24.65
FL	$23.97	$26.88	$30.05	$24.19	$27.75	$31.68
ID	$19.62	$21.98	$24.52	$19.75	$22.75	$25.98
IL	$21.11	$23.65	$26.41	$21.37	$24.48	$28.06
IN	$19.81	$22.19	$24.78	$19.98	$22.95	$26.40
IA	$19.65	$22.01	$24.60	$19.85	$22.79	$26.15
MI	$19.44	$21.73	$24.26	$19.65	$22.50	$25.82
MN	$18.56	$20.73	$23.19	$18.79	$21.48	$24.48
MO	$20.27	$22.74	$25.45	$20.57	$23.50	$26.91
NM	$19.97	$22.34	$24.96	$20.15	$23.10	$26.48
NY	$21.32	$23.85	$26.70	$21.45	$24.68	$28.25
OH	$20.88	$23.35	$26.17	$21.09	$24.18	$27.68
PA	$23.01	$25.80	$28.89	$23.29	$26.70	$30.53
TX	$20.22	$22.66	$25.32	$20.41	$23.42	$26.79
VT	$21.92	$24.50	$27.39	$22.05	$25.37	$28.97
VA	$23.24	$26.03	$29.16	$23.44	$26.93	$30.84
WA	$21.80	$24.37	$27.25	$22.06	$25.22	$28.72
WI	$18.63	$20.82	$23.32	$18.80	$21.56	$24.66
OTHER	$19.65	$21.98	$24.59	$19.80	$22.74	$26.08

As we expect, supply controls result in higher milk prices in all states with 100% participation. In addition, the same analysis can be done in terms of milk production. Table 38 compiles the simulated expected milk production in each state without and with supply controls, respectively. In addition to the mean value, the 10^{th}

Table 38. Expected State Level Monthly Milk Production (lbs.)

State	No Supply Controls 10th Percentile	No Supply Controls Expected Value	No Supply Controls 90th Percentile	100% Participation 10th Percentile	100% Participation Expected Value	100% Participation 90th Percentile
AZ	382,161,322	385,532,807	388,766,440	380,659,195	384,657,949	388,382,756
CA	3,482,435,662	3,514,865,483	3,545,948,186	3,470,932,752	3,506,737,471	3,541,377,831
FL	197,692,088	199,437,559	201,129,581	196,943,657	198,990,892	200,959,364
ID	1,140,337,826	1,151,193,469	1,162,904,650	1,136,876,586	1,148,474,707	1,159,975,843
IL	173,213,128	174,701,000	176,268,698	172,452,220	174,287,341	175,971,711
IN	325,220,330	328,143,005	331,291,060	323,818,319	327,374,102	330,844,724
IA	397,382,715	400,883,452	404,765,664	395,914,586	399,925,186	404,139,455
MI	769,731,158	776,860,860	784,805,489	767,094,049	775,007,363	783,034,130
MN	807,704,163	815,362,424	822,994,500	805,279,532	813,388,723	821,189,351
MO	116,986,672	117,987,375	119,059,610	116,474,284	117,714,718	118,855,816
NM	687,367,877	693,574,674	700,091,506	685,085,995	691,966,764	698,479,682
NY	1,141,336,737	1,151,963,284	1,163,124,977	1,137,702,997	1,149,234,252	1,160,796,558
OH	473,379,004	477,666,736	482,401,604	471,662,443	476,530,029	481,371,967
PA	912,135,703	920,216,655	928,844,641	908,691,214	918,032,177	926,879,028
TX	821,380,128	828,662,113	836,282,074	818,380,861	826,779,486	835,820,399
VT	222,694,450	224,764,496	226,908,099	222,008,834	224,232,015	226,397,462
VA	150,275,261	151,621,039	153,059,217	149,675,016	151,265,684	152,783,577
WA	525,015,464	530,101,987	534,975,504	523,407,326	528,841,621	533,644,723
WI	2,417,497,579	2,440,304,698	2,465,220,715	2,410,215,225	2,434,398,724	2,459,113,588
OTHER	2,063,639,350	2,082,220,959	2,101,936,487	2,056,205,138	2,077,347,325	2,098,515,649

and 90th percentiles are reported, as well. It is easy to see the increases in state level milk prices when supply controls are introduced are driven by marked decreases in milk production, adding up to a 0.235% decrease in national output.

Expected Indemnities

Given the simulations conducted, expected margins may be computed over the course of the same 4-year period and expected payments under different coverage levels may be computed. After price paths of milk and feed component prices are simulated, 2-month margins may be calculated. From these 2-month margins, the margin shortfalls in relation to coverage thresholds may be calculated and analyzed. These margin thresholds are summarized below in Table 39, where annual expected payments per hundredweight of milk produced are reported at each coverage level, as well as the 10th and 90th percentiles for both no supply controls as well as 100% participation in supply controls.

Table 39. Expected Annual National Margin Shortfalls ($/cwt/year)

	No Supply Controls			100% Participation		
Coverage Level	10th Percentile	Expected Value	90th Percentile	10th Percentile	Expected Value	90th Percentile
$4.00	$0.0000	$0.1607	$0.3757	$0.0000	$0.0032	$0.0000
$4.50	$0.0000	$0.2342	$0.6250	$0.0000	$0.0094	$0.0000
$5.00	$0.0000	$0.3390	$0.9524	$0.0000	$0.0246	$0.0700
$5.50	$0.0000	$0.4890	$1.3279	$0.0000	$0.0599	$0.2045
$6.00	$0.0000	$0.7006	$1.7947	$0.0000	$0.1338	$0.3833
$6.50	$0.0000	$0.9954	$2.3547	$0.0000	$0.2722	$0.6819
$7.00	$0.0936	$1.4040	$3.1566	$0.0332	$0.5096	$1.1241
$7.50	$0.3306	$1.9551	$4.0500	$0.2266	$0.8869	$1.7229
$8.00	$0.7276	$2.6809	$5.2709	$0.5514	$1.4427	$2.5569

After compiling the annual margin shortfalls at each coverage level, it is possible to begin to calculate the expected government loss ratios under each of the proposals as well as the 2014 Farm Bill, because premium rates are static as outlined in the legislation. Expected government loss ratios are calculated by dividing expected payments to producers by premiums paid by producers. Because premium rates differ between producers with bases below 4,000,000 pounds of production and those with greater than 4,000,000 pounds, loss ratios for each of these premium rates are included. This analysis is conducted for provisions as outlined in DFA (Table 40). After, an approach to compare DFA and DSA side-by-side is conducted to analyze expected government loss ratios for DSA premiums under constant volatility; that is, examine loss ratios in a market without supply controls but with the same premiums as found in DSA. DSA loss ratios are also computed for the market in which there exists 100% participation in the supply control program. Finally, expected government loss ratios are computed for the actual program as outlined in the 2014 Farm Bill.

Table 40. DFA Expected Government Loss Ratios

Coverage Threshold	1st 4 million pounds	Production>4 million pounds	Expected Indemnities ($/cwt./yr.)	Loss Ratio (<4 million pounds)	Loss Ratio (>4 million pounds)
$4.00	None	$0.030	0.16071		5.36
$4.50	$0.010	$0.045	0.23416	23.42	5.20
$5.00	$0.020	$0.066	0.33897	16.95	5.14
$5.50	$0.035	$0.110	0.48904	13.97	4.45
$6.00	$0.045	$0.185	0.70058	15.57	3.79
$6.50	$0.090	$0.290	0.99536	11.06	3.43
$7.00	$0.180	$0.380	1.40399	7.80	3.69
$7.50	$0.600	$0.830	1.95508	3.26	2.36
$8.00	$0.950	$1.060	2.68095	2.82	2.53

Government loss ratios are in line with previous studies, with government loss ratios at much higher levels for smaller farms compared to larger farms, Again, it is unsurprising the DFA was favored by those states dominated by smaller producers in the Northeast and Midwest as opposed to those state with a higher prevalence of Western-style dairy farms.

Table 41. DSA with Constant Volatility Expected Government Loss Ratios

Coverage Threshold	1st 4 million pounds	Production>4 million pounds	Expected Indemnities ($/cwt./yr.)	Loss Ratio (<4 million pounds)	Loss Ratio (>4 million pounds)
$4.00	None	None	0.16071		
$4.50	$0.010	$0.020	0.23416	23.42	11.71
$5.00	$0.020	$0.040	0.33897	16.95	8.47
$5.50	$0.035	$0.100	0.48904	13.97	4.89
$6.00	$0.045	$0.150	0.70058	15.57	4.67
$6.50	$0.090	$0.290	0.99536	11.06	3.43
$7.00	$0.400	$0.630	1.40399	3.51	2.23
$7.50	$0.600	$0.830	1.95508	3.26	2.36
$8.00	$0.950	$1.060	2.68095	2.82	2.53

Assuming constant volatility, Table 41 reports loss ratios under DSA. While loss ratios are relatively comparable for the small farms, loss ratios tend to exhibit greater variability for larger farms when compared to the DFA. In particular, at lower levels of coverage, large farms receive a proportionally larger payment in relation to their premium than under DFA, assuming constant volatility. These results are summarized in Table 42. It is clear that because the industry was set-up to have 100% producer participation in this scenario and all-milk produced adhered to the provisions included in the supply control legislation, expected government loss ratios were able to be minimized compared to the previous two programs. In this special instance, supply controls were able to lower government costs, but 100% participation in such a program is a lofty and relatively unrealistic goal. As stated before, this apparent savings in indemnities paid by the government comes at the cost of social welfare.

Table 42. DSA Expected Government Loss Ratios

Coverage Threshold	1st 4 million pounds	Production>4 million pounds	Expected Indemnities ($/cwt./yr.)	Loss Ratio (<4 million pounds)	Loss Ratio (>4 million pounds)
$4.00	None	None	0.00319		
$4.50	$0.010	$0.020	0.00939	0.94	0.47
$5.00	$0.020	$0.040	0.02464	1.23	0.62
$5.50	$0.035	$0.100	0.05987	1.71	0.60
$6.00	$0.045	$0.150	0.13382	2.97	0.89
$6.50	$0.090	$0.290	0.27218	3.02	0.94
$7.00	$0.400	$0.630	0.50963	1.27	0.81
$7.50	$0.600	$0.830	0.88686	1.48	1.07
$8.00	$0.950	$1.060	1.44267	1.52	1.36

Table 43 below focuses on the expected government loss ratios simulated with the 2014 Farm Bill premium rates and a dairy industry without supply controls.

Table 43. 2014 Farm Bill Expected Government Loss Ratios

Coverage Threshold	1st 4 million pounds	Production>4 million pounds	Expected Indemnities ($/cwt./yr.)	Loss Ratio (<4 million pounds)	Loss Ratio (>4 million pounds)
$4.00	None	None	0.16071		
$4.50	$0.010	$0.020	0.23416	23.42	11.71
$5.00	$0.025	$0.040	0.33897	13.56	8.47
$5.50	$0.040	$0.100	0.48904	12.23	4.89
$6.00	$0.055	$0.155	0.70058	12.74	4.52
$6.50	$0.090	$0.290	0.99536	11.06	3.43
$7.00	$0.217	$0.830	1.40399	6.47	1.69
$7.50	$0.300	$1.060	1.95508	6.52	1.84
$8.00	$0.475	$1.360	2.68095	5.64	1.97

Results from all four scenarios described above are summarized below in Tables 44 and 45. First, results for small farms, or those with production less than 4 million pounds per year, are summarized. After, larger farms, or farms with greater than 4 million pounds of annual production, are summarized.

Table 44. Expected Government Loss Ratios, Small Farms

Coverage Threshold	DFA	DSA, constant volatility	DSA	2014 Farm Bill
$4.00	-	-	-	-
$4.50	23.42	23.42	0.94	23.42
$5.00	16.95	16.95	1.23	13.56
$5.50	13.97	13.97	1.71	12.23
$6.00	15.57	15.57	2.97	12.74
$6.50	11.06	11.06	3.02	11.06
$7.00	7.80	3.51	1.27	6.47
$7.50	3.26	3.26	1.48	6.52
$8.00	2.82	2.82	1.52	5.64

Looking at the loss ratios across the different scenarios for smaller farms, it is clear the compromise achieved in the Farm Bill negotiations resulted in a similar premium structure for margin coverage thresholds of $6.50 and below. After moving above this level, however, differences in premium structures result in very different expected government loss ratios. At margin levels above $7.00, the 2014 Farm Bill is expected to results in government loss ratios much higher than under DFA or DSA with constant volatility. This is represented graphically in Figure 8.

Likewise, the same analysis may be conducted for large farms, or those producers with an annual production base of greater than 4,000,000 pounds of milk. Again, government loss ratios are compiled for each of the four scenarios and summarized in Table 45 below.

Table 45. Expected Government Loss Ratios, Large Farms

Coverage Threshold	DFA	DSA, constant volatility	DSA	2014 Farm Bill
$4.00	5.36	-	-	-
$4.50	5.20	0.47	11.71	11.71
$5.00	5.14	0.62	8.47	8.47
$5.50	4.45	0.60	4.89	4.89
$6.00	3.79	0.89	4.67	4.52
$6.50	3.43	0.94	3.43	3.43
$7.00	3.69	0.81	2.23	1.69
$7.50	2.36	1.07	2.36	1.84
$8.00	2.53	1.36	2.53	1.97

When comparing government loss ratios at low margin thresholds, there is a clear difference between those found in DFA and those found in both the DSA and 2014 Farm Bill. Unsurprisingly, states dominated by larger farms tended to favor the DSA during Farm Bill negotiations. At margins above $6.50, however, negotiations resulted in a compromise that left the 2014 Farm Bill premiums for insuring margins above this level less favorable than those contained in the original language of both DFA and DSA. An illustration of this phenomenon is contained in Figure 9.

It is important to keep in mind that although government loss ratios are reduced in the case of both small and large farms with the introduction and implementation of supply controls, these savings are not without cost. Although the DMSP has the capability to reduce government payments in the form of indemnities, it simply shift the costs and burden directly to consumers and the economy at large in terms of higher milk prices and deadweight loss—over $140 million per month in net welfare alone. Despite the fact that supply controls have the capability of saving the government outlays in terms of indemnity payments, these savings come at the expense of consumers and the efficiency of the economy at large. Rather than rely on artificial market-distorting mechanisms such as supply controls to influence the cost of the margin insurance program, allowing the premium rates to fluctuate and reflect actual market conditions would allow for less adverse selection into the program and lower government loss ratios.

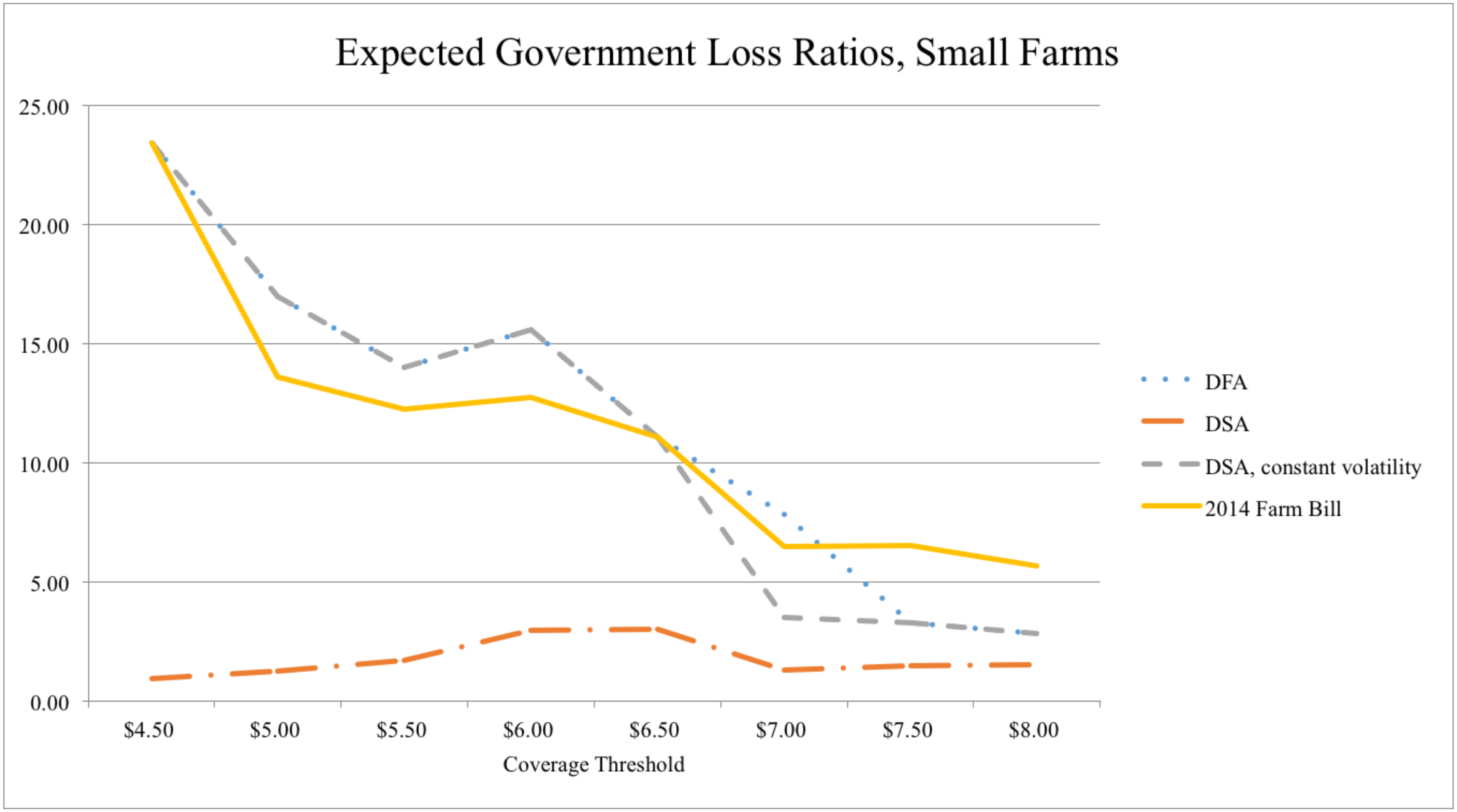

Figure 8. Expected Annual Government Loss Ratios, Small Farms

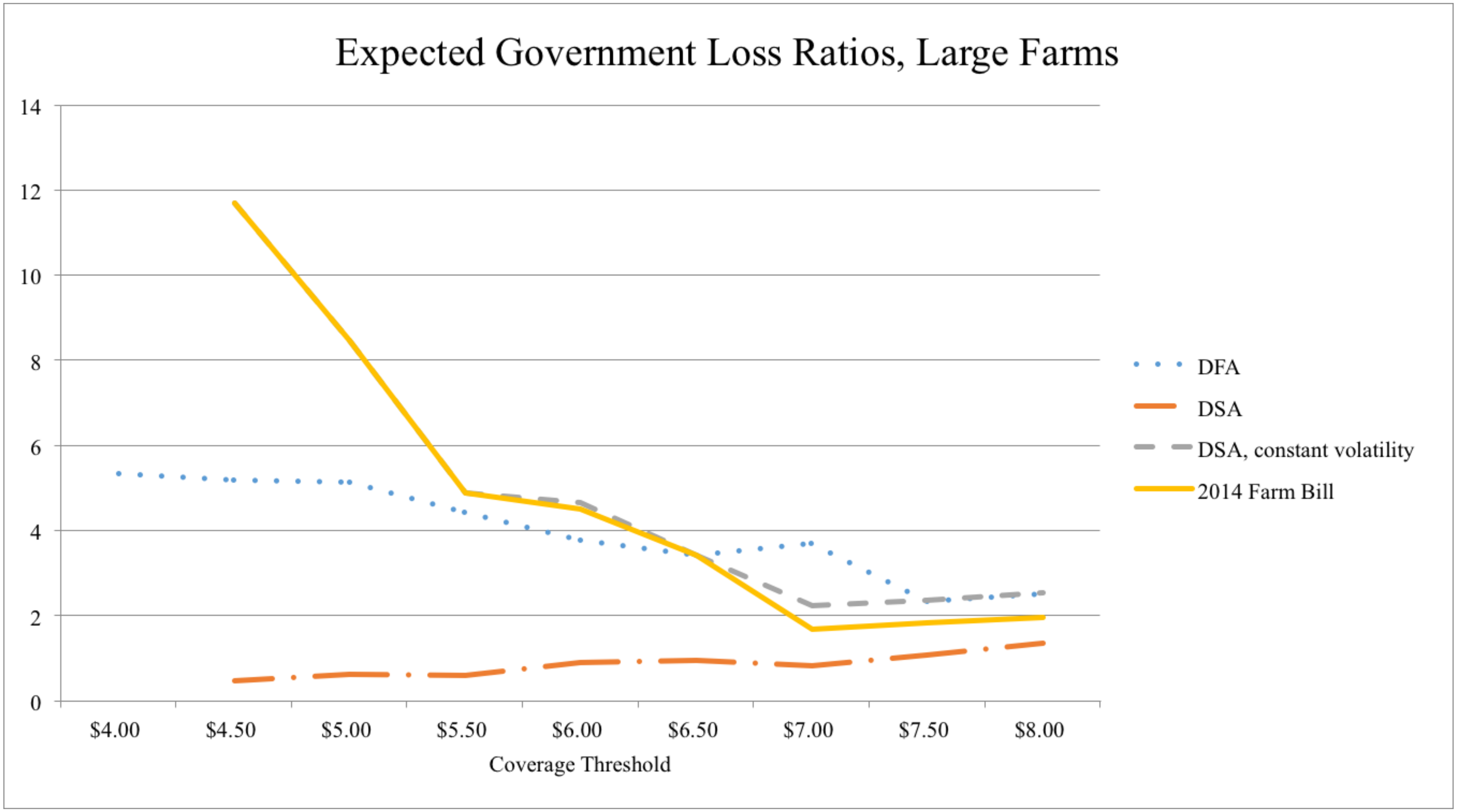

Figure 9. Expected Annual Government Loss Ratios, Large Farms

CHAPTER 8

CONCLUSIONS

This thesis analyzed the margin insurance products debated throughout the course of the 2014 Farm Bill negotiations and the efficacy of supply controls in reducing costs of such a program. A new approach to modeling the milk market was developed in order to model state level milk supply and demand and to account for spatial dependencies. An instrumental variables approach is also employed to account for simultaneity of price and quantity determination in supply and demand systems. This type of modeling structure is necessary to examine the margin insurance programs and will be useful in future research for evaluating regional winners and losers. Results indicate that although supply controls could reduce indemnities paid by the government, they result in a transfer of wealth from consumers to producers, with significant deadweight loss occurring as a result of this transfer. This deadweight loss could cost up to hundreds of millions of dollars monthly.

This work provided unique extensions to the modeling of the market for U.S. milk. Previous studies not only tend to focus on modeling from a national and annual perspective, but they suffer from biased and inconsistent estimates because they ignore simultaneity of price and quantity as well as spatial dependencies. After a cursory look at the U.S. dairy industry and the programs debated leading up to the passage of the 2014 Farm Bill, the data utilized is briefly described and analyzed. A number of approaches were taken to accurately model the supply and demand system, and a spatial system was developed with the hope it is utilized in future studies on implications of dairy markets and policy in the future.

Coupled with the supply and demand models, a unique approach was taken to simulate future states of the world utilizing the estimated models, but taking into account volatilities and expectations inherit in the marketplace. By properly calibrating this system to forward looking futures and options data, the method is more in line with appropriate actuarial approaches than *ad hoc* historical pricing that is currently used by codifying premium rates into legislation. The dependencies inherit in the futures price and spot price complexes allow simulation of state level cash prices which aggregate to national level totals for use in this policy analysis, as these program payments rely on national input and output prices. This method of simulating spatial supply and demand systems while maintaining proper volatilities and correlations among the moving parts may be applied to a wide variety of economic modeling applications in dairy markets.

A baseline scenario was simulated in which there were no supply controls, but rather allowed for the market to adjust itself. Under this policy, consumer surplus, producer surplus, producer revenue, as well as state and national prices and quantities were obtained. After, the DMSP supply controls were layered on top of the simulation to shock production if national level margins fell below threshold levels as outlined in the DSA. The same variables were collected and analyzed with the assumption that 100% of the milk produced in the U.S. over the four year simulation period were participating in the DMSP. As a result, deadweight loss per month and the size of the transfer of wealth from consumers to producers was able to be computed, as well as state level increases in price or decreases in quantity. For robustness purposes, these values were also collected at both the 10^{th} and 90^{th} percentiles. Finally, expected indemnities and government loss ratios were computed for the DFA, DSA under constant volatility, DSA with DMSP, and the 2014 Farm Bill Dairy Title.

It is clear that supply controls would have a non-trivial effect on dairy markets and entail expected costs to the tune of potentially hundreds of millions of dollars per month, amounting to several billion dollars in deadweight loss over the course of the Farm Bill period. Despite only raising milk prices by an average of $0.70 per month over the course of four years, when spread across a sector of the economy as large as the U.S. dairy industry, the effects are large and costly. Much like Bastiat's parable of the broken window, the unintended consequences of reducing government outlays affects economic activity in a way that is unseen, but ultimately is a net loss to society, namely through the loss in economic surplus and economic efficiency. These losses and shifts of welfare can be very large and damaging to the dairy market and consumers alike, and shifting costs from the government to consumers should not be a goal of a farm safety net programs; rather, providing some level of certainty and downside risk reduction should be the purpose of such programs. Savings would be better and more efficiently achieved by re-rating the premiums paid by producers to reflect actual market conditions, risks, and expectations in order to target budgeted government costs, as opposed to utilizing static premiums under supply controls.

Because this study presents unique and novel approaches to modeling the milk supply and demand system, particularly in terms of the level to which it is disaggregated, it allows for numerous research opportunities going forward. In particular, the ability to finally examine state level prices and quantities that aggregate up to a national model is of particular interest for researchers, policymakers, and commodity groups alike. Because instruments are never perfect, further research into stronger instruments, or supply and demand shifters, could be an interesting step foward.

Although the supply controls were not ultimately included in the 2014 Farm Bill, the idea of including supply controls in future pieces of dairy legislation is very likely to come up again if history is any guide. The models developed in this research may be utilized to examine specific participation levels in various supply control programs, particularly in the event certain regions are more likely to participate in such programs, and the flow of wealth from one region to the other could be computed and analyzed. The transfers of wealth from regions with low participation in programs containing supply controls toward regions with high participation is a logical next step with this research, as these transfers could be very large.

The model may be utilized to assist producers in making annual participation decisions in the DPMPP, as far as when to participate and at what coverage levels and percentages he or she should select. Because of the disaggregation of the models, it could be possible to give a producer a better idea of his or her own basis risk and expected indemnities compared to those models which simply rely on national level input and output prices. The methods utilized in this study are not only restricted to the milk markets, but could be extended to other supply and demand systems in which spatial dependencies exist.

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