THESIS

# AN ANALYSIS OF THE DAIRY INDUSTRY: REGIONAL IMPACTS AND RATIONAL PRICE FORMATION


Submitted by

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ABSTRACT

AN ANALYSIS OF THE DAIRY INDUSTRY: REGIONAL IMPACTS AND RATIONAL PRICE FORMATION

In the first chapter an Input-Output model was used to estimate the economic contribution of the combined dairy industry to the local Colorado economy. Due to the substantial increase in the dairy industry over the last decade, there was need to quantify the economic role of dairy industry, from dairy producers to dairy processers, and measure the linkages with allied industries in terms of output, value added, and employment contributions. It was estimated that the total economic contribution of the dairy industry exceeded $3 billion in 2012, and accounted for roughly 4,333 jobs.

In the chapter two Class III milk futures contracts are examined for the presence of rational price formation due to increasing uncertainty surrounding revenue streams for dairy producers. Presence of rational price formation suggests an efficient market, allowing for increased confidence in the futures market. A system of 12 seemingly unrelated regressions is used to investigate rational price formation. Futures contracts are found to be acting in an allocative capacity from 11 months to 3 months prior to expiration month. In the last 2 months, the forward pricing role is dominant taking into account the supply and demand dynamics in the market. It is found that Class III milk futures play both roles well, indicating that they are efficient in utilizing all information available through the last 12 months of trading.

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# Chapter One:

# Economic Contribution of the Dairy Industry to the Colorado Economy

## Introduction

The Pacific and Mountain dairy states[1] have significantly increased their share of the United States (US) national dairy herd and now account for approximately 38% of the total dairy cows in the US (USDA, 2012). Pacific and Mountain dairy states have increased herd size by 14% and 29% correspondingly from 2000 to 2012, while more traditional dairy regions such as the Northeast and Lake[2] States have decreased 18% and 3%, respectively. This information implies a pattern of transfer of production out of the traditional dairy regions to the Pacific and Mountain regions.

Within the Mountain dairy region, Colorado has experienced some of the highest growth. Colorado is seen as a promising dairy location due the space available, proximity to feed inputs, and expected population growth in the state (Pritchett, Thorvaldson, & Fraiser, 2006). Table 1.1 shows the evolution of the Colorado dairy industry from 2000 to 2012; cow numbers have increased 51% to 134,000, and total production by 67% to 3.2 million pounds of milk over the same time period (USDA, 2012). As the role of dairy farms have increased in states regarded as relatively new dairy producing states, quantifying the economic contribution of the industry becomes necessary (Cabrera et. al, 2008).

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[1] USDA Region Classification: Pacific Region: Washington, Oregon, California, Alaska, and Hawaii. Mountain Region: Montana, Nevada, Arizona, New Mexico, Colorado, Utah, Wyoming, and Idaho. USDA (2012)

[2] USDA Region Classification: Northeast: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland. Lake States: Michigan, Wisconsin, Minnesota. USDA (2012)

Table 1.1. Colorado Dairy Industry Growth

| | **2000** | **2012** | **% Increase** |
|---|---|---|---|
| Cow numbers (thousands) | 89 | 134 | 51% |
| Milk per cow (lbs/yr) | 21,618 | 23,978 | 11% |
| Total milk prod (mil. lbs) | 1,924 | 3,213 | 67% |

Three reasons have been identified for quantifying the economic contribution of the dairy industry to a state; use in policy decisions, benefits for society, and potential effect on linked industries (Cabrera et. al, 2008). Helmburger & Chen (1994) examined the short and long term benefits and costs of terminating milk support programs. Through an analysis of three policy options, they were able to identify the contribution of dairy farms to the economy under each scenarios. Balagtas et al. (2003) studied potential repercussions for linked industries and the overall benefits to society. Through an investigation of new markets and uses for current agricultural products, they were able to anticipate the effect on the market of innovations. In addition to the three primary reasons to quantify the economic contribution of the dairy industry, it also provides a sense of pride for dairy farmers in the state, and provides the public with an awareness of the economic contribution the dairy farm industry to the community (Cabrera et. al, 2008). Day and Minnesota IMPLAN Group Inc. (2013) list other uses of impact or contribution analysis, ranging from effective ways to invest into local economies, to identifying impacts on tax revenues.

Economic contribution is defined as the gross change in economic activity associated with an industry, event, or policy in an existing regional economy. This is not to be confused with impact analysis, which considers the increase or reduction in total economic activity in a region due to some event like a new environmental regulation, a change in tax policy, or entrance of a new business (Watson et al. 2007). Economic contribution analysis generates results broken into three categories; direct, indirect, and induced contributions. *Direct economic contributions* are essentially those resulting from the dairy industries purchases, i.e. purchase of feed grain by a dairy producer, and the jobs which are created in the dairy producer's operation. *Indirect economic contributions* are the revenues from the sale of dairy products re-spent in the local economy. The indirect contribution of the dairy industry on local economies includes purchases of a variety of agricultural inputs and professional services by industries supporting the dairy industry, i.e. a feed supplier has increased purchases of feed to meet the increased demand from the dairy producer (Day & Minnesota IMPLAN Group Inc., 2013). Indirect contributions can also appear as jobs and income in local industries serving the dairy industry (vets, feed suppliers, implement suppliers, trucking and transport). *Induced economic contributions* are the local goods and services purchased by people using the salaries and wages earned contributing to the productivity of the dairy industry (typically thought of as longer term contributions, Cabrera et al. 2008). The induced effects can be thought of in terms of jobs and income for retailers, bank tellers, grocery store clerks, restaurant employees, and gas station attendants, among others (Neibergs & Brady, 2013).

An economic contribution study is a variation of an Input-Output (I-O) model, which should not be confused with the annual sales of an industry. An I-O model, or economic contribution study, helps track the flow of money from one entity to another, allowing for the representation of the interconnectedness of industries, households, and government entities within the study area (Day & Minnesota IMPLAN Group Inc., 2013), and the sales of an industry is just the beginning of the analysis. This rationale is important for this study, as the output of one industry becomes the input for another industry. In the scope of this study, the output from dairy producers becomes the input for the fluid milk and butter processing, as well as the cheese processing industry. Using sales as a starting point also becomes important in the evaluation of any shocks to an industry, as the increase or decrease in sales is first step in generating any potential shocks (Day & Minnesota IMPLAN Group Inc., 2013).

The dairy industry, as part of the broader agricultural sector, is classified as a basic industry to the Colorado state economy. Basic industries provide income to a region by producing an output, purchasing production inputs, services and labor. The production of dairy milk and processing products represent the direct economic contribution of the industry to the locality (Seidl & Weiler, 2000). This logic dictates the method of further analysis contained within this paper. We estimate the economic contribution of each of the separate areas contained in the whole dairy industry; dairy producers, fluid milk and butter manufacturing, cheese manufacturing, and ice cream and frozen dessert manufacturing. In addition to this, we aggregate all of previously mentioned areas into a combined industry, which represents the contribution of the dairy industry as a whole to Colorado.

There is relatively little prior literature that have used I-O analysis to estimate the contribution of the dairy industry to the state, regional, or local economy. Relevant studies include Neibergs and Brady (2013), Washington State; Cabrera et al. (2008), New Mexico; Janssen et al. (2006), alternative sized dairy farms in South Dakota; Hussain et al. (2003), Earth County, Texas; and Seidl and Weiler, (2000), North Eastern Colorado. Neibergs and Brady (2013), used a survey of producers to generate primary data used to compare to the I-O generated results. Seidl and Weiler's study in 2000 provides us with a unique "starting value", from which to compare how the economic contribution of the dairy industry has grown over the 12 years spanning the two studies. I-O analysis has been used extensively in other sectors of the economy.

Within the broader agricultural sector I-O analysis has been used to evaluate the economic contributions of different sectors to the state or regional economies. Mon and Hooland (2005) used I-O models to evaluate organic apple production in Washington State, while Daniel, English, & Jensen, (2007) investigated the effect of increasing ethanol and biofuel production in the US. Outside of agriculture, I-O models and IMPLAN have been widely used in the forestry industry. IMPLAN was originally developed by the US Forest Service (Hotvedt, Busby, & Jacob, 1988) and has continued to be used in studies since, such as Hjerpe, and Kim, (2008) who analyzed the economic impacts of reducing wildfire risk through various management methods. In Colorado, the primary use of I-O models have been within the water sector. Gunter et al. (2012), and McKean and Spencer (2003) both used I-O models in examinations of how to deal with drought issues in specific watersheds. Howe and Goemans, (2003), and Pritchett, Thorvaldson, and Fraiser (2006) examined water transfer issues using the I-O methodology, and Houk, Fraiser and Schuck (2004) used it to study the effects of water logging and soil salinization. In addition to the areas already mentioned, I-O models have also been used in regional economic studies (Weiler et al. 2003). The significant body of literature that uses I-O modeling techniques is a testament to the accuracy and effectiveness of the method, and so was chosen as the primary method of analysis in the examination of the contribution that dairy has on the Colorado economy.

This paper adds to the limited body of literature on the contribution of the dairy producers industry to regional economies, and also goes further by quantifying the estimated contribution of the entire dairy industry to the regional economy. Quantifying the dairy industry provides a snapshot of the contributions being made to the regional economy, aiding in future economic analysis, policy making and allowing for the examination of benefits provided to society from the dairy industry. The work done in this study provides a holistic view of the dairy industry by examining each sector of the industry, (dairy producers, fluid milk and butter manufacturers, cheese manufactures, and ice cream and frozen dessert manufacturers), and the industry as a whole to accurately quantify the contributions made to the local Colorado economy.

The remainder of this paper is organized as follows. The methods and materials section describes the I-O model in more detail applying it specifically to the Colorado dairy industry with further descriptions of the data used. The results and conclusion section follows.

## Methods and Materials

An I-O analysis was conducted using the IMpact analysis for PLANning (IMPLAN) model software. First developed by Leontief (1936), the I-O model provides a simple method to describe an economy by tracing a change in inputs purchased resulting from a shock in final demand[3]. I-O models provide estimates of the change in in economic activity, i.e. a change in total revenues, across all sectors of a local economy resulting from a change in final demand. I-O analysis uses an economic framework that traces the flow of goods and services, income, and employment among related sectors in a defined regional economy. Therefore, the results can be interpreted as a snapshot of a regional economy in equilibrium (Cabrera, et. al, 2008). Linear

[3] Final demand is defined as the value of goods and services produced and sold to final users (Minnesota IMPLAN Group Inc., 2013). This does not include the sale of intermediate goods used as an input to production in another industry.

relationships are used within I-O analysis to reflect production processes that equate industry inputs and outputs (e.g. dairy farms) within a specific geographic region (e.g., CO). I-O models are “demand driven” models, in which the demand for the output of an industry can be examined to determine its impacts on the other sectors of the economy as a result of their interdependences.

The IMPLAN model, as an interpretation of the I-O theory, is based on the US national income, product accounts, and various other regional data sources. County level data contained within IMPLAN’s software was used to create the regional economy, which the authors described as the whole state of Colorado. I-O models are relatively easy to use and results can be obtained quickly and at a low cost (with the availability of data and software packages, such as IMPLAN). This model is very widely used so results are comparable to other studies, and all sectors of a regional economy are included. IMPLAN collect data from the U.S. Bureau of Labor Statistics (BLS) Covered Employment and Wages (CEW) program, U.S. Bureau of Economic Analysis (BEA) Regional Economic Information System (Rea) program, and various other[4] economic reports (Day & Minnesota IMPLAN Group Inc., 2013).

IMPLAN is a backward economic linkage model, and as such, it only includes the impacts of the industry being studied. This is one of the main shortcomings of I-O models in that they do not model impacts to industries in the supply chain that use the output from the primarily impacted industries (Gunter et al. 2012). For this study, both the dairy producing and processing sectors are of relevance, so the sum of both economic contributions would be equal to the importance of the whole dairy industry to Colorado. Stevens et al. (2005) found milk to be

[4] U.S. Bureau of Economic Analysis Benchmark I/O Accounts of the U.S., BEA Output estimates, BLS Consumer Expenditure Survey, U.S. Census Bureau County Business Patterns (CBP) program), U.S. Census Bureau Decennial Census and Population Surveys, U.S. Census Bureau Economic Censuses and Surveys, U.S. Department of Agriculture Census. There is a 5 month lag in the data being released to the public due to the collection time (Day & Minnesota IMPLAN Group Inc., 2013).

essentially a necessity with nearly inelastic demand and therefore we have assumed that if there were no dairy industry in Colorado, then consumers would still buy the same amount of dairy products, however, these would be imported from outside the region. Dollars spent on imports would represent a loss to the region (Neibergs & Brady, 2013).

Results of an economic contribution study are usually described in terms of multipliers, where a multiplier refers to the total amount of economic activity generated by a dollar of export sales (Seidl & Weiler, 2000). The most common multipliers are Type I (direct + indirect effects), and Type II or social accounting matrix, SAM (SAM = direct + indirect + induced effects). These contributions are analyzed in terms of industry outputs, employment, labor income, and value added to the economy (Day and Minnesota IMPLAN Group Inc., 2013). In addition to the results of IMPLAN in multiplier form, results are also displayed in dollar terms for output and value added, and number of employees. For these results, output is described in terms of dollars of sales per dollar of sales outside the region, and employment is the number of jobs created per one million dollars of sales (Seidl & Weiler, 2000). Value added is the dollars of local earnings per dollar of export sales; it can also be described as the difference between an industry's total output and the cost of its intermediate inputs. Value added consists of compensation of employees, taxes on production and imports less subsidies, and gross operating surplus (Minnesota IMPLAN Group Inc., 2013).

## Results and Discussion

Our IMPLAN analysis looks at the dairy industry in its separate entities and then as a whole, in which the parts are combined into one "dairy industry". The specific areas of focus were: (1)

dairy producers, (2) fluid milk and butter processors, (3) cheese manufacturers, and (4) ice cream and frozen dessert manufacturing. For each of separate industries we identified multipliers and the economic contribution towards the Colorado economy. Our last industry is (5) the total Colorado dairy industry. This industry was generated using the IMPLAN software, and is an aggregation of all the specific dairy areas mentioned above.

*Dairy Producer Sector*

The dairy producer industry within Colorado is comprised of dairy cattle and milk producers, NAICS[5] classification 12, and was estimated to have total direct sales of $368,328,484 which provided $593,525,940 of total economic contribution. Table 1.2 indicates that the dairy producer industry indirectly contributed $167,155,589 of output to the local economy, as well as an induced contribution of $58,041,867. There was a $279,439,104 contribution through value added processes within the industry in the 2012 calendar year. The dairy industry was directly responsible for a total of 1,238 jobs in the state, while indirect (i.e. suppliers) and induced (i.e. banks, and groceries) industries contribute 631, and 402 jobs respectively.

The total output multiplier for the dairy producers industry was estimated at 1.61, indicating that $1.61 total sales take place in Colorado for each dollar of sales outside of Colorado, for example sales of $1 million of milk generated $1.61 million in local economic activity. Dairy producers provided an estimated 7 jobs per million dollars of sales, 3.83 directly within the dairy producers industry, 1.95 indirectly, and 1.24 through induced industries. As a stand-alone industry, the dairy producer industry ranked as the 130th largest industry in the Colorado economy.

[5] North American Industry Classification System

| Table 1.2. Dairy Producers- Multipliers and Economic Contribution | | | | |
|---|---|---|---|---|
| | **Output** | **Value Added** | **Employment** | **Employee Compensation** |
| Direct | 1.00 | 0.47 | 3.83 | 0.10 |
| Indirect | 0.45 | 0.16 | 1.95 | 0.09 |
| Induced | 0.16 | 0.10 | 1.24 | 0.06 |
| *Total* | *1.61* | *0.73* | *7.02* | *0.25* |
| Direct | $ 368,328,484 | $ 179,867,492 | 1,238 | $ 10,072,020 |
| Indirect | $ 167,155,589 | $ 61,431,114 | 631 | $ 9,352,637 |
| Induced | $ 58,041,867 | $ 38,140,498 | 402 | $ 5,728,336 |
| *Total* | *$ 593,525,940* | *$ 279,439,104* | *2,270* | *$ 25,152,992* |

*Fluid Milk and Butter Processors*

Table 1.3 details the estimates of multipliers and the respective economic contribution from the fluid milk and butter manufacturing sector in Colorado, NAICS 55. IMPLAN estimated that direct sales of milk and butter provide $759,565,524 in economic contribution, and resulted in over $1.6 billion in total economic output for the region in 2012. There was an indirect economic contribution from the fluid milk and butter sector of over $660 million (i.e. increased sales for suppliers of inputs to the fluid milk and butter processors) and in excess of $176 million of induced economic activity (i.e. contribution from industries where labor spend their wages, such as grocery stores). Value added from fluid milk and butter manufacturing sector provided an additional $363,482,912 in economic activity.

The sector was estimated to employ a total of 1,140 people statewide, comprised of 134 directly employed in the fluid milk and butter manufacturing, 663 indirectly employed, and a further 343 people employed in induced industries. An estimated 6.07 jobs will be created for every $1 million dollars of sales, of which the majority of jobs would occur in indirectly related industries, such as suppliers to the fluid milk and butter manufacturing industry. A total output multiplier of 2.11 indicated that $2.11 of total sales take place for every dollar of sales outside

Colorado. The fluid milk and butter manufacturing industry, on its own, ranked as the 72nd largest industry in the Colorado economy.

Table 1.3. Fluid Milk and Butter Manufactures- Multipliers and Economic Contribution

| | **Output** | **Value Added** | **Employment** | **Employee Compensation** |
|---|---|---|---|---|
| Direct | 1.00 | 0.23 | 0.71 | 0.09 |
| Indirect | 0.88 | 0.40 | 3.53 | 0.20 |
| Induced | 0.23 | 0.15 | 1.82 | 0.08 |
| *Total* | *2.11* | *0.77* | *6.07* | *0.37* |
| Direct | $ 759,465,524 | $ 106,542,389 | 134 | $ 31,882,610 |
| Indirect | $ 666,183,459 | $ 187,972,635 | 663 | $ 70,904,518 |
| Induced | $ 176,049,260 | $ 68,967,888 | 343 | $ 30,534,391 |
| *Total* | *$ 1,601,698,242* | *$ 363,482,912* | *1,140* | *$ 133,321,518* |

*Cheese Manufacturing*

Table 1.4 displays the economic contribution of the cheese manufacturing industry (NAICS 56). A total output of $766,760,610 was derived from direct sales of $368,261,484 in 2012. Within the output estimates, the cheese industry contributed $325,747,566 through indirect economic contribution and a further $72,741,560 through induced industries.

The cheese manufacturing industry contributed over $70 million through value added processes. An output multiplier of 2.08 for the industry indicated $2.08 of local sales for every $1 dollar of sales of cheese products. The industry was estimated to employ 773 people, 131 within the direct cheese manufacturing, 441 indirectly (i.e. suppliers of inputs needed in the cheese manufacturing process), and 201 through induced industries (i.e. grocery stores). The breakdown of jobs shows similarities to that of the fluid milk and butter manufacturing industry, as most likely the supplier companies are the same. Total employee compensation was estimated at just over $42 million. IMPLAN analysis estimated that there are almost 6 jobs created for every $1 million of sales, most of the additional jobs occurred in indirect industries. The cheese manufacturing industry, as an individual industry, ranks as the 116th largest industry in the Colorado economy.

Table 1.4. Cheese Manufacturing- Multipliers and Economic Contribution

| | **Output** | **Value Added** | **Employment** | **Employee Compensation** |
|---|---|---|---|---|
| Direct | 1.00 | 0.09 | 1.01 | 0.06 |
| Indirect | 0.88 | 0.37 | 3.40 | 0.18 |
| Induced | 0.20 | 0.13 | 1.55 | 0.07 |
| *Total* | *2.08* | *0.59* | *5.97* | *0.31* |
| Direct | $ 368,261,484 | $ 10,855,485 | 131 | $ 7,753,776 |
| Indirect | $ 325,747,566 | $ 44,363,577 | 441 | $ 24,739,715 |
| Induced | $ 72,741,560 | $ 14,866,194 | 201 | $ 9,656,106 |
| *Total* | *$ 766,750,610* | *$ 70,085,256* | *773* | *$ 42,149,597* |

*Ice Cream and Frozen Dessert Manufacturing*

Ice cream and frozen dessert manufacturing (NAICS 58) were estimated to have sales of $31,246,249 in 2012, which resulted in a total economic contribution of $61,544,628, represented in Table 1.5. The ice cream and frozen dessert manufacturing industry had the smallest output of the four individual dairy sectors. The value added within the industry accounted for almost $15 million. The output multiplier of 1.97 indicated that $1.97 of local sales occur for every dollar of total sales. The sector was estimated to provide the most jobs per $1 million of sales, 7.51, evenly spread through the direct, indirect and induced industries. The total number of jobs within the industry was 150, 49 directly employed in the ice cream and frozen dessert manufacturing industry, 55 jobs in indirect industries, and 46 in induced industries. The ice cream and frozen dessert manufacturing industry alone ranked as the 289th largest industry in the Colorado economy.

Table 1.5. Ice Cream and Frozen Dessert Manufacturing- Multipliers and Economic Contribution

| | **Output** | **Value Added** | **Employment** | **Employee Compensation** |
|---|---|---|---|---|
| Direct | 1.00 | 0.24 | 2.44 | 0.17 |
| Indirect | 0.68 | 0.32 | 2.76 | 0.19 |
| Induced | 0.29 | 0.19 | 2.31 | 0.11 |
| *Total* | *1.97* | *0.75* | *7.51* | *0.47* |
| Direct | $ 31,246,249 | $ 4,872,188 | 49 | $ 3,484,563 |
| Indirect | $ 21,112,901 | $ 6,337,554 | 55 | $ 3,991,377 |
| Induced | $ 9,185,478 | $ 3,737,545 | 46 | $ 2,224,069 |
| *Total* | *$ 61,544,628* | *$ 14,947,287* | *150* | *$ 9,700,009* |

*Backward Linkages*

To understand the backward linkages that exist within each industry, we must examine the demand that each industry has on related industries. An analysis of each industry's balance sheet provides information on the top ten gross inputs, by value, and their respective regional purchase coefficient's (RPC) as estimated by the production functions within IMPLAN. Gross inputs are the total inputs purchased by the industry being analyzed from the industries listed, while regional purchase coefficients are the proportion of the total demand for a commodity that is supplied by producers within Colorado (Minnesota IMPLAN Group Inc., 2013). RPC's are represented monetary terms by the term Regional Input, defined as the share of gross inputs sourced from the local economy. Results are presented for the top ten related industries by gross input from related industries for dairy producers, fluid milk and butter manufacturing, cheese manufacturing, and ice cream and frozen dessert manufacturing.

Table 1.6 summarizes the industry demand for dairy producers, by listing the top ten gross inputs sourced for the industry. Feed was estimated as the largest input into the production of milk, and the RPC of 0.83 (83%) indicated that the majority of the feed was sourced locally. Results from the survey respondents indicated that this is very close to actual practices. Results from the survey also indicated that the majority of grains were sourced from out of state, confirming the very low RPC reported in Table 9. Overall, the dairy producers sourced 60% of inputs from local businesses, providing economic support for the local economy.

Table 1.6. Industry Demand for Dairy Producers

| NAICS | Description | Gross Inputs ($) | RPC | Regional Inputs ($) |
|---|---|---|---|---|
| 00 | Total Commodity Demand | 314,086,807 | 0.60 | 187,096,662 |
| 42 | Other animal food | 119,872,558 | 0.83 | 99,894,919 |
| 10 | All other crop farming products | 34,418,418 | 0.09 | 2,970,965 |
| 115 | Refined petroleum products | 21,302,347 | 0.03 | 742,147 |
| 02 | Grains | 16,811,846 | 0.03 | 490,100 |
| 319 | Wholesale trade distribution services | 15,934,068 | 0.96 | 15,283,302 |
| 11 | Cattle from ranches and farms | 14,499,111 | 0.92 | 13,348,307 |
| 19 | Agriculture and forestry support services | 12,892,363 | 0.72 | 9,263,355 |
| 360 | Real estate buying and selling, leasing, managing, and related services | 11,462,997 | 0.99 | 11,392,696 |
| 354 | Monetary authorities and depository credit intermediation services | 11,230,772 | 0.63 | 7,081,783 |
| 31 | Electricity, and distribution services | 8,800,020 | 0.80 | 7,018,471 |

The industry demand for fluid milk and butter manufacturing results are represented in Table 1.7. It was estimated that 76% of the total commodity demanded by this industry was met by local suppliers. It is assumed that the remaining 24% of milk is sourced from neighboring states such as Kansas, Nebraska and Idaho. Locally sourced milk accounted for 88% of the milk used in the fluid milk manufacturing sector and accounted for 68% of the sales of all locally produced milk.

| Table 1.7. Industry Demand for Fluid Milk and Butter Manufacturing | | | | |
|---|---|---|---|---|
| **NAICS** | **Description** | **Gross Inputs ($)** | **RPC** | **Regional Inputs ($)** |
| 00 | Total Commodity Demand | 1,238,215,340 | 0.76 | 938,029,175 |
| 12 | Dairy cattle and milk products | 434,912,820 | 0.88 | 381,244,554 |
| 55 | Fluid milk and butter | 220,162,963 | 0.93 | 204,652,859 |
| 319 | Wholesale trade distribution services | 62,123,794 | 0.96 | 59,586,586 |
| 381 | Management of companies and enterprises | 49,088,152 | 0.99 | 48,645,241 |
| 335 | Truck transportation services | 46,378,562 | 0.80 | 37,187,976 |
| 127 | Plastics materials and resins | 44,585,435 | 0.03 | 1,353,382 |
| 107 | Paperboard containers | 34,604,464 | 0.48 | 16,476,510 |
| 149 | Other plastics products | 23,846,824 | 0.19 | 4,511,229 |
| 57 | Dry, condensed, and evaporated dairy products | 23,742,482 | 0.37 | 8,832,445 |
| 31 | Electricity, and distribution services | 23,289,704 | 0.80 | 18,574,741 |

Table 1.8 summarizes the industry demand for the cheese industry. Of a total of almost $700 million in inputs, Colorado's local economy provided 64%. Cheese manufacturing sourced 88% of milk inputs from local producers, but cheese only accounted for 31% of total Colorado milk sales. As expected, the top ten gross inputs for fluid milk and butter manufacturing, closely resemble the top ten gross inputs for cheese manufacturing.

| Table 1.8. Industry Demand Cheese Manufacturing | | | | |
|---|---|---|---|---|
| **NAICS** | **Description** | **Gross Inputs ($)** | **RPC** | **Regional Inputs ($)** |
| 00 | Total Commodity Demand | 696,665,344 | 0.64 | 443,397,977 |
| 56 | Cheese | 242,970,488 | 0.39 | 94,807,367 |
| 12 | Dairy cattle and milk products | 200,638,966 | 0.88 | 175,880,107 |
| 319 | Wholesale trade distribution services | 46,931,584 | 0.96 | 45,014,844 |
| 55 | Fluid milk and butter | 28,839,849 | 0.93 | 26,808,131 |
| 335 | Truck transportation services | 22,907,420 | 0.80 | 18,367,982 |
| 57 | Dry, condensed, and evaporated dairy products | 20,915,784 | 0.37 | 7,780,885 |
| 381 | Management of companies and enterprises | 15,438,227 | 0.99 | 15,298,931 |
| 142 | Plastics packaging materials and un-laminated films and sheets | 8,985,203 | 0.13 | 1,126,630 |
| 31 | Electricity, and distribution services | 8,041,440 | 0.80 | 6,413,463 |
| 107 | Paperboard containers | 7,906,752 | 0.48 | 3,764,707 |

Table 1.9 indicates that the ice cream and frozen dessert manufacturing had an estimated $46 million of inputs, of which 59% are provided by local industries. Once again, it was estimated that 88% of milk inputs required was sourced from local dairies, accounting for less than 1% of total local dairy milk sales.

Table 1.9. Industry demand for Ice Cream and Frozen Dessert Manufacturing

| NAICS | Description | Gross Inputs ($) | RPC | Regional Inputs ($) |
|---|---|---|---|---|
| 00 | Total Commodity Demand | 46,597,342 | 0.59 | 27,531,365 |
| 05 | Tree nuts | 685,109 | 0.00 | 2,970 |
| 12 | Dairy cattle and milk products | 1,861,287 | 0.88 | 1,631,604 |
| 13 | Poultry and egg products | 856,080 | 0.16 | 135,226 |
| 21 | Coal | 9,016 | 0.12 | 1,065 |
| 31 | Electricity, and distribution services | 898,287 | 0.80 | 716,430 |
| 32 | Natural gas, and distribution services | 124,910 | 0.92 | 115,050 |
| 33 | Water, sewage treatment, and other utility services | 39,900 | 0.97 | 38,709 |
| 39 | Maintained and repaired nonresidential structures | 478,050 | 0.97 | 463,586 |
| 44 | Corn sweeteners, corn oils, and corn starches | 1,219,806 | 0.01 | 18,047 |
| 45 | Soybean oil and cakes and other oilseed products | 3,638 | 0.01 | 23 |

The industry demand tables show the importance of the codependent system that exists between local dairy producers and manufacturing plants located within the state, without one, the other would not exist in the same capacity.

*Selected County Specific Data*

Three counties were analyzed in-depth. Weld, Morgan, and Larimer counties represent the top three dairy counties by production and cow numbers. And as such, further analysis was undertaken to identify their contributions to the state economies, both individually and as an aggregated area.

Table 1.10. Dairy cattle and milk production

| | **Weld County** | | | | **Larimer County** | | | | **Morgan County** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) |
| Direct | 1.00 | 0.47 | 2.71 | 0.05 | 0.07 | 0.47 | 7.44 | 0.07 | 0.03 | 0.47 | 1.62 | 0.03 |
| Indirect | 0.16 | 0.06 | 0.90 | 0.03 | 0.03 | 0.07 | 1.28 | 0.03 | 0.02 | 0.04 | 0.57 | 0.02 |
| Induced | 0.06 | 0.04 | 0.56 | 0.02 | 0.03 | 0.07 | 0.98 | 0.03 | 0.01 | 0.03 | 0.41 | 0.01 |
| *Total* | *1.22* | *0.57* | *4.18* | *0.09* | *0.13* | *0.61* | *9.70* | *0.13* | *0.06* | *0.54* | *2.60* | *0.06* |
| | | | | | | | | | | | | |
| Direct | 241,900,524 | 115,264,764 | 520 | 6,781,063 | 27,101,616 | 18,229,320 | 286 | 1,940,034 | 57,498,029 | 43,525,752 | 106 | 1,893,539 |
| Indirect | 38,442,444 | 14,211,101 | 173 | 4,144,502 | 11,455,379 | 2,795,765 | 49 | 820,018 | 29,087,622 | 3,614,399 | 37 | 957,921 |
| Induced | 14,703,297 | 9,435,441 | 108 | 2,478,152 | 11,532,753 | 2,557,768 | 38 | 825,557 | 18,849,324 | 2,499,893 | 27 | 620,751 |
| *Total* | *295,046,265* | *138,911,306* | *801* | *13,403,717* | *50,089,748* | *23,582,853* | *373* | *3,585,609* | *105,434,975* | *49,640,044* | *171* | *3,472,211* |

Table 1.10 represents the county specific data relating to dairy cattle and milk production for the top three producing states. Weld County contributes the highest output at $295,046,265, followed by Morgan ($105,434,975), and Larimer at $50,089,748. Weld County also employs the most people (801), however Larimer is second in this indicator at 373 employees, and Morgan County with 171 employees. Larimer County also shows the highest employment multiplier at 9.70.

Table 1.11. Fluid milk and butter manufacturing

| | Weld County | | | | Larimer County | | | | Morgan County | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) |
| Direct | 1.00 | 0.22 | 0.72 | 0.08 | 0.07 | 0.22 | 0.72 | 0.07 | 0.14 | 0.27 | 0.67 | 0.14 |
| Indirect | 0.33 | 0.15 | 1.43 | 0.05 | 0.04 | 0.10 | 1.27 | 0.04 | 0.03 | 0.13 | 1.00 | 0.03 |
| Induced | 0.06 | 0.04 | 0.58 | 0.02 | 0.02 | 0.05 | 0.77 | 0.02 | 0.02 | 0.04 | 0.68 | 0.02 |
| *Total* | *1.39* | *0.41* | *2.72* | *0.15* | *0.14* | *0.37* | *2.76* | *0.14* | *0.19* | *0.45* | *2.36* | *0.19* |
| | | | | | | | | | | | | |
| Direct | 256,739,530 | 41,790,840 | 68 | 15,779,247 | 13,988,013 | 3,661,696 | 5 | 951,810 | 28,803,536 | 6,463,246 | 8 | 4,080,629 |
| Indirect | 84,076,200 | 29,204,635 | 134 | 9,552,401 | 8,980,833 | 1,619,957 | 9 | 611,098 | 6,842,344 | 3,132,826 | 11 | 969,362 |
| Induced | 16,039,800 | 7,525,148 | 54 | 3,357,825 | 4,937,442 | 866,193 | 6 | 335,967 | 3,662,283 | 1,070,986 | 8 | 518,840 |
| *Total* | *356,855,530* | *78,520,623* | *256* | *28,689,472* | *27,906,288* | *6,147,846* | *20* | *1,898,875* | *39,308,163* | *10,667,059* | *26* | *5,568,831* |

With regard to fluid milk and butter manufacturing, Table 1.11 indicates the results of the analysis. Weld County had the highest output of $356,855,530, followed by Morgan County and Larimer County with values of $39,308,163 and $28,689,472 respectively. Employment results follow the same trend, Weld County indicating 256 employees in the industry, trailed by Morgan County and Larimer County with 26 and 20 employees each.

Table 1.12. Cheese manufacturing

| | Weld County | | | | Larimer County | | | | Morgan County | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) |
| Direct | 1.00 | 0.07 | 1.04 | 0.03 | 0.03 | 0.07 | 1.03 | 0.03 | 0.06 | 0.09 | 1.01 | 0.06 |
| Indirect | 0.28 | 0.13 | 1.21 | 0.04 | 0.04 | 0.08 | 1.07 | 0.04 | 0.05 | 0.16 | 1.22 | 0.05 |
| Induced | 0.04 | 0.02 | 0.35 | 0.01 | 0.01 | 0.03 | 0.45 | 0.01 | 0.01 | 0.03 | 0.44 | 0.01 |
| *Total* | *1.31* | *0.22* | *2.60* | *0.08* | *0.08* | *0.18* | *2.55* | *0.08* | *0.11* | *0.28* | *2.66* | *0.11* |
| | | | | | | | | | | | | |
| Direct | 3,096,295 | 80,387 | 2 | 47,397 | 9,582,920 | 712,626 | 12 | 252,941 | 324,545,031 | 19,562,722 | 247 | 18,572,772 |
| Indirect | 855,339 | 161,373 | 2 | 63,601 | 13,536,542 | 859,703 | 12 | 357,297 | 258,082,579 | 34,101,674 | 299 | 14,769,319 |
| Induced | 118,973 | 29,405 | 1 | 15,980 | 5,059,537 | 320,744 | 5 | 133,547 | 65,284,012 | 6,097,859 | 107 | 3,736,015 |
| *Total* | *4,070,608* | *271,165* | *4* | *126,979* | *28,178,999* | *1,893,073* | *29* | *743,785* | *105,434,975* | *49,640,044* | *171* | *3,472,211* |

Location of the cheese industry is clearly identifiable through an analysis of the results provided in Table 1.12. Morgan County contributes the highest output at $105,434,975. Larimer County contributes a total output of $28,178,999, while Weld County only contributes an output of $4,070,608. As expected, employment values mirror the output trend. Morgan County ranks highest, followed by Larimer County, and Weld County indicating the lowest employment in the sector. Values of 171, 29, and 4 employees in each respective county were observed.

The analysis also revealed that there was no ice cream and frozen dessert manufacturing sector in the three counties.

Table 1.13. Aggregated County Specific Dairy Industries

| | Weld County | | | | Larimer County | | | | Morgan County | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) | Output ($) | Value Added ($) | Employ ment | Employee Compensa tion ($) |
| Direct | 0.06 | 0.33 | 1.62 | 0.06 | 0.06 | 0.30 | 3.97 | 0.06 | 0.06 | 0.15 | 1.07 | 0.06 |
| Indirect | 0.04 | 0.09 | 0.94 | 0.04 | 0.04 | 0.08 | 1.03 | 0.04 | 0.05 | 0.12 | 1.28 | 0.05 |
| Induced | 0.02 | 0.04 | 0.54 | 0.02 | 0.02 | 0.05 | 0.78 | 0.02 | 0.01 | 0.03 | 0.47 | 0.01 |
| *Total* | *0.12* | *0.46* | *3.10* | *0.12* | *0.12* | *0.43* | *5.78* | *0.12* | *0.12* | *0.31* | *2.82* | *0.12* |
| Direct | 360,342,360 | 156,946,367 | 555 | 23,192,614 | 52,611,208 | 22,135,824 | 290 | 3,086,194 | 376,017,044 | 59,370,042 | 323 | 21,877,855 |
| Indirect | 205,840,175 | 43,161,208 | 321 | 13,248,433 | 31,961,430 | 5,604,647 | 75 | 1,874,870 | 337,112,534 | 48,670,549 | 386 | 19,614,268 |
| Induced | 89,789,867 | 17,595,519 | 185 | 5,779,120 | 21,602,397 | 3,883,301 | 57 | 1,267,205 | 79,525,181 | 12,028,767 | 141 | 4,627,025 |
| *Total* | *655,972,402* | *217,703,095* | *1,061* | *42,220,168* | *106,175,035* | *31,623,772* | *422* | *6,228,268* | *792,654,758* | *120,069,358* | *849* | *46,119,148* |

Table 1.13 shows the results of aggregating the all dairy sectors within each County. The aggregation of dairy within each county allows for the analysis of the dairy industry as a whole, taking into account all aspects of production and manufacturing. Morgan County had the largest total output contribution of the three counties, $792,654,758, this was followed by Weld County and lastly Larimer County who contributed $655,972,402 and $106,175,035 respectively. However an analysis of employees in each county shows that Weld County leads with an estimated 1,061 employees, where Morgan County was estimated to only contribute 849 jobs, and Larimer County 422 jobs. Larimer County is estimated to have the highest employment multiplier at 5.78, while Weld County and Morgan County have reported employment multipliers of 3.10 and 2.82 each.

Table 1.14. County Contributions

| Description | Weld County Output ($) | Weld County Value Added ($) | Weld County Employment | Larimer County Output ($) | Larimer County Value Added ($) | Larimer County Employment |
|---|---|---|---|---|---|---|
| Dairy cattle and milk production | 295,046,265 | 138,911,306 | 801 | 50,089,748 | 23,582,853 | 373 |
| Fluid milk and butter manufacturing | 356,855,530 | 78,520,623 | 256 | 27,906,288 | 6,147,846 | 20 |
| Cheese manufacturing | 4,070,608 | 271,165 | 4 | 28,178,999 | 1,893,073 | 29 |
| *Dairy Sector Total* | *655,972,402* | *217,703,095* | *1,061* | *106,175,035* | *31,623,772* | *422* |

Table 1.15. County Contributions Cont.

| Description | Morgan County Output ($) | Morgan County Value Added ($) | Morgan County Employment | Combined Counties Output ($) | Combined Counties Value Added ($) | Combined Counties Employment |
|---|---|---|---|---|---|---|
| Dairy cattle and milk production | 105,434,975 | 49,640,044 | 171 | 450,570,984 | 212,134,199 | 1,344 |
| Fluid milk and butter manufacturing | 39,308,163 | 10,667,059 | 26 | 424,069,977 | 95,335,527 | 303 |
| Cheese manufacturing | 647,911,621 | 59,762,255 | 652 | 680,161,255 | 61,926,492 | 686 |
| *Dairy Sector Total* | *792,654,758* | *120,069,358* | *849* | *1,554,802,216* | *369,396,217* | *2,333* |

Table 1.14 and Table 1.15 provide a summary of the County contributions by sector, as well as combining the three counties into one entity so as to evaluate the contribution of the region to the state economy. The results of Weld, Larimer and Morgan counties mirror the results discussed in Table 13, 14, 15, and 16. These will not be discussed to prevent repetition. However, aggregating the three counties into a single entity provides interesting results. The aggregated counties provide and estimated total output of $1,554,802,216. In addition to the output, an estimated 2,333 people were employed as a result of the dairy industry being present in the region.

*Combined Industry*

In an examination of the combined dairy industry (generated through the aggregation of the dairy producers, fluid milk and butter manufacture, cheese manufacture, ice cream and frozen dessert manufacturing industries) represented in Table 1.16, the industry as a whole provided over $3 billion in economic contribution to the Colorado state economy in 2012, ranking as the 43rd largest industry. As expected the ranking of the combined industry is higher than any of the individual industries by themselves, this final ranking more accurately represents the economic contribution that the dairy industry has on the Colorado economy. Approximately $1.5 billion was calculated in direct sales of dairy products, $1.2 billion in indirect economic activity, and over $300 million in induced economic activity. The dairy industry combined created 4,333 jobs and generated 5.91 jobs per $1 million in sales. Over $210 million was paid out in employee compensation.

Table 1.16. Combined Dairy Industry- Multipliers and Economic Contribution

| | **Output** | **Value Added** | **Employment** | **Employee Compensation** |
|---|---|---|---|---|
| Direct | 1.00 | 0.24 | 1.43 | 0.08 |
| Indirect | 0.81 | 0.32 | 2.78 | 0.18 |
| Induced | 0.22 | 0.14 | 1.69 | 0.08 |
| *Total* | *2.02* | *0.69* | *5.91* | *0.34* |
| Direct | $1,495,530,605 | $253,032,640 | 1,051 | $51,971,705 |
| Indirect | $1,205,968,467 | $331,560,978 | 2,040 | $110,175,334 |
| Induced | $322,020,348 | $143,360,878 | 1,242 | $48,177,078 |
| *Total* | *$3,023,519,421* | *$727,954,496* | *4,333* | *$210,324,117* |

An analysis of the gross inputs for the dairy sector as a whole is reported in Table 1.17, which indicates that of over $2 billion, 67% was sourced from local suppliers.

Table 1.17. Industry Demand Combined Dairy Industry

| NAICS | Description | Gross Inputs ($) | RPC | Regional Inputs ($) |
|---|---|---|---|---|
| 00 | Total Commodity Demand | 2,295,564,837 | 0.67 | 1,531,310,571 |
| 12 | Dairy Sector Total | 1,144,458,402 | 0.73 | 834,267,705 |
| 319 | Wholesale trade businesses | 136,023,998 | 0.96 | 130,418,362 |
| 42 | Other animal food manufacturing | 124,912,076 | 0.83 | 103,208,701 |
| 335 | Transport by truck | 70,909,960 | 0.80 | 56,898,172 |
| 381 | Management of companies and enterprises | 68,435,482 | 0.99 | 67,802,533 |
| 107 | Paperboard container manufacturing | 49,237,442 | 0.47 | 23,367,747 |
| 31 | Electric power generation, transmission, and distribution | 40,422,959 | 0.80 | 32,242,481 |
| 127 | Plastics material and resin manufacturing | 38,676,043 | 0.03 | 1,126,630 |
| 10 | All other crop farming | 35,865,391 | 0.09 | 6,413,463 |
| 354 | Monetary authorities and depository credit intermediation activities | 29,736,700 | 0.63 | 3,764,707 |

*Comparison across sectors*

Dairy producers within Colorado had an estimated output of $593,525,940, employment of 2,270, and value added of $279,439,104 (Table 1.2). These correspond with multipliers of 1.61, 7.02, 0.73, for output, employment and value added, respectively (Table 1.2). A direct comparison with Seidl and Weiler (2000) shows that that estimates for the 2012 output multiplier is lower (1.95), the employment multiplier estimate is significantly lower (14.94), and the value add multiplier is very similar (0.72). Numerically, total output rose from almost $400 million to almost $600 million, which represents substantial growth of the industry over the last decade. Interestingly, employment estimates show that there has been a consolidation of employees, 3,025 to 2,270, this can be explained by dairies existing in 2000 expanding and becoming more technologically advanced. It is expected that any future growth will require new dairies to be built, and not just an expansion of existing dairies. Value added has increased from $145 million to $279 million. Comparisons within the state show that the not only have the dairy producers increased in size dramatically, but also in efficiency.

In a comparison within the total dairy industry within Colorado, fluid milk and butter manufacturing has the highest overall output of $1.6 billion, followed by cheese manufacturing, dairy production, and lastly the ice cream and frozen dessert manufacturing.

Comparing Colorado data against other regional economies provide more interesting observations. New Mexico's dairy, analyzed by Cabrera et al. (2008) reported an output multiplier of 1.98, Ricketts (2000) reported an output multiplier of 2.60 for Missouri, Doherty and Morse (1999) who reported 2.37 for Minnesota, 1.85 was reported in Washington (Neibergs & Brady, 2013), and 1.32 in Earth County, Texas (Hussain, Buland, & Randals, 2003). The 2012 analysis of Colorado's dairy producers' output multiplier, 1.61, lies at the lower end of the range of multipliers analyzed. This indicates that larger dairies (found in Texas, Colorado and New Mexico) may have lower output multipliers due to the increased efficiency of the dairies, achieving greater output with fewer inputs. Weld, Larimer and Morgan counties account for approximately half of total dairy output and employment within the industry.

The fluid milk and butter manufacturing and cheese manufacturing provided a total output of $1.6 billion and $766 million, and a corresponding output multiplier of 2.11, and 2.08. These can be compared against the results estimated by Neibergs and Brady (2013) for Washington State's dairy processing industry which had a total output of $2.57 billion and a multiplier of 1.3. This indicates that Colorado's manufacturing industry compares well with Washington which has a significantly larger milk base.

## Conclusion

The objective of the research was to quantify the economic contribution of the Colorado dairy industry. Using an I-O model the industry was analyzed, for each of the four separate sectors within the Colorado dairy industry, dairy producers, fluid milk and butter manufacturers, cheese manufactures, ice cream and frozen dessert manufacturers. After estimating the economic contribution of each sector alone, the four individual components were aggregated into one industry. The quantification of the industry allows for future policy decisions to be made with the necessary knowledge, it provides an understanding of the social impact of the dairy industry, details the impacts on related industry, and allows for the long term benefits of the industry to be effectively analyzed. Primary results generated from the IMPLAN estimation were the total output from each of the four industries; $593,525,940, $1,601,698,242, $766,750,610, $61,544,628 respectively. This results in a combined economic contribution of over $3 billion to the Colorado regional economy. Dairy producer industry created a total of 2,270 jobs in the economy, fluid milk and butter manufacturing, 1,140, cheese manufacturing, 773, and ice cream and frozen dessert manufacturing created a total of 150 jobs in the regional economy. The total dairy industry combined to provide 4,333 jobs in the Colorado economy. For every $1 million dollars of sales in the respective industries, it was estimated that 7.02 jobs would be created in the dairy producers industry, 6.07 jobs in the fluid milk and butter manufacturing, 5.67 jobs in the cheese manufacturing industry, and 7.51 jobs in the ice cream and frozen dessert industry.

The implications of this research are that there is room for growth in the dairy industry in Colorado, and any additional growth in the dairy industry would be expected to benefit the Colorado economy.

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# Chapter 2:

# Bringing Transparency to Class III Milk Futures: Evidence of Rational Price Formation

## Introduction

Dairy producers have faced increased volatility in milk prices over the last decade. This increased uncertainty around revenues has added to management worries for dairy producers who already face substantial variability in feed input costs. Class III milk prices are the most traded contract of all futures contracts available to dairy producers, and as such are also the basis of farm gate milk prices. With increasing uncertainty, a need has developed to bring some clarity to the futures price evolution. There have been historically high levels of government involvement in the pricing of dairy products; however, this is tapering off. As a result, milk products are more responsive to supply and demand (Anderson & Ibendahl, 2000). With increased market exposure, volatility has increased in the milk price market (Bozic, Newton, Tharen, & Gould, 2012), coupled with increased volatility in feed inputs, producers have been advised to manage risk more intensely. The use of hedging using futures contracts has been a traditional risk management tool; however, trading volumes in the Class III milk futures contract remains thin. Low trading volumes have been associated with a lack of knowledge of the market and a lack of futures trading knowledge. To address some of the concerns of market participants, a step is taken to bring more transparency to the Class III milk futures contracts by investigating the presence of rational rice formation within the final year of a contracts life.

## Literature Review

The United States (US) milk market does not fit into the standard competitive industry mold. There have been numerous government programs which have altered the competitive landscape through time. Dairy price support programs, import quotas on dairy products, and federal milk marketing orders are examples of policy programs which have been implemented in attempts to aid dairy farmers. Processed fluid milk and manufactured products are subject to wholesale and retail price determination through the combined programs of price supports, quotas, and marketing orders (Chouinard, Davis, LaFrance, & Perloff, 2010). This demonstrates that the federal government has played a prominent role in the establishment of the farm value of milk, or dairy pricing. Despite heavy government intervention in milk pricing, it is not the only price determining method, market based pricing, similar to other agricultural commodity products are also mechanisms for price discovery. Cash and futures markets located at the Chicago Mercantile Exchange (CME), play key roles in price discovery.

The two predominant policy programs (sometimes called administered pricing programs) currently implemented are the dairy product price support program (DPPSP) and federal milk marketing orders (FMMOs) (Jesse and Cropp, 2008). The two policies originated sixty years ago and have existed in various forms since their creation. They operate independently unless market prices decline to such a point that support levels are breached. The DPPSP provides price support for dairy farmers through government purchases of dairy products at legislated minimum prices (Shields, 2009). Under the DPPSP policy, the federal government has the ability to purchase unlimited amounts of butter, American cheese, and nonfat dry milk from dairy processors at specified minimum prices. This creates a market floor price, and if prices drop to such a level, the DPPSP program will begin purchasing product to support the price level and will continue until the market price rises above the support price. However, when market prices are above support levels, DPPSP does not factor in the market and milk pricing is based on supply and demand (Shields, 2009).

The FMMO system was designed to stabilize market conditions and generally does not support prices. The FMMP program was enacted during the 1920s and early 1930s when volatility in market prices were at levels perceived to be too high. FMMOs mandate minimum prices that processors in milk marketing areas must pay producers or their agents (e.g. dairy cooperatives) for delivered milk depending on its end use, regardless of whether market prices are high or low. Minimum milk prices are based on current wholesale dairy product prices collected by USDA's National Agricultural Statistics Service (NASS) in a weekly survey of manufacturers, which are determined in large part by prices established on the CME (Shields, 2009). For this paper we are primarily concerned with Class III milk prices. The current Class III milk FMMO program is derived using the following formula:

$$(1)\quad Class\ III\ price/cwt = 9.6396\ X\ NASS\ cheese\ price/lb + 0.4199\ X\ NASS\ butter\ price/lb + 5.8643\ X\ NASS\ dry\ whey\ price/lb - 2.8189$$

The interpretation of the formula is as follows: a 10 cent-per-pound increase (decrease) in cheese, butter, and dry whey prices will lead to an increase (decrease) the Class III price by 96.4, 42.0, and 58.6 cents per hundredweight, respectively. The combined make allowance, which is built in manufacturing margin for processors, for cheese plants in this case is $2.82 per hundredweight of milk used to make cheese (Jesse and Cropp, 2008). Therefore, as the FMMO price is based on weekly USDA-NASS data, minimum prices rise and fall each month with industry-wide changes in the dairy and dairy product market. Farmers receive a price for their milk based on the minimum prices and on how their milk is utilized (fluid vs. manufacturing) in the marketing order, which collectively is called "classified pricing". FMMOs also address how market profits are distributed among the producers delivering milk to federal marketing order areas, called "pooling", whereby all farmers receive a "blend price" each month based on order-wide revenue. The blend price is the weighted average price in a marketing order, with the weights being the volume of milk sold in each of the four classes[6] (Shields, 2009).

Market based pricing in the dairy market works in the same manner as it would with other commodities, generating current and future price level estimates for milk and dairy products through competing bids from buyers and sellers who have different perceptions of overall demand and supply conditions, along with expectations for changes in government policy. Wholesale dairy product cash prices for cheese and butter are determined daily at the CME during trading sessions that usually last only five minutes, nonfat dry milk on the other hand also trades daily, but there is very little activity (Jesse and Cropp, 2008). These futures prices are the basis of numerous contracts nationwide between dairy manufacturers and wholesale or retail buyers of basic dairy products (Shields, 2009). Class III milk futures are the primary drivers of farm prices as it is the single largest class use of milk and because Class I (fluid) and Class II (soft manufactured product) minimum prices are established using Class III prices. Class III futures and options are 200,000 pound monthly contracts that cash settle when the Class III price is announced at the end of each month, contracts and options are available 24 months in advance (Wolf and Widmar, 2013).

[6] Class I-Fluid, Class II-Soft Manufactured Product, Class III-Hard Cheeses and Cream Cheese, and Class IV-Dry Milk Products and Butter

As we can see dairy pricing in the US is a combination of market-based and administered (through public dairy programs) prices. Each influences the other to determine the overall price level and price movements to some extent. In addition to the dynamics mentioned above, perishability and year round daily production create challenges for pricing and marketing milk and milk products (Shields, 2009). Dairy supply and demand also experience mismatched seasonality, supply peaks in fall and demand is highest in January (Dong, Du, & Gould, 2011).

Despite the use of administered pricing policies, the dairy market has experienced increased volatility in the Class III milk price. The volatility began after the 1970s and 1980s, where dairy programs provided substantial price support. After a decrease in price support in the mid-1980s volatility has increased on an annual basis ever since. A reduction in price support and an increasing export dependent market are two primary drivers of increased volatility. Wolf and Widmar (2013), using a monthly coefficient of variation to measure volatility, found that the average monthly coefficient of variation from increased from 13.6% for the 1990 through 1999 time period to 20.4% for the period of 2000 to 2012 period. Open interest and volume traded of Class III contracts have increased in the last 10 years (Wolf and Widmar, 2013), but are still very small compared to other agricultural commodities.

The increased volatility has added another challenge to farmers who rely on futures prices as a barometer of the market price for milk. In particular milk producers have faced challenges effectively using them as indicators of future events, or in risk management strategies. As a result of the heavy federal government involvement, market signals are not always interpreted correctly, and can result in a delay in producers getting the information necessary to make production decisions. Dairy farmers typically make production decisions based on price received for their products, and will respond to prices by either reducing or increasing production, if there is inefficiency in that price, production decisions will be adversely affected resulting in an over or under supply of milk (Shields, 2009). The relatively large volatility of Class III milk futures and the involvement of policy programs, may explain the lack of trading in the futures market. This is counter-intuitive, as increased risk of revenue streams should prompt producers to utilize hedging strategies more often, and also should entice speculators to the market who benefit from volatility.

As noted earlier, there has been some increase in futures trading, but not by as much as expected. Dairy farmers face risk related to output (milk) as well as feed costs (inputs), it is critical that they manage both aspects of risk (Shields, 2009). With regard to using Class III futures, some reasons for not trading in the futures market cited are lack of knowledge of futures trading, lack of understanding of the market, and the reliance on existing dairy policies and or cooperatives. Cooperatives are involved in risk management practices, including shifting production between plants or product types in order to receive the highest return, integrating into consumer and niche markets to diversify away from commodity market volatility, and forming partnerships with other firms to shift business risk (Shields, 2009).

Malkiel and Fama (1970) described an efficient market as one that incorporates all relevant and available information into the price. While another interpretation of an efficient market is found in Working’s 1958 paper describing the theory of anticipatory prices, which states that decisions on cash and futures prices take into account all available and relevant information concerning historical relationships as well as current and expected supply-demand conditions. From these definitions we can test for rational price formation in Class III milk contracts by examining past price performance.

Koontz, Hudson, and Hughes, (1992) argue that futures contract prices reflect expected market conditions when contracts are close enough to the delivery month that supply of the underlying commodity cannot be changed. However, it is also stated that before this period of "fixed-supply", futures contract prices should be priced to reflect the competitive equilibrium, or where output price equals average costs of production. The initial investigation into this line of analysis was conducted by Tomek and Gray (1970), who identified two roles of futures markets which are emphasized in the analysis of market performance. The first role, the allocative role, was investigated by Working (1948) in a study of grain basis relationships and storage costs. In the allocative role, availability of futures contracts for storable commodities, going out to a year in the future, are thought to provide price incentives which influence storage decisions and subsequently allocate grain consumption through the crop year. Analysis of the second role, forward pricing, emerged with the futures trading in semi-storable commodities (e.g. onions and potatoes) and nonstorable commodities (e.g. livestock). Price levels of futures contracts for nonstorable commodities, deliverable up to 24 months in the future in the case of Class III milk futures contracts, should forecast anticipated supply-demand conditions in these forward markets. Futures markets for semi storable commodities (such as Class III milk futures) are thought to combine these two roles (Koontz, Hudson, and Hughes, 1992).

Futures markets for seasonally produced commodities with continuous stocks are perhaps the best known and best understood. In these markets the average cash price for a season depends on the demand and supply conditions for the year, with monthly prices varying seasonally around the average. Hence, a futures price for a particular delivery month depends upon the expected average economic conditions for the year and upon conditions peculiar to that month (Tomek and Gray, 1970). They suggest that futures markets for all commodities play both roles, allocative and forward pricing, to some degree and that the storage characteristics of the commodity determine the extent of each role. Therefore, for storable commodities, both roles are played well, however, the role is primarily allocative, and by influencing storage decisions, futures prices become self-fulfilling forecasts. For semi-storable commodities, the futures market should play an allocative role across the time period that the crop is in storage (within the crop year) but a forward pricing role across periods when the crop is not stored (across crop years). Finally, for nonstorable commodities, such as livestock, the futures market should play a forward pricing role (Koontz, Hudson, and Hughes, 1992). If the futures do not play these roles well, then they would be inefficient and therefore participants in the futures market are not utilizing all information available.

To determine whether Class III milk futures, a semi-storable commodity, follow this price formation, we use the rational described by Koontz, Hudson, and Hughes, (1992), and Dewbre, 1981 who use competitive market equilibrium conditions to examine if futures prices follow a rational price formation process. The process implies that when a futures contract for a nonstorable commodity is near maturity, the forward pricing role is consistent with rational price formation, while further from maturity it will play more of an allocative role. Futures prices for nearby contracts should reflect underlying supply and demand information as the information becomes available. However, prior to committing the animals to feed, rational price formation would suggest that the futures prices for distant and very distant contracts trade around expected and then actual average costs of production. If futures contract prices reflect feeding costs, the futures market is rational because it reflects competitive market equilibrium conditions.

The semi-storable nature of Class III milk futures are expected to show this distinction between roles more clearly. The purpose of this paper is to provide an understanding of how Class III contracts trade, and by providing transparency to the market, it is anticipated that trading volume increases.

**Model**

The general model is based on research conducted by Koontz, Hudson, and Hughes, (1992), where they test the rational price formulation theory proposed by Working (1948) and Dewbre (1981). To begin this analysis, we determine a proxy for supply and demand (Equation 2) as well as feed cost equations (Equation 3) which will be included as independent variables in the final regression used to test for evidence of rational pricing (Equation 4).

A set of 12 seemingly unrelated regressions were run to capture the effect of the settlement price for a contract $i$ months from expiration from today $t$. Class III Milk futures have 12 contracts (one for every month January – December) trading at any point in time, $i = 0, \ldots, 11$. Seemingly unrelated regressions accounted for the effect of supply and demand in the last 12 months of a contracts life, before expiration. In Equation (2), $SD^*_{(t+i)}$ is a proxy that relates the effect that current, $t$, monthly supply and demand data, represented through an equilibrium price or settlement price, have on all other open contracts that are $i$ months from expiration. To account for seasonality within the demand functions dummy variables were included, excluding January. Dummy variables are represented using the variable $D$.

$$(2)\quad SD^{*}{}_{(t+i)} = \beta_0 + \sum_{i=0}^{i-1} \beta_1\, SP_{(t+i)} + \sum_{i=1}^{11} \beta_2 D + \mu_i$$

In contrast to the Koontz, Hudson, and Hughes, (1992) analysis which focused on beef cattle and hogs in feedlot programs where feed costs make up 80-90% of variable costs, dairy feeding costs are approximately 50-70% of variable costs (Bozic et al., 2012; Dhuyvetter, 2011). However, despite feed costs not accounting for as large a percentage of variable costs as in the beef and swine sectors, they were still the most prominent cost faced by producers (Wolf and Widmar, 2013). Traders and producers also have the ability to forecast feed costs, allowing for trading models to be built out.

In Equation (3), $FC^{*}{}_{K}$ refers to the ration or feed cost in a given month $K$. $FC^{*}{}_{K}$ is a function of $FC_{t-k}$ which represents feed cost in month $k$ prior to period $t$, where $(k = 0, .., 11)$. A time trend variable is also incorporated using time squared values. Seasonality within production is accounted for by using monthly dummy variables, which are all compared to January as the base month. Again, 12 seemingly unrelated regressions were run, this accounted for the 12 months of feed costs, i.e., feed costs for every month, in the last year of trading for any give contract.

$$(3)\quad FC^{*}{}_{K} = \delta_1 + \delta_2 time + \delta_3 time^2 + \sum_{k=1}^{K} \delta_4 D + \sum_{k=1}^{K} \delta_5 ARJFA_{t-k} + \epsilon_k$$

Equation (4) is the final equation in our system of equations, where $SP_{(t+i)}$ refers to the average monthly settlement price of the Class III Milk contract expiring in current month $t$ with $i$

months remaining for trade, $i$ (= 0,…, 11) signifying months prior to the delivery month[7] in time period $t$. $FC^{*}{}_{K}$ refers to the aggregate U.S. feed costs per cwt for any given dairy producer in month given by contract $k$ in time period $t$. While $SD^{*}{}_{(t+i)}$ is a proxy of supply and demand in the market, represented through the effect that the closing price of a contract in time $t$ with $i$ months remaining to delivery. In other words, Equation (4) illustrates that the settle price for a contract in any given month prior to expiration is affected by the feeding costs in that month, and the supply and demand conditions represented through the settlement price in time period $t$.

$$(4)\ SP_{(t+i)} = \alpha_0 + \alpha_1 FC^{*}{}_{K} + \alpha_2 SD^{*}{}_{(t+i)} + \varepsilon_k$$

The equations are defined as a contemporaneous system, where futures prices in a given delivery month were modelled as a function of feeding costs and supply and demand conditions in that month, and so on for months two to eleven. The contemporaneous system is thought to provide evidence of rational price formation. The focus of this system is based on the relationship between the feed and supply and demand variables and futures price during the placement period. The settlement price and feed cost variable values should move together over this time horizon and the relationship between the two variables should also expose the point at which the relationship deteriorates. This deterioration is thought to occur in the nearby months, during a period when the market views future supply of milk into the market as fixed, after this point the supply and demand variable will move with the settlement price.

The necessary condition for rational price formation is that the estimated coefficient on the cost variable is insignificantly different from one ($\beta_1 = 1$) in models where the time to maturity of the futures price variable is greater than the length of the feeding period. In other words, futures price should reflect costs in periods where supply decisions are flexible, and

[7] Delivery month is the month in which the contract will expire or settle. For example a July 2015 contract, will be delivered upon, or settle, or expire at the end of July in 2015.

subsequently reflect supply and demand conditions once they are perceived as fixed. However, if rational price formation links futures prices to costs early in the contract life, and if, after the placement period, futures prices symmetrically move above and below costs in the sample of data, then the estimated cost coefficient may continue to be insignificantly different from one in some nearby contract models. This means that even if the relationship between futures price and variable costs is deteriorating, the tying of the futures prices to costs early in trading and to symmetric price adjustments after the placement period may result in the appearance that prices continue to move with costs during the nearby months.

## Data

Data was collected from various sources to satisfy the requirements of Equation (2) and (3). Settlement price ($SP$) was collected from the Understanding Dairy Markets web resource (Gould, 2014), where daily announced Class III prices were collected from January 2001 to June 2013. The daily data was aggregated to monthly price averages, and the last day of the last closing month of the contract was used as the settlement price. It is noteworthy, that the actual announced price for Class III milk contracts were released on the first Friday following the closing month of the contract, as this is when the FMMO price is released (Jesse and Cropp, 2008). The reasoning for using this price and not the announced price, was that volatility decreased (Dong, Du, & Gould, 2011) due to the release of the weekly FMMO prices, and all positions would have been made prior to the closing of the month. The data set yielded 150 observations.

Monthly ration/feed cost ($FC^*$) was developed using the Agricultural Reform, Food and Jobs Act (ARFJA) Feed Ration as described by Bozic (2013). This ration was based on monthly average national prices of corn, soybean meal and alfalfa hay as denoted in annual USDA reports, the data collected covered the period January 2001 to June 2013 and is described by:

$$(5)\ \ ARFJA = 1.0728\ x\ Corn\ Price + 0.00735\ X\ Soybean\ Meal\ Price + 0.0137\ X\ Alfalfa\ Hay\ Price$$

Settlement price was used in both Equation (2) and (4), where is served as both a regressand and a regressor. Feed cost data calculated by Equation (5) was used in Equation (3) as the regressand.

Table 2.1 illustrates the summary statistics of all data used as inputs in Equations (2) and (3) (where ARFJA Ration was described using Equation (5)). There were 150 observations for all data collected, equating to monthly data points for the time period January 2001 to June 2013. *ARFJA Ration* represents the calculated values based on Bozic, (2013) data, while the 12 groups represented by $i = 0, \ldots, 11,$ where $i$ are the months before the expiration month of a contract $k$. These data show the ration cost for the month on a per hundredweight of milk basis. The mean ration cost was approximately seven dollars, however a maximum ration cost, realized during 2012, peaked at over \$15, while the minimum cost was less than \$4. The wide range of feed costs indicate how large an impact changing feed costs can have on a dairy producers' profitability.  Standard deviation of the values were similar for all data. *Settlement Price* $(i = 0, \ldots, 11)$ outlines a summary of the settlement price, or monthly average price that a contract $k,$ would trade for the 12 months prior to expiration. The mean milk price over the period of study was approximately \$14, while the highest price received was over \$21, and the lowest price was close to \$9. Standard deviation was higher closer to the expiration month and then reduced. Again these milk price data indicate the high volatility present in the price of milk over the period of study.

Table 2.1. Summary statistics for data collected- Agricultural Reform, Food and Jobs Act Feed Rations, and recoded Settlement Price[8]

| | **Mean** | **Std. Dev.** | **Min** | **Max** |
|---|---|---|---|---|
| ARFJA Ration (i=0) | 7.61 | 3.01 | 4.49 | 15.12 |
| ARFJA Ration (i=1) | 7.55 | 2.97 | 4.49 | 15.12 |
| ARFJA Ration (i=2) | 7.49 | 2.93 | 4.49 | 15.12 |
| ARFJA Ration (i=3) | 7.43 | 2.90 | 4.36 | 15.12 |
| ARFJA Ration (i=4) | 7.36 | 2.86 | 4.21 | 15.12 |
| ARFJA Ration (i=5) | 7.30 | 2.83 | 3.95 | 15.12 |
| ARFJA Ration (i=6) | 7.23 | 2.79 | 3.95 | 15.12 |
| ARFJA Ration (i=7) | 7.17 | 2.75 | 3.95 | 15.12 |
| ARFJA Ration (i=8) | 7.11 | 2.70 | 3.95 | 15.12 |
| ARFJA Ration (i=9) | 7.05 | 2.65 | 3.95 | 15.12 |
| ARFJA Ration (i=10) | 6.99 | 2.60 | 3.95 | 15.12 |
| ARFJA Ration (i=11) | 6.92 | 2.52 | 3.95 | 14.17 |
| Settlement Price (i=0) | 14.53 | 3.27 | 9.11 | 21.53 |
| Settlement Price (i=1) | 14.41 | 3.07 | 9.43 | 21.35 |
| Settlement Price (i=2) | 14.36 | 2.86 | 9.70 | 20.43 |
| Settlement Price (i=3) | 14.31 | 2.68 | 9.76 | 20.75 |
| Settlement Price (i=4) | 14.27 | 2.56 | 9.83 | 20.59 |
| Settlement Price (i=5) | 14.23 | 2.45 | 9.94 | 20.47 |
| Settlement Price (i=6) | 14.18 | 2.37 | 9.90 | 20.42 |
| Settlement Price (i=7) | 14.12 | 2.28 | 9.93 | 20.14 |
| Settlement Price (i=8) | 14.07 | 2.21 | 10.33 | 19.75 |
| Settlement Price (i=9) | 14.00 | 2.16 | 10.57 | 19.69 |
| Settlement Price (i=10) | 13.93 | 2.14 | 10.66 | 19.68 |
| Settlement Price (i=11) | 13.79 | 2.39 | 10.85 | 19.72 |

Table 2.2 shows results from Equation (2) and (3), in which the feed costs and the supply and demand proxy are estimated. These data are used as inputs in the final regression to examine the presence of rational price formation, Equation (4). The variable $FC^*, (i = 0, \dots, 11)$, represents the estimated feed cost value calculated using Equation (3), where feed costs were calculated as the feed cost in the month before expiration of the contract denoted by $i$. The results of the observations were similar to those calculated for the ARFJA Ration, detailed in Table 1, confirming the regression used correctly represented feed costs. Mean values ranged from \$7 to \$7.5 per hundredweight, while the minimum value was close to \$4 and the maximum value observed was \$14 per hundredweight. Standard deviation was roughly constant for all data.

The supply and demand proxy, $SD^*, (i = 0, \dots, 11)$, denoted the estimated supply and demand value generated using Equation (2). A contract in a distant month (or other contracts

[8] All data contained 150 observations

being traded at the same time) is affected by the current month's settlement price, and therefore the supply and demand proxy represents the effect on contracts further from expiration, $k$. Standard deviation in month $k$ was very low, which is expected due to only seasonal fluctuations being taken into consideration in the seasonal month, however, standard deviations started higher and then reduced further from expiration date. These values closely represent the settlement price values, indicating the use of an efficient regression in Equation (2). The mean value was close to $14.50, with a minimum value observed of less than $10, and a maximum value of close to $21.

The estimates generated, $FC^*$ and $SD^*$, were used as inputs in Equation (4) to produce an estimated settlement price, where $SP^*, (i = 0, \ldots, 11)$ represents the predicted values. These estimated settlement prices can be compared to the actual collected Settlement Price, detailed in Table 1. Mean values observed were around $14, while the minimum value was slightly below $11, the maximum value was above $22. Standard deviations for these estimated values, do indicated some potential issues. For contracts nine and ten months from expiration standard deviations are low, indicating an issue with the data, which will be addressed later in the paper.

Table 2.2. Summary statistics for predicted values resulting from FC* and SD* regressions, as well as predicted SP* values[9]

| | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| FC* (i=0) | 7.60 | 2.78 | 4.53 | 14.23 |
| FC* (i=1) | 7.61 | 2.98 | 4.48 | 14.83 |
| FC* (i=2) | 7.60 | 2.79 | 4.52 | 14.23 |
| FC* (i=3) | 7.60 | 2.78 | 4.52 | 14.25 |
| FC* (i=4) | 7.60 | 2.78 | 4.50 | 14.28 |
| FC* (i=5) | 7.60 | 2.78 | 4.53 | 14.23 |
| FC* (i=6) | 7.60 | 2.79 | 4.53 | 14.21 |
| FC* (i=7) | 7.60 | 2.78 | 4.53 | 14.24 |
| FC* (i=8) | 7.61 | 2.84 | 4.52 | 14.12 |
| FC* (i=9) | 7.60 | 2.81 | 4.51 | 14.17 |
| FC* (i=10) | 7.61 | 2.87 | 4.48 | 14.08 |
| FC* (i=11) | 7.60 | 2.76 | 4.55 | 14.29 |
| SD* (i=0) | 14.42 | 0.57 | 13.57 | 15.24 |
| SD* (i=1) | 14.48 | 2.84 | 9.90 | 20.99 |
| SD* (i=2) | 14.49 | 2.34 | 10.47 | 20.21 |
| SD* (i=3) | 14.49 | 2.55 | 10.24 | 20.44 |
| SD* (i=4) | 14.52 | 2.53 | 10.54 | 20.41 |
| SD* (i=5) | 14.52 | 2.43 | 10.85 | 20.21 |
| SD* (i=6) | 14.51 | 2.35 | 11.17 | 20.09 |
| SD* (i=7) | 14.49 | 2.28 | 11.18 | 19.81 |
| SD* (i=8) | 14.46 | 2.23 | 11.21 | 19.76 |
| SD* (i=9) | 14.42 | 2.20 | 11.14 | 19.56 |
| SD* (i=10) | 14.39 | 2.20 | 11.23 | 19.72 |
| SD* (i=11) | 14.36 | 2.20 | 11.13 | 19.78 |
| SP* (i=0) | 14.38 | 1.55 | 12.14 | 18.29 |
| SP* (i=1) | 14.41 | 2.87 | 9.86 | 20.96 |
| SP* (i=2) | 14.25 | 1.83 | 12.22 | 18.58 |
| SP* (i=3) | 14.15 | 1.65 | 12.37 | 18.11 |
| SP* (i=4) | 14.08 | 1.69 | 12.12 | 18.17 |
| SP* (i=5) | 14.12 | 1.27 | 12.52 | 17.14 |
| SP* (i=6) | 14.16 | 0.82 | 13.11 | 16.14 |
| SP* (i=7) | 14.10 | 1.16 | 12.78 | 16.93 |
| SP* (i=8) | 14.85 | 1.09 | 12.43 | 16.07 |
| SP* (i=9) | 14.19 | 0.40 | 13.71 | 15.19 |
| SP* (i=10) | 14.49 | 0.14 | 14.20 | 14.65 |
| SP* (i=11) | 13.69 | 1.98 | 11.17 | 17.82 |

## Results and Discussion

Prior to running equations (2, 3, and 4), all data was tested for stationarity. Testing for stationarity implies testing the mean and the variance to see if they change across time, in other words the test looks for a relationship between the error terms and the independent time-series variable (Gujarati and Porter, 2009). All data used within the model were tested for stationarity

[9] All data contained 150 observations

using the Augmented Dickey Fuller (ADF) test[10]. Results determined that the data set was stationary and no adjustments needed to be made.

As mentioned previously, 12 models were calculated for Equation (2) and (3), this allowed 12 seemingly related equations to be estimated for Equation (4), to reflect the 12 months that the futures contracts would trade over $i = 0, \ldots, 11$. On the completion of generating the $SD^*$ and $FC^*$ variables, an additional test was run to determine if the models exhibited serial correlation, or "a lag correlation between two different series" (Gujarati and Porter, 2009). Serial correlation in the case of our time series data would mostly likely be a problem of inertia, the Cobweb Phenomenon, or lags in the data, leading to successive observations being interdependent (Gujarati and Porter, 2009). This leads to the regressions not exhibiting efficient estimators, potentially not allowing for the identification of significant coefficients, underestimating the true variance, overestimating $R^2$, and ultimately resulting in $t$ and $F$ tests no longer being valid. The Durbin-Watson d-test[11] was run to detect the presence of serial correlation in the regressions. First-order serial correlation was found to be present in all three equation systems. The regressions were corrected using the Prais-Winsten transformation method, a generalized least-squares method to estimate the parameters in the regressions, the transformed regressions were regressed in the difference form while maintaining the first

[10] The ADF is used to test for stationarity and correct for correlation within the error term $\Delta X_t = \delta X_{t-1} + \mu_t$. $X_t$ represents the various independent variables used in the model. Variables are regressed against the lagged values of themselves, $X_{t-1}$ in addition to an error term $\mu_t$. Delta, $\delta$, is what the hypothesis test of the ADF test is analyzing. The null hypothesis is that if delta is equal to zero then there exists a unit root and the variable is non-stationary. The alternative hypothesis is that delta is greater than zero, meaning the time series is stationary.

[11] The Durbin-Watson d statistic is simply the ratio of the sum of squared differences in successive residuals to the RSS. $d = \frac{\sum_{t=2}^{t=n}(\hat{u}_t - \hat{u}_{t-1})^2}{\sum_{t=1}^{t=n}\hat{u}_t{}^2}$.

observation[12] (Gujarati and Porter, 2009). Examples of each regression system are included in the Appendix.

*Estimating a Supply and Demand Proxy*

Table 3 presents the estimation results of the regression used to estimate a supply and demand proxy, Equation (2). The results outline the impact of the settlement price (which acts as a proxy for the supply and demand equilibrium in the market) in time $t$, on distant contracts ($i = 1, \ldots, 11$). Resulting predicted values from Table 3 were used as an input for Equation (5). The dependent variables incorporated more information the further from the expiration month they were. For example, contract $(i = 0)$, expiring in time $t$ or $(i = 0)$, is affected only by seasonal effects, or in other words what month the contract is. However, a contract that is the seventh contract trading in time $t$, or $SD^*(i = 6)$, which is six months out from the expiration month $(i = 6)$, will incorporate the price of the six contracts that are closer to expiration as well as the seasonal effect (through dummy variables). The results reveal that the immediately prior contract month, for example price of contract $SD^*(i = 5)$, have the most significant effect on the contract being examined ($SD^*(i = 6)$). This trend is present in varying degrees for all dependent variables, such that the determination of a distant contracts price would primarily be influenced by the contract one month nearer to expiration, which is in turn influenced by the contract preceding it. There is also presence of significant effects from the contract two months prior to the contract being examined (e.g. $SD^*(i = 4)$, it is interesting to note however, that these effects are smaller in magnitude and primarily carry negative coefficients. The seasonal effect varies throughout the results shown, and no consistent pattern among the results were identifiable. Despite no pattern emerging, results did demonstrate that there were at least some significant

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[12] Due to the trend variable being present in the variable cost regression, an intercept term was allowed to be kept.

seasonal coefficients for all regressions run. The $R^2$ value is very high from $SD^*(i = 1)$ onwards, indicating that a contracts' price in time $t$ is mostly explained by contracts closer to expiration. The variable Rho indicates correlation between the variables, and can indicate the presence of serial correlation within the observations. Table 2.3 results demonstrate that Rho values are high in the expiration month, but are not an issue further out, which can be interpreted as serial correlation not being a large issue.

*Estimating Feed Cost*

The results outlined in Table 2.4 are representative of Equation (3) which outlines the estimated feed costs facing producers. Feed cost estimates were generated as a function of time and season. Predicted values of feed costs were used as an input into Equation (4) as part of the rational price formation analysis. Results from the estimation indicated that the time squared variable was significant for all 12 regressions, however the magnitude of the coefficient was very small. Seasonal effects of feed costs were present for all regressions, indicating the importance of seasonal fluctuations within crop prices having a large impact on feed costs. It was interesting to note that the seasonal impacts were never constant, a pattern emerged from the data that implied in any given contract month, a minimum of four dummy variables would be significant, but the months were different for each regression. Feed costs were included in the rational price formation process, as they were the main costs faced by dairy producers, this estimation of feed costs helps determine at which point the market perceives the supply of milk fixed. The presence of serial correlation was detected in the data testing stage, and as previously described the Prais-Winston correction was applied to all regressions. Despite this corrective procedure, it was noted that the Rho values in Table 2.4 were close to 1, indicating the presence of serial correlation. This was an unexpected result, and could have major consequences on any final results.

Table 2.3. OLS estimation results for the Supply and Demand proxy, using Equation (2)

| | Dependent Variables | | | | | |
|---|---|---|---|---|---|---|
| Independent Variables | **SD*(i=0)** | **SD*(i=1)** | **SD*(i=2)** | **SD*(i=3)** | **SD*(i=4)** | **SD*(i=5)** |
| **SP (i=10)** | | | | | | |
| **SP (i=9)** | | | | | | |
| **SP (i=8)** | | | | | | |
| **SP (i=7)** | | | | | | |
| **SP (i=6)** | | | | | | |
| **SP (i=5)** | | | | | | |
| **SP (i=4)** | | | | | | 1.402*** |
| | | | | | | *(0.09)* |
| **SP (i=3)** | | | | | 1.615*** | -0.335** |
| | | | | | *(0.07)* | *(0.15)* |
| **SP (i=2)** | | | | 1.226*** | -0.680*** | 0.0101 |
| | | | | *(0.05)* | *(0.11)* | *(0.12)* |
| **SP (i=1)** | | | 0.883*** | -0.334*** | 0.0363 | -0.0693 |
| | | | *(0.04)* | *(0.05)* | *(0.06)* | *(0.06)* |
| **SP (i=0)** | | 0.905*** | -0.117*** | 0.0275 | 0.00954 | -0.0288 |
| | | *(0.03)* | *(0.04)* | *(0.02)* | *(0.02)* | *(0.02)* |
| **Feb** | -0.205 | 0.36 | -0.0416 | 0.11 | 0.0379 | -0.0536 |
| | *(0.34)* | *(0.26)* | *(0.11)* | *(0.07)* | *(0.08)* | *(0.07)* |
| **Mar** | -0.0451 | 0.402 | 0.157 | 0.235** | -0.0149 | -0.161** |
| | *(0.46)* | *(0.29)* | *(0.15)* | *(0.09)* | *(0.08)* | *(0.08)* |
| **Apr** | 0.228 | 0.44 | 0.382** | 0.312*** | -0.0418 | -0.352*** |
| | *(0.54)* | *(0.30)* | *(0.17)* | *(0.10)* | *(0.08)* | *(0.08)* |
| **May** | 0.429 | 0.577* | 0.529*** | 0.179 | -0.145* | -0.631*** |
| | *(0.59)* | *(0.31)* | *(0.18)* | *(0.11)* | *(0.08)* | *(0.08)* |
| **Jun** | 1.128* | 0.600* | 0.450** | 0.0453 | -0.404*** | -0.424*** |
| | *(0.62)* | *(0.31)* | *(0.20)* | *(0.12)* | *(0.08)* | *(0.09)* |
| **Jul** | 0.909 | 0.602* | 0.567*** | -0.267** | -0.205** | -0.436*** |
| | *(0.63)* | *(0.31)* | *(0.20)* | *(0.12)* | *(0.09)* | *(0.09)* |
| **Aug** | 1.434** | 0.398 | 0.071 | -0.132 | -0.176** | -0.415*** |
| | *(0.62)* | *(0.32)* | *(0.20)* | *(0.12)* | *(0.08)* | *(0.08)* |
| **Sep** | 1.462** | 0.127 | -0.113 | -0.139 | -0.281*** | -0.163* |
| | *(0.60)* | *(0.32)* | *(0.19)* | *(0.11)* | *(0.08)* | *(0.09)* |
| **Oct** | 1.284** | -0.32 | -0.142 | -0.182* | -0.0961 | -0.140* |
| | *(0.55)* | *(0.31)* | *(0.18)* | *(0.11)* | *(0.08)* | *(0.08)* |
| **Nov** | 0.711 | 0.135 | -0.196 | -0.0682 | -0.0545 | -0.220*** |
| | *(0.48)* | *(0.30)* | *(0.15)* | *(0.09)* | *(0.08)* | *(0.08)* |
| **Dec** | 0.652* | -0.434 | 0.00764 | 0.00436 | -0.0924 | -0.161** |
| | *(0.36)* | *(0.27)* | *(0.12)* | *(0.07)* | *(0.08)* | *(0.07)* |
| **Cons** | 13.77*** | 1.112** | 3.266*** | 1.166*** | 0.425*** | 0.562*** |
| | *(1.22)* | *(0.43)* | *(0.43)* | *(0.24)* | *(0.12)* | *(0.13)* |
| **Obs** | 150 | 150 | 150 | 150 | 150 | 150 |
| **R-squared** | 0.1 | 0.895 | 0.885 | 0.964 | 0.993 | 0.991 |
| **Rho** | 0.919 | 0.286 | 0.815 | 0.665 | 0.092 | 0.188 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.3. OLS estimation results for the Supply and Demand proxy, using Equation (2). Cont..

| | Dependent Variables | | | | | |
|---|---|---|---|---|---|---|
| Independent Variables | **SD*(i=6)** | **SD*(i=7)** | **SD*(i=8)** | **SD*(i=9)** | **SD*(i=10)** | **SD*(i=11)** |
| **SP (i=10)** | | | | | | 1.345*** |
| | | | | | | *(0.09)* |
| **SP (i=9)** | | | | | 1.025*** | -0.394*** |
| | | | | | *(0.07)* | *(0.13)* |
| **SP (i=8)** | | | | 1.265*** | 0.13 | 0.00317 |
| | | | | *(0.08)* | *(0.12)* | *(0.13)* |
| **SP (i=7)** | | | 1.374*** | -0.18 | -0.103 | -0.0842 |
| | | | *(0.09)* | *(0.14)* | *(0.12)* | *(0.13)* |
| **SP (i=6)** | | 1.145*** | -0.476*** | 0.0906 | -0.310*** | 0.137 |
| | | *(0.09)* | *(0.14)* | *(0.14)* | *(0.11)* | *(0.13)* |
| **SP (i=5)** | 1.317*** | -0.0779 | 0.201 | -0.301** | 0.394*** | 0.0623 |
| | *(0.08)* | *(0.15)* | *(0.15)* | *(0.14)* | *(0.12)* | *(0.13)* |
| **SP (i=4)** | -0.309** | -0.13 | -0.109 | 0.196 | -0.139 | -0.0675 |
| | *(0.13)* | *(0.14)* | *(0.15)* | *(0.14)* | *(0.12)* | *(0.12)* |
| **SP (i=3)** | 0.0213 | 0.198 | -0.0255 | 0.00369 | 0.0477 | -0.0378 |
| | *(0.14)* | *(0.15)* | *(0.15)* | *(0.14)* | *(0.12)* | *(0.13)* |
| **SP (i=2)** | -0.035 | -0.134 | 0.0968 | -0.188* | -0.174* | 0.105 |
| | *(0.11)* | *(0.11)* | *(0.12)* | *(0.11)* | *(0.09)* | *(0.10)* |
| **SP (i=1)** | -0.00618 | -0.0729 | -0.131** | 0.0721 | 0.144*** | -0.140*** |
| | *(0.05)* | *(0.06)* | *(0.06)* | *(0.06)* | *(0.05)* | *(0.05)* |
| **SP (i=0)** | -0.0148 | 0.0526** | 0.0483** | 0.0326 | -0.0232 | 0.0582*** |
| | *(0.02)* | *(0.02)* | *(0.02)* | *(0.02)* | *(0.02)* | *(0.02)* |
| **Feb** | -0.0927 | -0.246*** | -0.0318 | 0.125* | 0.0351 | 0.00181 |
| | *(0.06)* | *(0.07)* | *(0.07)* | *(0.07)* | *(0.06)* | *(0.06)* |
| **Mar** | -0.276*** | -0.409*** | -0.0443 | 0.237*** | -0.0873 | 0.123 |
| | *(0.07)* | *(0.08)* | *(0.09)* | *(0.08)* | *(0.07)* | *(0.08)* |
| **Apr** | -0.491*** | -0.417*** | 0.00213 | 0.230** | 0.0258 | 0.125 |
| | *(0.08)* | *(0.09)* | *(0.11)* | *(0.10)* | *(0.08)* | *(0.09)* |
| **May** | -0.385*** | -0.301*** | 0.0297 | 0.318*** | 0.181** | 0.189** |
| | *(0.09)* | *(0.10)* | *(0.11)* | *(0.10)* | *(0.09)* | *(0.09)* |
| **Jun** | -0.351*** | -0.241** | 0.0998 | 0.473*** | 0.211** | 0.279*** |
| | *(0.08)* | *(0.10)* | *(0.10)* | *(0.10)* | *(0.09)* | *(0.10)* |
| **Jul** | -0.316*** | -0.118 | 0.258** | 0.409*** | 0.213** | 0.366*** |
| | *(0.08)* | *(0.10)* | *(0.10)* | *(0.10)* | *(0.09)* | *(0.09)* |
| **Aug** | -0.191** | -0.00451 | 0.225** | 0.431*** | 0.287*** | 0.420*** |
| | *(0.08)* | *(0.09)* | *(0.09)* | *(0.09)* | *(0.08)* | *(0.09)* |
| **Sep** | -0.128* | -0.0884 | 0.278*** | 0.621*** | 0.282*** | 0.324*** |
| | *(0.08)* | *(0.08)* | *(0.09)* | *(0.08)* | *(0.09)* | *(0.09)* |
| **Oct** | -0.171** | -0.0375 | 0.434*** | 0.531*** | 0.227*** | 0.126 |
| | *(0.07)* | *(0.08)* | *(0.08)* | *(0.09)* | *(0.08)* | *(0.09)* |
| **Nov** | -0.0457 | 0.0695 | 0.443*** | 0.393*** | 0.0172 | -0.0156 |
| | *(0.07)* | *(0.08)* | *(0.08)* | *(0.08)* | *(0.08)* | *(0.08)* |
| **Dec** | 0.042 | 0.0438 | 0.261*** | 0.165** | -0.118** | 0.0256 |
| | *(0.07)* | *(0.07)* | *(0.07)* | *(0.07)* | *(0.06)* | *(0.06)* |
| **Cons** | 0.566*** | 0.420*** | 0.137 | -0.222 | -0.0226 | -0.0105 |
| | *(0.13)* | *(0.15)* | *(0.16)* | *(0.15)* | *(0.14)* | *(0.14)* |
| | | | | | | |
| **Obs** | 150 | 150 | 150 | 150 | 150 | 150 |
| **R-squared** | 0.992 | 0.99 | 0.989 | 0.989 | 0.992 | 0.992 |
| **Rho** | 0.215 | 0.261 | 0.241 | 0.295 | 0.325 | 0.267 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.4. OLS estimation results for Feed Cost variable, using Equation (3)

| | Dependent Variables | | | | | |
|---|---|---|---|---|---|---|
| Independent Variables | **FC*(i=0)** | **FC*(i=1)** | **FC*(i=2)** | **FC*(i=3)** | **FC*(i=4)** | **FC*(i=5)** |
| **time** | -0.0139 | -0.000407 | -0.0129 | -0.0125 | -0.0124 | -0.0139 |
| | *(0.03)* | *(0.00)* | *(0.03)* | *(0.03)* | *(0.03)* | *(0.03)* |
| **time2** | 0.000495** | 4.81E-05 | 0.000450** | 0.000447** | 0.000425** | 0.000493** |
| | *0.00* | *(0.00)* | *(0.00)* | *(0.00)* | *(0.00)* | *(0.00)* |
| **Feb** | 0.0766 | 0.0136 | 0.0722 | 0.0747 | 0.114 | 0.0775 |
| | *(0.09)* | *(0.11)* | *(0.09)* | *(0.09)* | *(0.10)* | *(0.10)* |
| **Mar** | 0.0962 | -0.0362 | 0.0849 | 0.0904 | 0.131 | 0.0982 |
| | *(0.13)* | *(0.13)* | *(0.13)* | *(0.13)* | *(0.13)* | *(0.13)* |
| **Apr** | 0.232 | 0.0818 | 0.213 | 0.22 | 0.261* | 0.234 |
| | *(0.15)* | *(0.14)* | *(0.15)* | *(0.15)* | *(0.15)* | *(0.15)* |
| **May** | 0.445*** | 0.172 | 0.424** | 0.426*** | 0.465*** | 0.447*** |
| | *(0.16)* | *(0.14)* | *(0.16)* | *(0.16)* | *(0.16)* | *(0.17)* |
| **Jun** | 0.436** | -0.0296 | 0.402** | 0.416** | 0.446*** | 0.438** |
| | *(0.17)* | *(0.14)* | *(0.17)* | *(0.17)* | *(0.17)* | *(0.17)* |
| **Jul** | 0.399** | -0.0567 | 0.344* | 0.361** | 0.406** | 0.400** |
| | *(0.17)* | *(0.14)* | *(0.18)* | *(0.18)* | *(0.17)* | *(0.18)* |
| **Aug** | 0.359** | -0.0635 | 0.306* | 0.302* | 0.339* | 0.360** |
| | *(0.17)* | *(0.14)* | *(0.18)* | *(0.18)* | *(0.17)* | *(0.17)* |
| **Sep** | 0.16 | -0.227 | 0.11 | 0.104 | 0.11 | 0.16 |
| | *(0.17)* | *(0.14)* | *(0.17)* | *(0.17)* | *(0.17)* | *(0.17)* |
| **Oct** | -0.116 | -0.324** | -0.162 | -0.168 | -0.163 | -0.117 |
| | *(0.15)* | *(0.14)* | *(0.16)* | *(0.16)* | *(0.15)* | *(0.15)* |
| **Nov** | -0.108 | -0.0664 | -0.134 | -0.155 | -0.147 | -0.108 |
| | *(0.13)* | *(0.13)* | *(0.13)* | *(0.14)* | *(0.13)* | *(0.13)* |
| **Dec** | -0.0808 | -0.0497 | -0.0798 | -0.108 | -0.112 | -0.081 |
| | *(0.10)* | *(0.12)* | *(0.10)* | *(0.10)* | *(0.10)* | *(0.10)* |
| **ARFJA** | | | | | | |
| **ARFJA_1** | | 0.903*** | | | | |
| | | *(0.04)* | | | | |
| **ARFJA_2** | | | 0.0984 | | | |
| | | | *(0.09)* | | | |
| **ARFJA_3** | | | | 0.0962 | | |
| | | | | *(0.09)* | | |
| **ARFJA_4** | | | | | 0.152* | |
| | | | | | *(0.09)* | |
| **ARFJA_5** | | | | | | 0.00466 |
| | | | | | | *(0.09)* |
| **ARFJA_6** | | | | | | |
| **ARFJA_7** | | | | | | |
| **ARFJA_8** | | | | | | |
| **ARFJA_9** | | | | | | |
| **ARFJA_10** | | | | | | |
| **ARFJA_11** | | | | | | |
| **Constant** | 4.737*** | 0.504** | 4.291*** | 4.303*** | 4.047*** | 4.717*** |
| | *(1.03)* | *(0.23)* | *(1.01)* | *(1.02)* | *(0.99)* | *(1.10)* |
| **Observations** | 150 | 150 | 150 | 150 | 150 | 150 |
| **R-squared** | 0.344 | 0.977 | 0.392 | 0.385 | 0.404 | 0.345 |
| **Rho** | 0.948 | 0.311 | 0.938 | 0.940 | 0.937 | 0.948 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.4. OLS estimation results for Feed Cost variable, using Equation (3). Cont…

| | Dependent Variables | | | | | |
|---|---|---|---|---|---|---|
| Independent Variables | **FC*(i=6)** | **FC*(i=7)** | **FC*(i=8)** | **FC*(i=9)** | **FC*(i=10)** | **FC*(i=11)** |
| **time** | -0.0141 | -0.0135 | -0.019 | -0.0161 | -0.0203 | -0.0117 |
| | *(0.03)* | *(0.03)* | *(0.03)* | *(0.03)* | *(0.03)* | *(0.03)* |
| **time2** | 0.000510** | 0.000485** | 0.000609*** | 0.000543*** | 0.000604*** | 0.000451** |
| | *(0.00)* | *(0.00)* | *(0.00)* | *(0.00)* | *(0.00)* | *(0.00)* |
| **Feb** | 0.0746 | 0.0782 | 0.0657 | 0.0949 | 0.104 | 0.0751 |
| | *(0.09)* | *(0.09)* | *(0.09)* | *(0.10)* | *(0.09)* | *(0.09)* |
| **Mar** | 0.0884 | 0.0989 | 0.0698 | 0.11 | 0.157 | 0.0815 |
| | *(0.13)* | *(0.13)* | *(0.13)* | *(0.13)* | *(0.13)* | *(0.13)* |
| **Apr** | 0.216 | 0.238 | 0.193 | 0.239 | 0.283* | 0.201 |
| | *(0.15)* | *(0.15)* | *(0.15)* | *(0.15)* | *(0.15)* | *(0.15)* |
| **May** | 0.429** | 0.456*** | 0.371** | 0.447*** | 0.482*** | 0.419** |
| | *(0.17)* | *(0.17)* | *(0.16)* | *(0.16)* | *(0.16)* | *(0.17)* |
| **Jun** | 0.421** | 0.447** | 0.310* | 0.422** | 0.462*** | 0.415** |
| | *(0.18)* | *(0.18)* | *(0.17)* | *(0.17)* | *(0.17)* | *(0.17)* |
| **Jul** | 0.387** | 0.408** | 0.275 | 0.364** | 0.408** | 0.389** |
| | *(0.18)* | *(0.18)* | *(0.18)* | *(0.18)* | *(0.17)* | *(0.17)* |
| **Aug** | 0.349** | 0.367** | 0.248 | 0.325* | 0.327* | 0.357** |
| | *(0.17)* | *(0.18)* | *(0.17)* | *(0.18)* | *(0.17)* | *(0.17)* |
| **Sep** | 0.15 | 0.167 | 0.0662 | 0.131 | 0.129 | 0.177 |
| | *(0.17)* | *(0.17)* | *(0.17)* | *(0.17)* | *(0.16)* | *(0.17)* |
| **Oct** | -0.12 | -0.11 | -0.196 | -0.138 | -0.139 | -0.1 |
| | *(0.15)* | *(0.16)* | *(0.15)* | *(0.15)* | *(0.15)* | *(0.15)* |
| **Nov** | -0.105 | -0.104 | -0.185 | -0.124 | -0.118 | -0.0962 |
| | *(0.13)* | *(0.13)* | *(0.13)* | *(0.13)* | *(0.13)* | *(0.13)* |
| **Dec** | -0.0791 | -0.0813 | -0.121 | -0.0959 | -0.0812 | -0.0757 |
| | *(0.10)* | *(0.10)* | *(0.10)* | *(0.10)* | *(0.10)* | *(0.10)* |
| **ARFJA** | | | | | | |
| **ARFJA_1** | | | | | | |
| **ARFJA_2** | | | | | | |
| **ARFJA_3** | | | | | | |
| **ARFJA_4** | | | | | | |
| **ARFJA_5** | | | | | | |
| **ARFJA_6** | -0.0332 | | | | | |
| | *(0.09)* | | | | | |
| **ARFJA_7** | | 0.0197 | | | | |
| | | *(0.09)* | | | | |
| **ARFJA_8** | | | -0.207** | | | |
| | | | *(0.08)* | | | |
| **ARFJA_9** | | | | -0.0877 | | |
| | | | | *(0.09)* | | |
| **ARFJA_10** | | | | | -0.167* | |
| | | | | | *(0.09)* | |
| **ARFJA_11** | | | | | | 0.0792 |
| | | | | | | *(0.09)* |
| **Constant** | 4.889*** | 4.641*** | 5.802*** | 5.167*** | 5.560*** | 4.359*** |
| | *(1.13)* | *(1.11)* | *(1.22)* | *(1.15)* | *(1.17)* | *(1.12)* |
| **Observations** | 150 | 150 | 150 | 150 | 150 | 150 |
| **R-squared** | 0.337 | 0.347 | 0.333 | 0.338 | 0.34 | 0.347 |
| **Rho** | 0.950 | 0.947 | 0.957 | 0.951 | 0.953 | 0.948 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

*Rational Price Formation*

Table 2.3 and 2.4, have outlined the estimators which will be used as inputs into Equation (4), which tests for the presence of rational price formation. Results are presented in a diagonal format, so as to show each of the 12 seemingly unrelated regressions distinctly, the presentation also allows for the time between each contract to be perceived correctly. For each regression result, the dependent variable (e.g.$SP\ (i = 0)$) was a function of the feed costs in that month, $(FC^{*})$, and the supply and demand proxy, $(SD^{*}(i = 0))$, and each regression represents a different month. The necessary condition for rational price formation is that the estimated coefficient on the cost variable is insignificantly different from one ($\beta_1 = 1$). Theory also indicates that the futures will play an allocative and forward pricing role in the lifetime of the contract.

Results outlined in Table 2.5 provide evidence of rational price formation in Class III milk futures contracts. The coefficient on feed costs is insignificantly different from one at $SP\ (i = 2)$, this implies that the market views the supply of milk as fixed from this period onwards for a given contract. Further evidence of the rational price formation, is that the coefficient on supply and demand is insignificant at $SP\ (i = 1)$, indicating that the market is now only taking into account the supply and demand information available on the market.

An interpretation of the feed cost coefficient becoming insignificantly different from one, can be tied into dairy production practices through an examination of breeding practices. In a 12 month time horizon, cows are initially bred at 12 months of age and gestation is 9 month[13]. It is assumed that the dairy cow will be integrated into the milking herd at the 10$^{th}$ month (provided they are bred on the first try). This can be interpreted as the dairy producer views his production

[13] On average a cow will give birth once every 12 months providing there are no delays in breeding.

fixed at the point of a cow entering the milking herd, at this point onwards feed costs associated with that production would also be made and not change until that cow has to be bred again.

Results within Table 2.5 show that the Settlement Price of a contract in the distant months follows the feed cost, or cost of production, in line with the competitive equilibrium argument. Although Settlement Price is a function of feed costs in distant months, the relationship does break down. An analysis of coefficients on $FC^{*}$ show the coefficients decreasing from 0.653 in $FC^{*}(i = 2)$, to 0.452 in $FC^{*}(i = 7)$, however the coefficients are still highly statistically significant at this point. During this period when futures contract prices are tracking the feed costs, the futures contract is said to be playing an allocative role. Once supply is perceived as fixed, in $SP\ (i = 1)$, the market focuses on supply and demand data, and it is said the futures contracts play a forward pricing role, it is interesting to note that the forward pricing role is only present for the last two months of a contract's life.

A problem arises in the results when Rho is examined. The values of Rho, indicating correlation are very high, signifying the presence of serial correlation. Serial correlation also provides a potential explanation for the coefficients found on $FC^{*}(i = 8)$ and $SD^{*}(i = 8)$ where the sign of the coefficient reverses. These two results, values of Rho and the change in coefficient sign, indicate serial correlation is adversely affecting the results of Equation (4), resulting in biased results.

An examination of the inputs reveals that feed costs are the primary driver of the serial correlation that is present in Equation (4).

Table 2.5. OLS estimations for the presence of rational price formation through Equation (3)

| | Dependent Variables | | | | | |
|---|---|---|---|---|---|---|
| Independent Variables | **SP (i=0)** | **SP (i=1)** | **SP (i=2)** | **SP (i=3)** | **SP (i=4)** | **SP (i=5)** |
| **FC*(i=0)** | 0.531** | | | | | |
| | *(0.26)* | | | | | |
| **SD*(i=0)** | 0.830*** | | | | | |
| | *(0.28)* | | | | | |
| **FC*(i=1)** | | 0.0848** | | | | |
| | | *(0.04)* | | | | |
| **SD*(i=1)** | | 0.949*** | | | | |
| | | *(0.04)* | | | | |
| **FC*(i=2)** | | | 0.653*** | | | |
| | | | *(0.23)* | | | |
| **SD*(i=2)** | | | 0.00344 | | | |
| | | | *(0.08)* | | | |
| **FC*(i=3)** | | | | 0.632*** | | |
| | | | | *(0.22)* | | |
| **SD*(i=3)** | | | | -0.0632 | | |
| | | | | *(0.08)* | | |
| **FC*(i=4)** | | | | | 0.716*** | |
| | | | | | *(0.20)* | |
| **SD*(i=4)** | | | | | -0.170** | |
| | | | | | *(0.07)* | |
| **FC*(i=5)** | | | | | | 0.562*** |
| | | | | | | *(0.20)* |
| **SD*(i=5)** | | | | | | -0.176** |
| | | | | | | *(0.07)* |
| **FC*(i=6)** | | | | | | |
| **SD*(i=6)** | | | | | | |
| **FC*(i=7)** | | | | | | |
| **SD*(i=7)** | | | | | | |
| **FC*(i=8)** | | | | | | |
| **SD*(i=8)** | | | | | | |
| **FC*(i=9)** | | | | | | |
| **SD*(i=9)** | | | | | | |
| **FC*(i=10)** | | | | | | |
| **SD*(i=10)** | | | | | | |
| **FC*(i=11)** | | | | | | |
| **SD*(i=11)** | | | | | | |
| **Cons** | -1.633 | 0.0349 | 9.232*** | 10.26*** | 11.11*** | 12.41*** |
| | *(4.51)* | *(0.47)* | *(2.00)* | *(1.87)* | *(1.77)* | *(1.80)* |
| **Obs** | 150 | 150 | 150 | 150 | 150 | 150 |
| **R-squared** | 0.094 | 0.869 | 0.076 | 0.087 | 0.14 | 0.143 |
| **Rho** | 0.887 | 0.240 | 0.900 | 0.911 | 0.921 | 0.930 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.5. OLS estimations for the presence of rational price formation through Equation (3). Cont..

| | Dependent Variables | | | | | |
|---|---|---|---|---|---|---|
| Independent Variables | **SP (i=6)** | **SP (i=7)** | **SP (i=8)** | **SP (i=9)** | **SP (i=10)** | **SP (i=11)** |
| **FC*(i=0)** | | | | | | |
| **SD*(i=0)** | | | | | | |
| **FC*(i=1)** | | | | | | |
| **SD*(i=1)** | | | | | | |
| **FC*(i=2)** | | | | | | |
| **SD*(i=2)** | | | | | | |
| **FC*(i=3)** | | | | | | |
| **SD*(i=3)** | | | | | | |
| **FC*(i=4)** | | | | | | |
| **SD*(i=4)** | | | | | | |
| **FC*(i=5)** | | | | | | |
| **SD*(i=5)** | | | | | | |
| **FC*(i=6)** | 0.369* | | | | | |
| | *(0.21)* | | | | | |
| **SD*(i=6)** | -0.126* | | | | | |
| | *(0.07)* | | | | | |
| **FC*(i=7)** | | 0.452** | | | | |
| | | *(0.17)* | | | | |
| **SD*(i=7)** | | -0.0535 | | | | |
| | | *(0.07)* | | | | |
| **FC*(i=8)** | | | -0.347 | | | |
| | | | *(0.25)* | | | |
| **SD*(i=8)** | | | -0.0586 | | | |
| | | | *(0.08)* | | | |
| **FC*(i=9)** | | | | 0.182 | | |
| | | | | *(0.20)* | | |
| **SD*(i=9)** | | | | -0.0694 | | |
| | | | | *(0.08)* | | |
| **FC*(i=10)** | | | | | -0.0365 | |
| | | | | | (0.21) | |
| **SD*(i=10)** | | | | | -0.0174 | |
| | | | | | *(0.08)* | |
| **FC*(i=11)** | | | | | | 0.452*** |
| | | | | | | *(0.12)* |
| **SD*(i=11)** | | | | | | 0.377*** |
| | | | | | | *(0.14)* |
| **Cons** | 13.20*** | 11.44*** | 18.34*** | 13.80*** | 15.02*** | 4.838*** |
| | *(1.96)* | *(1.68)* | *(3.81)* | *(2.32)* | *(2.86)* | *(1.48)* |
| **Obs** | 150 | 150 | 150 | 150 | 150 | 150 |
| **R-squared** | 0.122 | 0.168 | 0.044 | 0.107 | 0.064 | 0.091 |
| **Rho** | 0.944 | 0.933 | 0.991 | 0.975 | 0.988 | 0.582 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

## Conclusion

The objective of the research was to test Class III milk pricing for the presence of rational price formation. Through an analysis of Class III milk futures contracts 12 months before expiration, an analysis of pricing rational takes place to determine whether the market is acting efficiently. Theory suggests that contracts in distant months reflect market conditions, or feed costs, but as the contract moves closer to expiration, the supply of the commodity becomes fixed and the market price the contract according to the supply and demand dynamics affecting the market. Using a system of 12 seemingly unrelated regressions, it is determined that Class III milk futures contracts do follow rational pricing. Futures contracts are found to be acting in an allocative capacity from 11 months to 3 months prior to expiration month. In the last 2 months, the forward pricing role is dominant taking into account the supply and demand dynamics in the market. If is found that Class III milk futures play both roles well, indicating that they are efficient in utilizing all information available through the last 12 months of trading.

The implications of this study are that by creating a more transparent Class III futures market it will entice more participants into the market. Increased trade within the market allows for more effective hedging strategies, as speculators take on risk as opposed to producers. Additional trading within the market allows for a more accurate price formation process to take place as more information can be incorporated into the market through the different trading strategies that individual traders may take. Through more trading, and more efficient price determination, there is the potential for government involvement to decrease and allow a truly competitive market to evolve.

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