Dairy Confined Animal Feeding Permits on Public Notice as a Leading Indicator of Milk Supply

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Gabriella Sorg

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Co-Advisors: Michael Boland and Marin Bozic

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Abstract

Trends toward larger dairy farms and stricter environmental regulations imply that an increasing percentage of United States milk cows will be located on farms regulated by Confined Animal Feeding Operation (CAFO) permits. The objective of this research is to test whether a change in the aggregate state dairy cow herd size can be predicted by a respective change in the number of cows permitted under the CAFO, i.e. if CAFO permits can serve as a leading indicator for dairy herd changes. A model of Texas is used to test if cows on CAFO permit public notice can help predict change in aggregate state dairy herd size.

Some CAFO permit data, like facility capacity, are available through public notices that must be published to inform the community of facility changes. Individual permit data on changes in animal capacity for facilities were collected from public notices published from January 2005 to December 2018. Data from CAFO permits are transformed into six-month moving sums and run as a lagged variable against year-over-year change in United States Department of Agriculture (USDA) number of Texas milk cows. A variable for USDA Margin Protection Program estimation of milk margin above feed costs is used as a control variable. Results suggest that a six-month lagged and summed variable of the number of cows on CAFO permit public notice is statistically significant to the year-over-year change in milk cows in Texas. Economic significance and feasibility of industry implementation are less certain.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

1.1 Motivation for this research

The number of milk cows in the United States (U.S.). has remained steady at about nine million over the past fifteen years. However, there has been a movement of milk cows among states as the dairy herd shifts to different regions. Because of the nature of milk as a continuously produced and perishable product, the location of these cows is important to milk processors and farmers. Cow numbers are a strong indicator of milk production. Therefore, a more accurate and long-range prediction of the number of dairy cows could be a useful tool in forecasting milk production and provide a leading indicator for milk production in the U.S. This is valuable since, historically, dairy farmers are individual economic agents who, on their own, cannot impact the market. Thus, dairy farmers and stakeholders in the dairy industry such as policymakers and agribusiness firms seek to understand the viability of this important agricultural sector in the food economy. This research tests if public notices for dairy Confined Animal Feeding Operations (CAFOs) can provide useful information to help predict changes in the number of milk cows.

The dairy industry currently uses a variety of methods to forecast milk production in the U.S. Most of these methods use historical relationships between collected variables and milk production to predict future milk production. The relationships between historical milk production and historical data for variables such as milk prices, feed costs, number of milk cows, and profit margins are used to attempt to predict future milk production by using current estimated values of these variables. These variables are estimated in an assortment of ways. One method is milk processor surveys. These include cooperatives with members surveying their dairy farmers to understand the number of cows and productivity per cow. This helps the processor better understand their own milk supply. A second method is relying on monthly dairy cow numbers provided by the United States Department of Agriculture (USDA). These data are used to help construct other estimates of the U.S. dairy industry such as the World Agricultural Supply and Demand Estimates report, which is used to help understand the dairy supply in the U.S. Some of these data are also reported by private sector consultants. These historical relationships have not proven to be extremely reliable predictors because the relationships can change over time. Dairy farmers are quick to respond to current market conditions by expanding or culling the number of cows milked. These historical relationships do not always apply to the present time because changes in farmer behavior, productivity per cow, forage quality, feed inputs, or other factors can alter the relationships between milk production and a variable like feed costs.

Historical relationships use data that are looking backward in time in an effort to predict the future milk supply. Examining plant capacity changes according to company press releases, 10-k reports of firms that report to the U.S. Securities and Exchange Commission, and other public data sources are data that look forward in time. These data can be more difficult to attain due to company privacy rights and because most dairy processors are closely held firms. Nevertheless, when available, forward-looking data are also used to help forecast future milk supply. This research attempts to add another forward-looking variable or leading indicator to the forecasting model. A leading indicator is a measure of a variable that would predict the future milk supply reasonably well. An increase in the number of milk cows on CAFO permits would suggest that the future dairy herd size is going to increase and hence, increase the supply of milk. A leading indicator for the dairy industry on cow numbers would be useful for farmers, stakeholders, and policymakers because knowledge of future changes in the milk supply before the rest of the dairy industry economy moves in a certain direction is valuable information.

Data from public notices for dairy CAFO permits could be a useful leading indicator of the milk supply because they provide individual farm-level documentation of a dairy facility's intents to build or expand. The real-time and farm-level nature of this data could make it interesting to use in similar ways Big Data is being used in predictive analytics. Big Data is seen as a new opportunity to build more sound predictive analytics throughout the agricultural sector due to precision agriculture and other technological advancements.

Coble et al. (2016) defines Big Data in terms of volume, velocity, variety and veracity. Volume, although not given a specific value, refers to Big Data as surpassing the size typical software can handle. Velocity of Big Data is acquiring data as events occur, while variety refers to new types of data and sources, and veracity is the accuracy of the data gathered. Although CAFO permit data probably does not qualify as Big Data under this definition, it shares many similar properties that make it appealing as a data source. Big Data in agriculture is often farm-level data. This means that the sample used for analysis may actually represent the majority or even the entirety of a population (Mayer-Schönberger and Cukier 2014).

The CAFO permits, depending on the state, can also represent a majority of dairy cows or dairy farm expansions. In a state like Texas where the average farm size has surpassed the CAFO permit threshold of 700 cows, the majority of cows should be reflected in CAFO permits. The CAFO permit data also shares the “velocity” characteristic of Big Data. Such permit public notices are not just in real time, but they are notifications of intents for cow numbers to grow in the future. Data from CAFO permit public notices are also publicly available. Coble et al. (2018) suggests that the private sector has possession of much of the valuable Big Data collected today. The CAFO permit data is publicly available data that could be exploited in similar ways as Big Data to improve predictive analytics as a leading indicator.

Traditionally, dairy cooperatives did not impose any constraints on an individual member’s desire to grow their dairy herd. Lack of coordination of supply growth decisions induced quasi-periodic dairy price cycles. Farmer decisions on culling and expansions also lead to supply variability. Many farmers often expand at the same time due to a good economic environment. Milk is a unique product since it is highly perishable unless cooled and processed immediately, and it is produced daily. The variability of milk production combined with its need to reach the market quickly means that price variability must occur to balance out supply and demand. More accurate forecasting could act as a coordinating mechanism by signaling dairy market over and undersupply to help producers coordinate and time expansions. Managing supply through better information sharing could help reduce periods of oversupply. This research tests if the declared intent of farmers to expand production by applying for CAFO permits can help construct a more accurate prediction of milk-cow growth than historical relationships. Improving the forecast of the number of milk cows leads to an improved forecast of milk production. Rapid milk production changes can cause rapid price changes, which have a pronounced effect on dairy farmers' and dairy cooperatives' revenues and profits.

1.2 Thesis objective

The objective of this research is to test whether the number of cows being permitted under the CAFO can help predict a change in the size of a state's aggregate dairy herd. Various lags are used to test this objective. To do so, CAFO permit data is collected by month from January of 2005 to December of 2018 and used to develop a potential leading indicator for changes in number of milk cows. In general, CAFO permits regulate dairy producers in an effort to minimize dairy farm contribution to water quality issues. This permitting process yields written notices that are available to the public. Although the permitting process and public notice requirements vary by state, most public notices contain the facility's proposed maximum headcount by animal type. This animal capacity data is collected and utilized to determine the effectiveness of dairy CAFO permit public notices as an expectation of future dairy herd expansion.

1.3 Overview of CAFO permits and selection of Texas as state of interest

The CAFO permitting process varies slightly by state, but all states must meet the U.S. Environmental Protection Agency (EPA) standards that are outlined by the Clean Water Act (CWA) and regulated under the National Pollutant Discharge Elimination System (NPDES) permitting program. The current CWA was originally enacted in 1948 as the Federal Water Pollution Control Act. After major revisions, it was renamed the Clean Water Act in 1972. According to the U.S. EPA website, "The CWA establishes the basic structure for regulating discharges of pollutants into the waters of the U.S. and regulating quality standards for surface waters." Under the CWA, it is illegal for any point source to discharge pollutants into surface waters without a permit. The NPDES permit program regulates these point sources, including animal feeding operations (AFOs). AFOs are identified as a point source because of their potential to release pollutants like nitrogen and phosphorus from manure and wastewater into waters. Most states have obtained authorization to administer the NPDES program itself. CAFO permits are issued by the EPA for a few states (e.g. Alaska, Idaho, Massachusetts, etc.) that have not obtained this authorization.

This research began by gathering and analyzing public notices for dairy CAFO permits and the permitting process for 24 of the top states with regard to milk production in 2017. In alphabetical order, these states were: Arizona, California, Colorado, Florida, Idaho, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Nebraska, New Mexico, New York, Ohio, Oregon, Pennsylvania, South Dakota, Texas, Utah, Vermont, Virginia, Washington, and Wisconsin. The goal of this research was to determine the feasibility of collecting dairy CAFO public notices. An experiment was conducted to collect monthly dairy CAFO public notices for these 24 states over the February to December 2018 time period. The ability to find, understand, and transform the written public notices into meaningful data was attempted for each month. Over the course of these 11 months, public notices for dairy CAFO permits were collected successfully during at least one of these months for 11 states. These states were: Colorado, Indiana, Iowa, Kansas, Minnesota, Nebraska, Pennsylvania, South Dakota, Texas, Utah, and Wisconsin. The last chapter discusses the limitations in collecting the data in these other states.

Of the 24 states, Texas was found to have some of the best readily available historical public notice data. Texas has also seen a large increase in the number of milk cows over the past 15 years due to an increase in milk processing capacity and a more friendly environment for dairy production than other regions. This combination of data availability and dairy herd growth led Texas to be chosen as a state to research the objective.

1.4 Organization of the thesis

Chapter 2 outlines previous economic research with CAFOs and housing industry research that tested similar concepts of permits as a potential leading indicator. Chapter 3 discusses the Texas dairy industry and describes the CAFO permitting process for the state of Texas. Collection of the CAFO data and descriptive statistics on analysis variables are explained in Chapter 4, while Chapter 5 describes theory and methodology.

Chapter 6 provides the results and discussion, and the final chapter discusses the conclusion, implications, and limitations of this research.

Chapter 2

Literature Review

2.1 Summary of previous economic research on CAFOs

CAFO permits have been of research interest in recent years. The largest repository of research publications in agriculture and applied economics is AgEcon Search housed at the University of Minnesota Libraries. In July of 2019, a search of their online databases returned 34 publications using the search word "CAFOs" with the oldest one published in 2001 (University of Minnesota 2019). However, most of these publications focus on the environmental aspects or effects CAFO regulations have on farmers. Some brief summaries of this kind of research are highlighted in this section. Sneeringer and Key (2013) used census data to test if farmers required by their size to get a CAFO permit behaved differently than farmers estimated to produce the same amount of manure but not required by their size to get a CAFO permit. They found farmers exhibited behaviors of managing manure more agronomically that were required to obtain a CAFO permit.

Huang and Short (2002) modeled the economic impact that the EPA's proposed changes to the dairy CAFO permitting regulations would have on dairies in the corn belt, upper-Midwest, and northeast regions. These proposed changes would increase the number of farms requiring permits. A sample of 18 farms in this region were used to model effects. They found results varied based on manure storage method and nutrient management requirement. Farmers with lagoon storage of manure for pasture and crop land saw almost no impact from proposed phosphorus based nutrient management plan and the current nitrogen based nutrient management plan. On the other hand, most farms using underground or above ground slurry tanks would be required to find more acreage to spread manure under the proposed phosphorus-based or the current nitrogen-based nutrient management plans.

The two summaries of previous CAFO research accurately reflect how the majority of CAFO research has been on the regulations' effects on farmers and the environment. Research that involves constructing a dataset from actual individual permit information was not located. This study expands on the way that CAFO permits are used in research by extracting farm level data from CAFO permits, which has not been done before in the literature. This farm level data can be used to test if there is positive correlation between dairy herd growth and permit data.

2.2 Summary of research on permits as a leading indicator in the housing industry

Similar data has been used in other industries to develop a leading indicator. Dua et al. (1999) experimented with using housing permits as a leading indicator of U.S. home sales. They had a standard model that included the variables: home sales, price of homes, mortgage rate, real personal disposable income, and unemployment rate. Six different leading indicators, including building permits authorized, were added to the model individually to evaluate their forecasting abilities. The model that included building permits authorized produced the most accurate forecast when compared to the other five models. Results also suggested that replacing building permits with housing starts produced almost the same results. Idiosyncratic differences of the permitting process and the dairy and housing industries make it tough to compare more than summaries of this research. Nevertheless, government permitting has been used in the past as a leading indicator to more accurately predict growth in another industry.

The research in this paper contributes to the literature by using intents of farmers to develop a leading indicator for number of milk cow. This type of leading indicator has not been done before for milk cows using CAFO data.

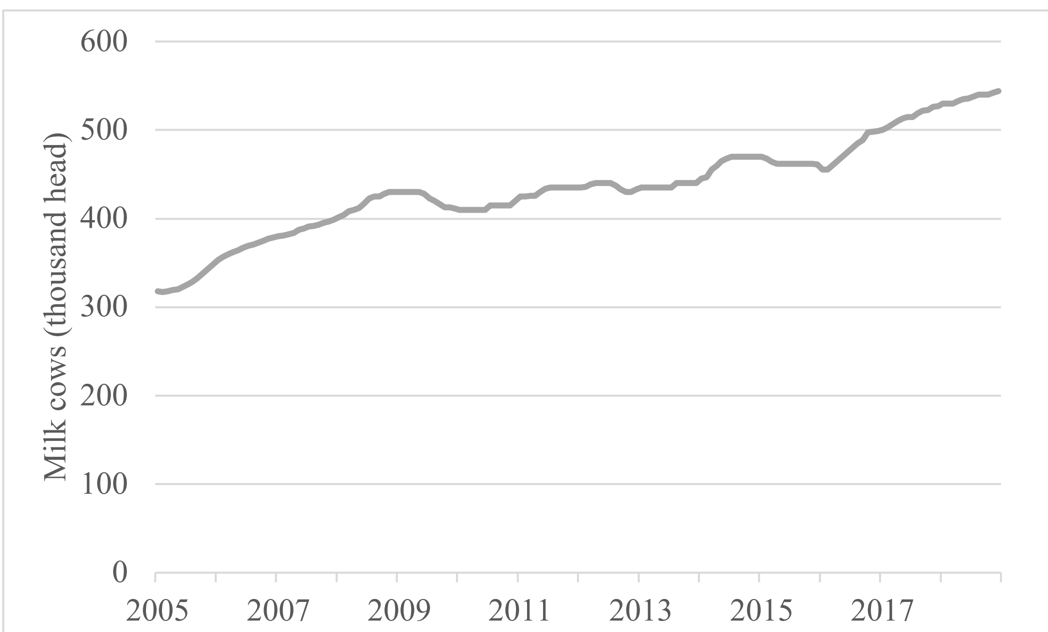
Chapter 3

The Texas Dairy Industry and Texas CAFO Permits

3.1 The Texas dairy industry

One of the reasons Texas is used as an example for this research is rapid growth in its dairy herd as shown in Figure 3.1. The variability in its dairy cow herd numbers from 2005 to 2018, is important for testing the research objective. For example, in January 2005, Texas had 318,000 milk cows. By December of 2018, Texas had experienced a 70% increase to 544,000 cows. This can be partially credited to especially rapid growth during the 2005 to 2008 and 2016 to 2017 time periods.

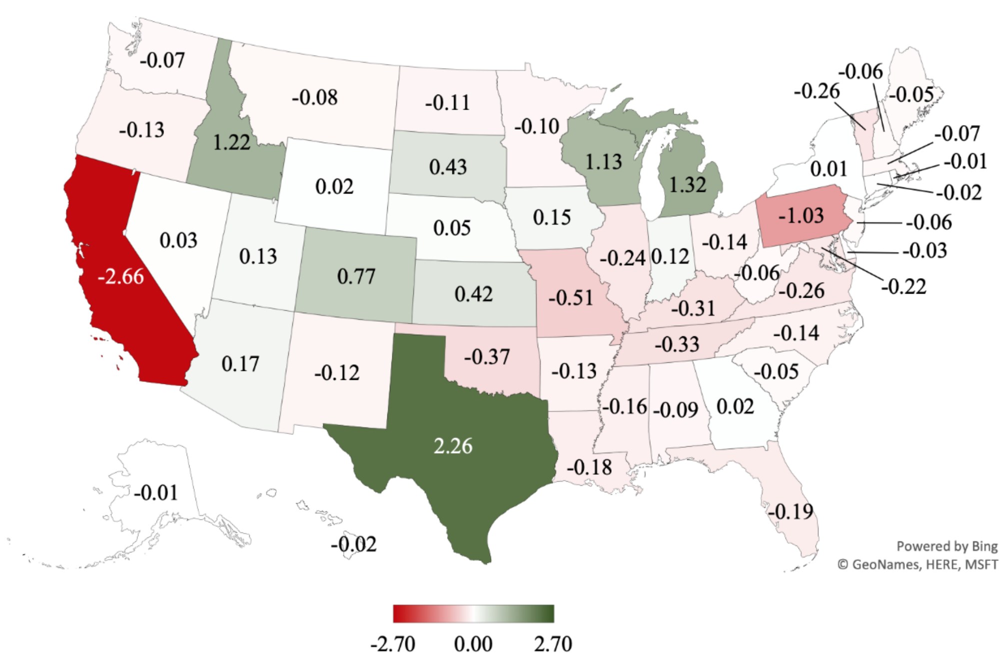
Figure 3.1 Total Milk Cows in Texas from January 2005 to December 2018, monthly



Source: Author's graphic using USDA, NASS 2019b
Note: Data from March to June of 2013 is missing due to a limitation of NASS funding at the time. Those monthly data are linearly interpolated in this figure.

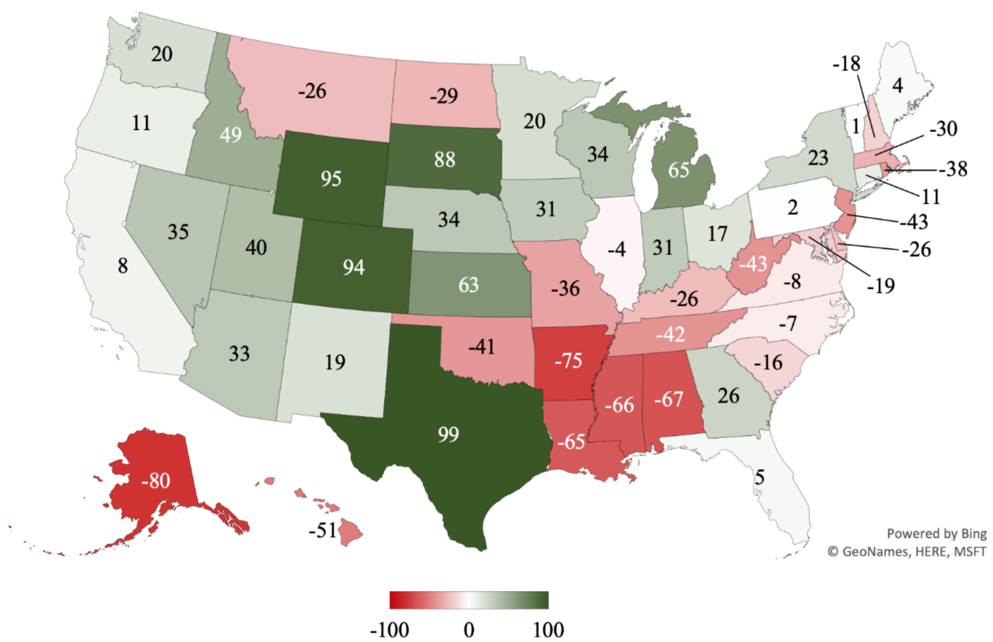
Most of the growth of the dairy industry in Texas is attributed to one region, the Texas Panhandle, which provides a dry climate suitable for dairying and resources favorable for modern commercial dairy farms. Impacts of the significant growth in the Texas Panhandle can be seen in Figure 3.2 and Figure 3.3. These maps of the U.S. highlight the extreme growth in Texas from 2005 to 2018 compared to other states. Many other states declined in milk production from 2005 to 2018, and Texas was the only state to increase milk production by 99%. The relatively mild climate makes the cost of facilities to house cows much less expensive than in northern states with colder winters, which have higher facility and energy costs. The presence of feedlots in the area also meant that a transportation system was already in place to bring in necessary feed commodities such as distiller's grains from corn-ethanol plants.

Figure 3.2 Cumulative Change in State-Level Percentage of U.S. Production, 2005 to 2018



Source: Author's map using USDA, NASS 2019b

Figure 3.3 Cumulative Percentage Change in State Milk Production, 2005 to 2018



Source: Author's map using USDA, NASS 2019b

The Texas Panhandle is also located over the Ogallala Aquifer that has been a source of water for crops and livestock. Equally as important, the region has historically had more lax requirements for permitting larger modern livestock facilities than many other regions or even states (Bechtel 2016). In addition, corn-ethanol plants that were constructed in the southwestern Great Plains provide a source of inexpensive dry distiller's grains which have been adapted to feed rations of milk cows.

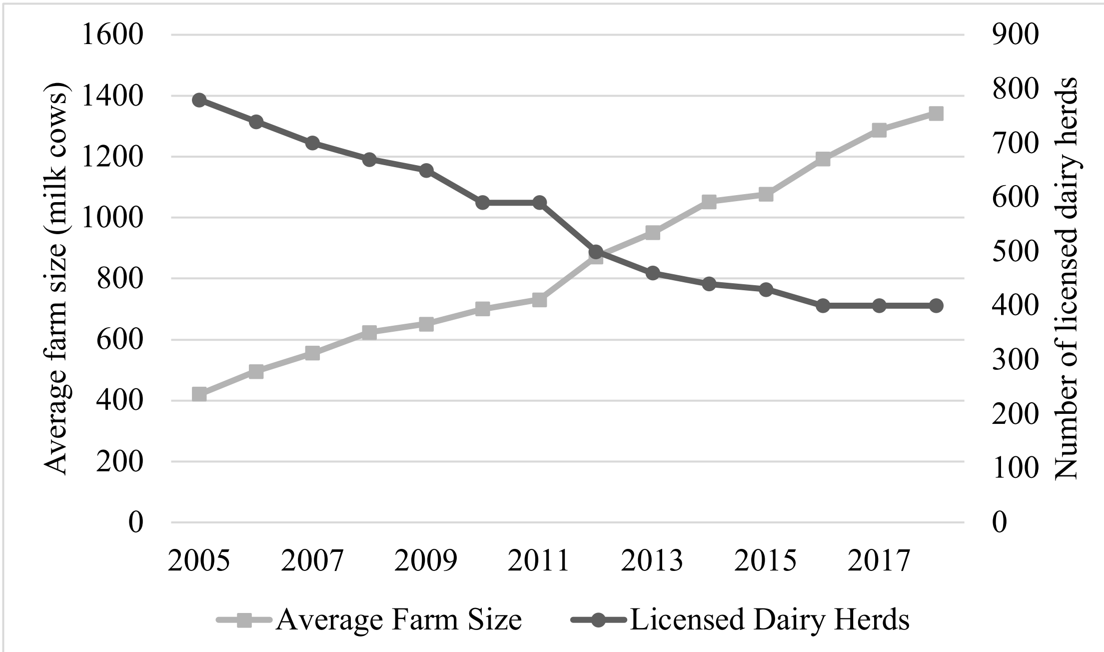
Dairy herd growth is supported by corresponding growth of processing capacity in the region from companies like Hilmar Cheese Company, Inc. and Southwest Cheese. In 2003, some cooperative members of Greater Southwest Agency, a federated cooperative composed of individual dairy cooperatives, announced their intent to build and operate Southwest Cheese Company. It began operations in October of 2005 and reached full production capacity in August of 2007 in Clovis, New Mexico. Southwest Cheese Company is the result of a unique joint venture between Glanbia plc, an Irish dairy cooperative with 50% ownership, and Dairy Farmers of America, Inc. and Select Milk Producers Inc. Production capacity of the cheese and whey plant increased by about 40% after the completion of an expansion in 2010 (Southwest Cheese Production Facility 2019). According to the Southwest Cheese Company website, it now processes over 3.8 billion pounds of milk annually, produces more than 388 million pounds of cheese, and 29.1 million pounds of whey protein powders.

In 2005, Hilmar Cheese announced construction of a plant in Dalhart, Texas that was completed in 2007. About 35,000 cows supplied the facility with approximately two million pounds of milk per day that it processed into half a million pounds of cheese each day. The Dalhart facility completed its first phase of construction in 2009, which allowed it to process about 5 million pounds of milk per day. Completion of phase two in 2011 allowed the facility to double processing capacity to one million gallons of milk per day. The expectation was that this facility would need milk from about 150,000 cows by the ninth year of production (Hilmar Cheese Plant 2019). Hilmar announced in August of 2014 that an expansion it completed earlier that year had it processing almost 200 tanker loads of milk each day. This same announcement said that it was beginning an additional expansion project that would allow it to process up to 20% more milk than it was at that time (Hilmar Cheese Company 2014).

The low-cost environment for large dairies in the Texas Panhandle led to concurrent construction of large dairy farms and massive dairy processing plants in the region. Large farms with the ability to fill their own tanker or tanker loads of milk are appealing to processors as they lessen total hauling costs. To put the size of these processing plants in perspective, the 150,000 cows expected to be necessary to furnish the milk supply of Hilmar Cheese would have been about 30% of the total Texas herd in 2016. Southwest Cheese does not clearly state what percentage of its milk originates from Texas. However, it is likely that the building of that plant also had a large effect on cow numbers in the Texas Panhandle as this plant is generally regarded as the largest cheese plant in North America.

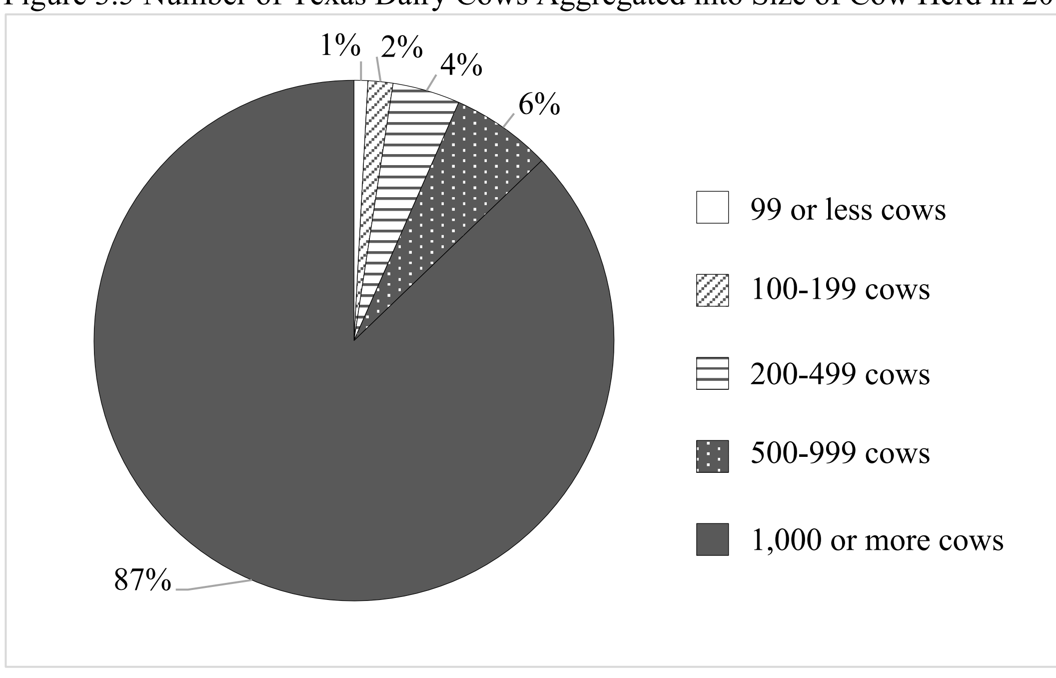
Dairy farms are steadily increasing in average cow numbers across the nation, and Texas is no exception. In fact, Texas may be leading the consolidation trend as its average farm size has surpassed the CAFO threshold of 700 cows. According to annual milk production reports released by the USDA National Agricultural Statistics Service (NASS), the average farm size in Texas has more than doubled since 2005. Figure 3.4 shows the growth in average herd size from 421 milk cows in 2005 to 1,343 milk cows in 2018. The figure also demonstrates the plummeting of licensed dairy herds from 780 in 2005 to 400 herds in 2018. A larger farm size implies that most new milk cows entering the Texas herd need to be covered by a CAFO permit. The 2017 USDA Census of Agriculture indicated that 87% of all milk cows in Texas at the time were part of a milk cow herd with 1,000 cows or more as shown in Figure 3.5. All of those cows should be part of a facility's CAFO permit because they exist on an operation that contains over 700 milk cows. Consequently, 87% of milk cows in Texas should be traceable within the public domain through CAFO permits.

Figure 3.4 Average Farm Size and Licensed Dairy Herd Numbers in Texas, 2005 to 2018



Note: Average farm size is calculated by dividing aggregate Texas dairy herd size by number of licensed dairy herds.
Source: Author's graphic using USDA, NASS 2019b

Figure 3.5 Number of Texas Dairy Cows Aggregated into Size of Cow Herd in 2017



Source: Author's graphic using USDA, NASS 2019a

3.2 Texas CAFO permits

Texas is authorized to administer its own CAFO permits under the Texas Surface Water Quality Standards, which meet the requirements of the CWA. Most states operate under similar rules and regulations because of the obligation to meet CWA standards. This section outlines Texas policies specifically, although most apply to other states as well. Facilities may need a CAFO permit for a variety of reasons from animal capacity to proximity to water or even a combination of the two. First, all facilities needing a CAFO permit fit the Texas Commission on Environmental Quality (TCEQ) definition of an AFO. By the TCEQ definition, an "(AFO) is a lot or facility, other than an aquatic animal production facility, where animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and in which the animal confinement areas do not sustain crops, vegetation, forage growth, or post-harvest residues in the normal growing season over any portion of the lot or facility" (TCEQ 2019). Milking parlors are classified as confinement areas, and any animal brought into a confinement area for any portion of a day is considered to be confined for the whole day (USEPA 2012). Therefore, virtually all modern dairies should qualify as an AFO.

A dairy that is an AFO is required to be permitted if it qualifies as a small, medium, or large CAFO. Large CAFOs are defined based on the quantity of livestock they confine. Medium and small CAFOs are also defined based on quantity of livestock but meet some piece of additional criteria as well. The Texas Administrative Code defines CAFO sizes, with regard to dairy cattle, in the following way. A large CAFO is any AFO that confines at least the number of animals defined in Table 3.1. A medium

CAFO is an AFO that is within the size range in Table 3.1 and meets at least one of the following criteria: (a) discharges pollutants into water in the state through a man-made ditch, flushing system or other similar man-made device; (b) discharges pollutants directly into water in the state; (c) facility is located in the dairy outreach program areas of Bosque, Comanche, Erath, Hamilton, Hopkins, Johnson, Rains, and Wood counties; (d) AFO is designated by the executive director as a CAFO because it is a significant contributor of pollutants into or adjacent to water in the state. The dairy outreach program areas are more heavily regulated because they were identified by the state as having a higher potential to contribute to water quality problems. A small CAFO is an AFO that is within the capacity range in the Table 3.1 and is designated by the executive director as a CAFO because it is a significant contributor of pollutants into or adjacent to water in the state and is not a large or medium CAFO.

Table 3.1 Definitions of Small, Medium, and Large CAFOs in Texas

Animal Type	**Capacity Threshold (number of animals)**		
	Large CAFOs	**Medium CAFOs**[1]	**Small CAFOs**[2]
Mature dairy cattle (milking or dry)	700 or more	200-699	Less than 200
Cattle other than mature dairy cattle or veal calves	1,000 or more	300-999	Less than 300

[1]Must also meet at least one of the four criteria listed in the definition of a medium CAFO.
[2]Only a CAFO when designated by the executive director on a case by case basis.
Source: Texas Administrative Code, 2019

Texas dairies may apply for coverage under a general CAFO permit or an individual CAFO permit. The general permit is created by the State to cover a scope of operations that typically share similar characteristics. The Texas general permit was authorized for use in 2004. Authorizers and applicants prefer general permits over individual permits because the process to obtain coverage is simpler. The permit conditions are already in place, and the facility needs to prove that it can meet them. This process generally requires less paperwork and is more cost effective for the State than individual permits. On the other hand, individual permits are personalized to the specific operation. The permit has to be created based on specifications of the facility (USEPA 2012). Individual permits are still necessary requirements for some dairies. The TCEQ website instructs facilities to apply for an individual permit with the following excerpt,

> *If any of the following statements are true, you must obtain coverage under this individual permit: a) your CAFO is within one mile of coastal natural resource areas; b) your CAFO is a dairy CAFO and in segment 1226 or 1255 of the Bosque River watershed (which are sole-source impairment zone); c) your CAFO is, or will be, in the protection zone of a sole-source surface drinking water supply; d) your CAFO is in an impaired watershed where the total maximum daily load (TMDL) plan requires water quality protection measures more stringent than those required by the general permit; e) your CAFO is required by our executive director to obtain and operate under an individual permit; and f) your CAFO has a compliance history rating of "poor. (TCEQ 2019)*

If none of these statements are true, facilities are able and encouraged to apply for the general permit. The majority of permits issued in Texas are general permits.

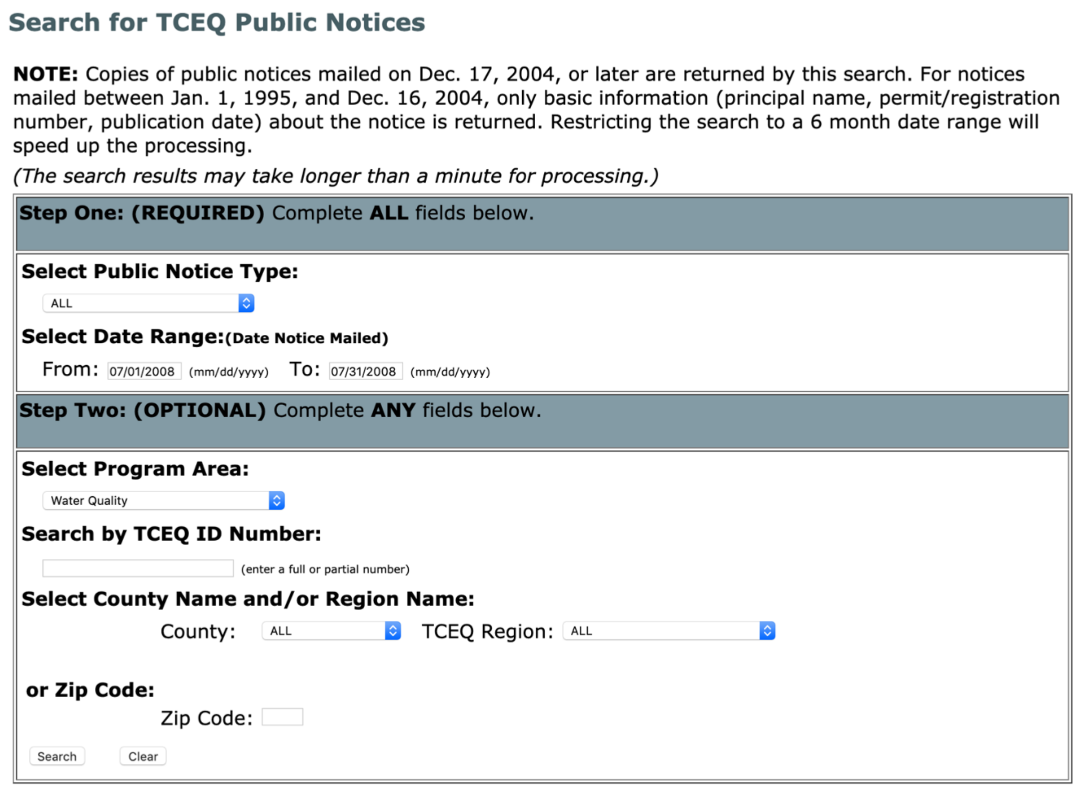
Chapter 4

Data Collection Process and Description of Dataset

4.1 Collection of the CAFO data

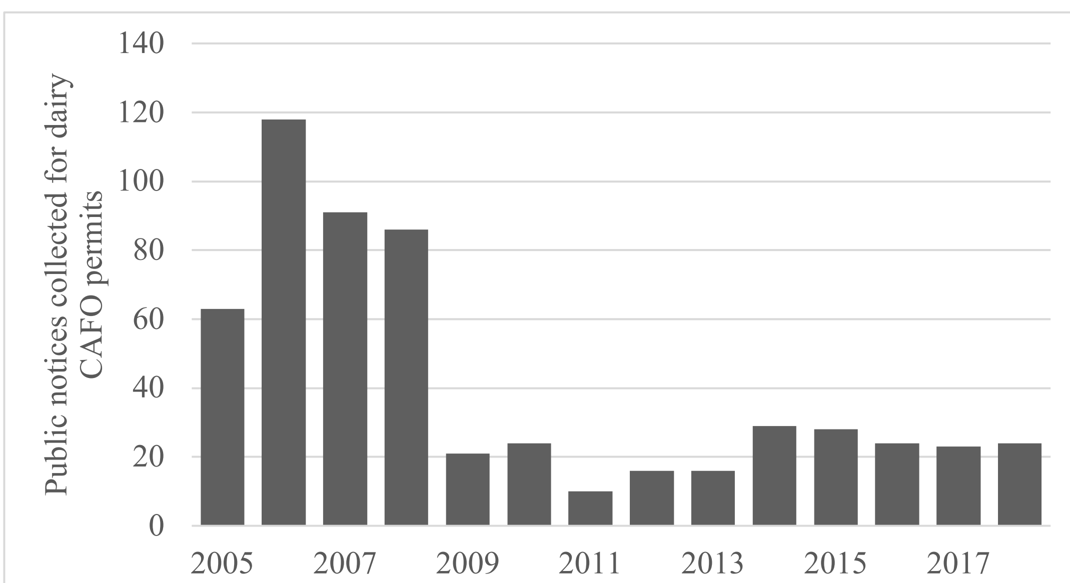
The TCEQ has a searchable database for public notices. The database contains copies of public notices mailed on December 17, 2004 or later. Historical public notices were collected for dairies in Texas by month from 2005 to 2018. The month in question was entered into the date range field and "Water Quality" was selected from the "Select Program Area" drop down menu. Figure 4.1 is an example of these search criteria for July of 2008. The database would then return a list of notices with links to a copy of the written notice. All public notices with the word "dairy" in them were saved under that month. These notices were published online in PDF format and averaged two to three pages in length. A total of 573 public notices were gathered from the 14-year time period. The years 2006, 2007, and 2008 returned the most public notices for dairy CAFO permits with 118, 91, and 86, respectively. These statistics are illustrated in Figure 4.2.

Figure 4.1 TCEQ Database Search Selection Example for July of 2008



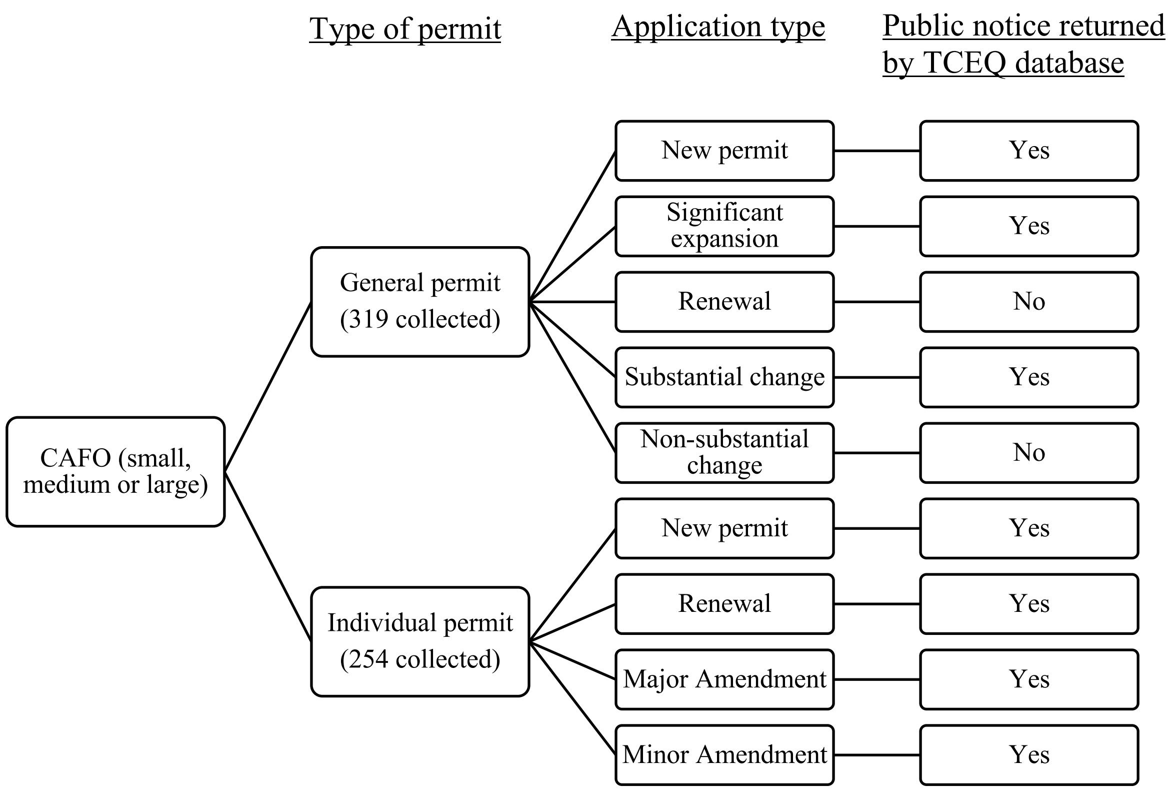
Source: This figure is taken from the TCEQ webpage

Figure 4.2 Public Notices Collected for Dairy CAFO Permits by Year



Public notice requirements vary by permit and application type. Figure 4.3 outlines the changes each permit type can apply for and the public notice requirements for those changes. Only the application types with “yes” in the “Public notice returned by TCEQ database” column are able to be collected and included in this dataset. All changes to individual permits return a public notice in the TCEQ database. This means all animal capacity changes proposed in individual permits should be captured by the dataset. On the other hand, general permit changes do not all require public notices that are returned by the TCEQ online database. As shown in the flowchart, public notices for non-substantial changes and renewals of general permits are not able to be collected. However, both of these changes should not result in an increase in animal capacity under TCEQ definitions. Non-substantial changes can include decreases in headcount that therefore are not included in this dataset.

Figure 4.3 Texas CAFO Permitting Process Flowchart



4.2 Description of CAFO dataset constructed

The CAFO dataset was built with the information provided in the 573 public notices that were collected from the TCEQ online database from January of 2005 to December of 2018. Data from individual public notices are entered as single observations with the main goal of constructing a variable that states the permittee's intended change in milk cow capacity at the facility. Due to varying amounts and type of information provided by public notices, they are categorized into nine different "permit types." These permit types will be defined.

Permit type #1 consists of new permits that are assumed to be for new facilities based on the phrasing in the public notice. Any new permit may state that it is giving "authorization to operate a new dairy facility." This statement means that the permit is new, but the facility may or may not be new. The facility could be an existing facility with milk cows, but one that is getting permitted for the first time. Therefore, the phrasing that precedes the location of the facility is used to determine if it is truly new or existing. Permit type #1 facilities use either the phrasing "the proposed facility will be located" or "the facility will be located." Under these assumptions, the animal capacity a permit type #1 facility is applying for is entered as the change in CAFO milk cows because it is assumed to be an increase from zero head.

Permit type #2 consists of expansions or amendments to existing facilities that are already permitted. These public notices state the current permitted capacity but do not break it down by animal type such as cows versus heifers. The proposed capacity is also included and is broken down by animal type. Change in CAFO milk cows is entered assuming that the facility has kept the same ratio of milking versus non-milking animals.

New permits that have been assumed by phrasing to be existing facilities are classified as permit type #3. The phrasing preceding location of the facility in these permits is "the existing facility is located," "the facility is located," or "the proposed facility is located." These permits have no information on the current animal capacity of the facility. Therefore, a stronger assumption is made that these facilities are all doubling in size. Under these assumptions, permits of type #3 only account for about two percent of the total additional milk cows on CAFO permits from 2005 to 2018.

Permit type #4 includes notices of receipt of application and intent for individual permits. Some changes to individual permits require two public notices. The first is a notice of receipt of application and intent, and the second is a notice of preliminary decision. Permits cannot be fully approved until they release a notice of preliminary decision. Consequently, data is only entered from notices of preliminary decision to avoid double counting changes in capacity. Approximately 20% of public notices collected were of this type. Logically, almost half of the notices collected for individual permits were notices of receipt of application and intent. Public notices categorized as type #4 never result in a value for change in milk cow capacity because they will be counted later if they advance to notice of preliminary decision.

Notices that are type #5 define the change in both milk cows and non-milking animals. There are no assumptions necessary to input the change in milk cows for permits of this type. Unfortunately, they only account for 10 total permits over the course of 14 years.

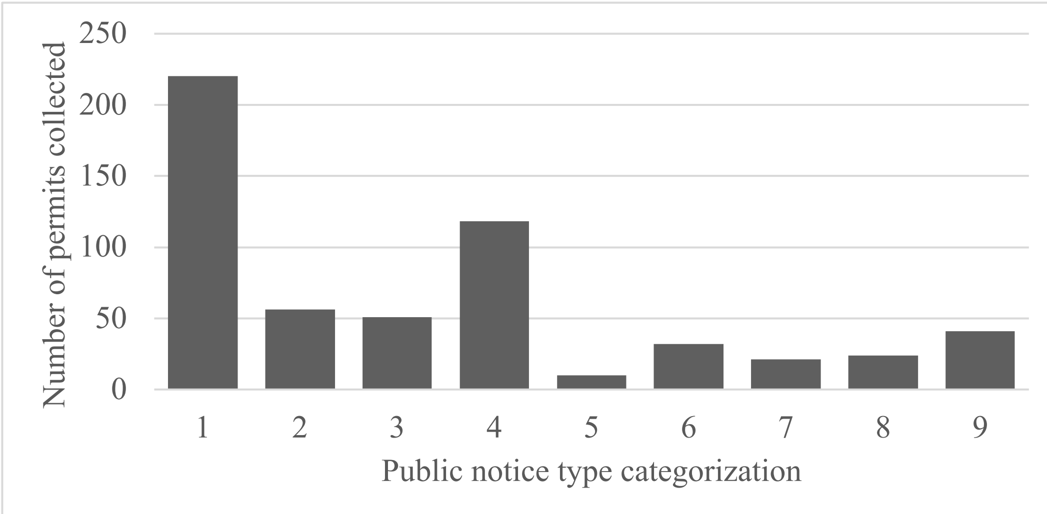
Permit type #6 is the classification for straight renewals of individual permits. These permits do not include a change in animal capacity, so no change in milk cows is entered. Only individual permits can fall into this category because renewals of general permits are not returned by the TCEQ online database.

Type #7 public notices are for permits applying for changes in animal capacity. The public notice itself is the same as type #2. It includes information on current animal capacity not broken down by animal type and proposed capacity broken down by animal type. The difference is that the information on milk cows versus non-milking animals is able to be extracted from a previous permit. Like type #5, no assumptions are necessary to input change in permitted capacity of milk cows. Once again, this permit type is uncommon as only 21 were collected.

Public notices that were collected but are unnecessary to include for various reasons make up the category of type #8. The majority of these are duplications of a previously entered public notice. Some of them are released again because a detail other than animal capacity was revised. Others are returned again in the database for unknown reasons. In one case, a public notice was collected because it contained the word dairy, but it was for a dairy food processing facility. Type #8 public notices never result in an entered change for milk cow capacity.

Finally, public notices of type #9 are amendments or changes to a CAFO permit that do not include a change in animal capacity. Most of these are proposed changes in manure handling or another environmental stipulation. Similar to types #4, #6, and #8, these notices never result in a change in milk cow capacity. Figure 4.4 displays the 573 public notices collected by their categorization type.

Figure 4.4 Breakdown of all Permits Collected by Categorized Type



Changes in cow numbers on CAFO permits in this dataset total 1,086,379 over the 14-year time period. The majority of the increase in cows on CAFO permits comes from public notices for facilities that were assumed to be new or type #1. From 2005 to 2018, 87% of new CAFO cows in this dataset came from those permits. Expansions that were assumed to be proportionally the same (type #2) contributed about 9.8% of the new CAFO cows while type #3 made up about 2%. Together types #5 and #7 contributed the remaining 1%.

The largest increases in cows on CAFO permits were result of the years with the most dairy public notices collected. In the 14-year time period from 2005 to 2018, about 79% of new cows on CAFO permits were from public notices issued in the first four years. The next two years with the largest increase in CAFO cows are 2017 and 2018. Together they make up about 10% of the 14-year total.

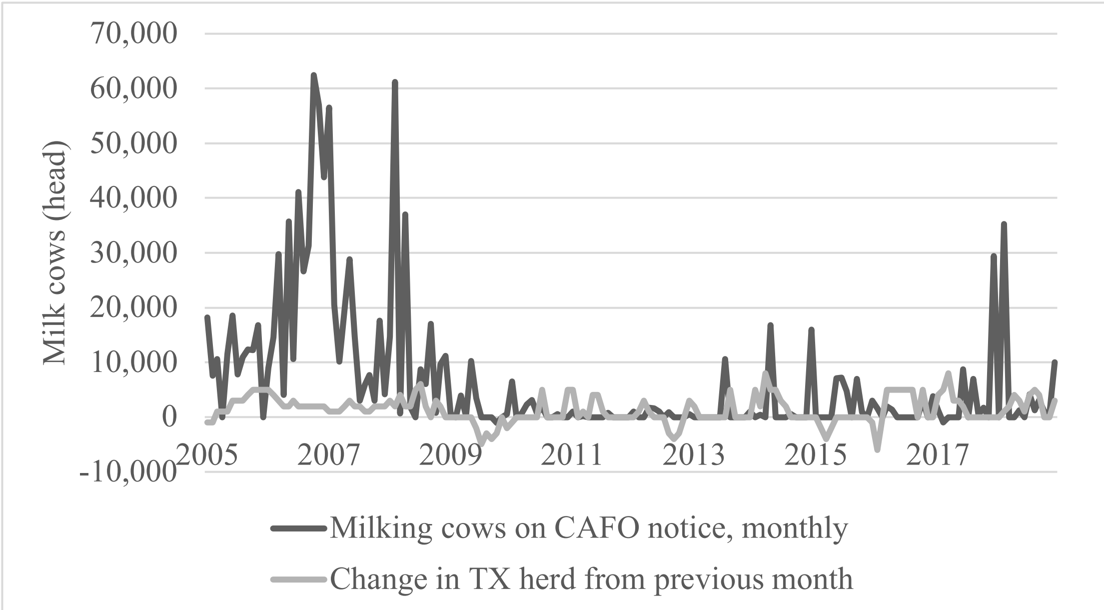
The largest proposed increases in milk cows on a single permit under the stated assumptions were for 36,000, 28,000, and 22,800 additional milk cows. The public notice for an increase of 36,000 cows on a general permit was released in February of 2008. This permittee was proposing a facility in Moore County, Texas with a capacity of 36,000 head of which all would be milk cows. The second largest proposed increase in milk cows of 28,000 comes from a public notice released in February of 2018. A permittee was applying for a facility in Moore, Hartley and Sherman Counties, Texas with a maximum capacity of 94,300 head of which 28,000 head would be milk cows. A public notice released in April of 2008 rounds out the three largest proposed capacity increases in cows in this dataset. In this case, a permittee was applying for a facility with a maximum capacity of 28,800 head of which 22,800 would be milking in Moore County, Texas.

The average proposed capacity change in milk cows from all permit types that have the potential to propose an increase in milk cows (types #1, #2, #3, #5, and #7) is about 3,035 additional milk cows. Within that group of public notices there are 34 permits with a proposed change in milk cow head of zero. This is possible because these notices were for facilities that only intend to raise non-milking dairy animals like calves or heifers. In a few cases, these permits are switching from a general to an individual permit or vice versa without changing animal capacity. This dataset also includes five permits for which the change in milk cows is negative. Facilities that propose reconfiguring their animal capacity to include fewer milk cows are responsible for these negative changes that total a loss of 4,165 milk cows. When changes of zero milk cows are excluded, the average proposed change in milk cow capacity is about 3,353. Rationally, changes in CAFO cows for type #1 permits or assumed new facilities are larger than any other application type at an average increase of about 4,504 milk cows (excluding changes of zero) per permit.

4.3 Descriptive statistics of aggregated CAFO variables

The analysis uses a dataset that aggregates changes in milk cows on CAFO permits to create 168 monthly observations from January of 2005 to December of 2018. The average monthly change is an increase by about 6,466 milk cows. The range is wide with the maximum change of 62,450 milk cows occurring in public notices from October of 2006 and the minimum of -1,060 milk cows occurring in October of 2009. The standard deviation is 12,170 cows. Forty percent of the months have zero additional milk cows on CAFO permits. Figure 4.5 plots these monthly values for cows on CAFO permit public notice against the USDA monthly change in milk cows in Texas. This chart illustrates the sizable intentions of dairymen to build and expand in the early 2000s as well as the stagnant period from 2010 to 2012 with few proposed new CAFOs and expansions.

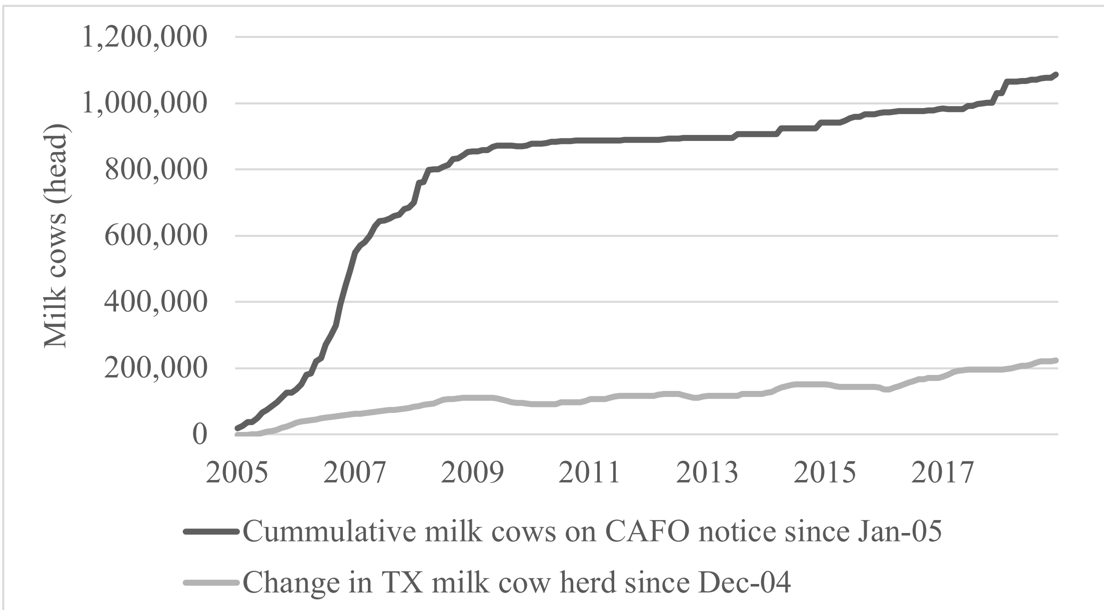
Figure 4.5 Monthly CAFO Data and USDA Monthly Change in Milk Cows



Source: Author's graphic using collected CAFO data and USDA, NASS 2019b
Note: Milk cow data from March to June of 2013 is missing due to a limitation of NASS funding at the time. Those monthly data are linearly interpolated to construct figure.

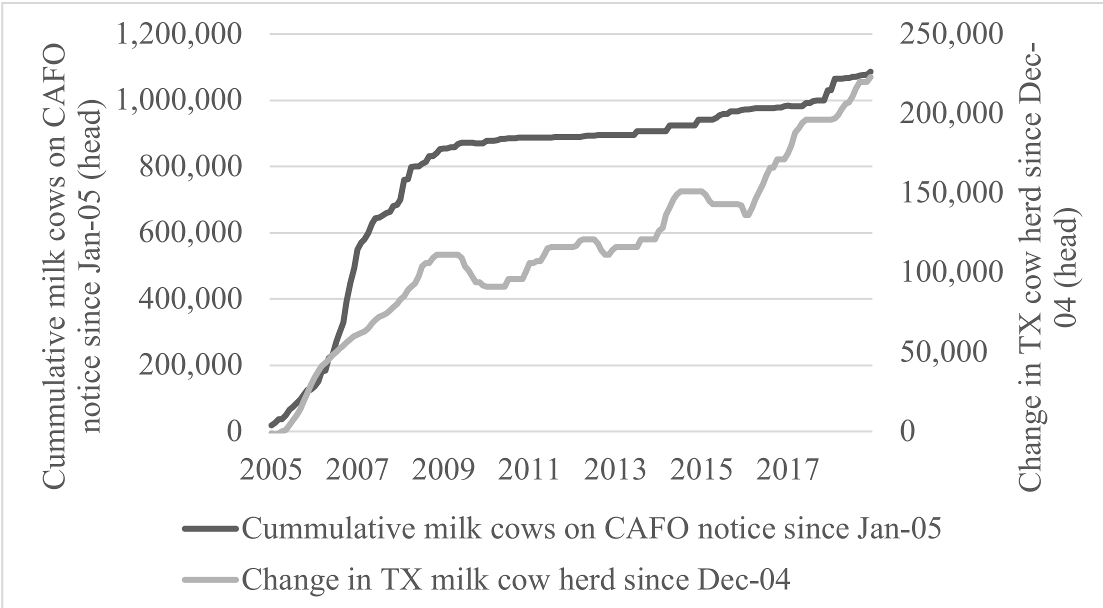
Figure 4.6 and Figure 4.7 also illustrate the relationship between the gathered monthly CAFO data and the number of milk cows in Texas according to USDA estimates. The two figures use the same data, but Figure 4.7 has a secondary axis to better show the relationship between the two measurements. The darker lines depict the cumulative values of milk cows on CAFO permit public notice since January of 2005. For example, the value for March of 2005 is the sum of total milk cows on CAFO notice from January, February, and March of 2005. The lighter line is simply the change in the Texas cow herd according to USDA since December of 2004. It is the respective month's value of milk cows less the value of milk cows from December 2004. Together these two measurements show that a major increase of dairy cows in Texas often coincided with an increase of dairy cows on CAFO permit public notice. The figures also show little growth in the Texas cow herd or even decline when cows on dairy CAFO permit public notice were more stagnant.

Figure 4.6 Cumulative CAFO Milk Cows and USDA Estimated Change in Texas Cow Herd (one axis)



Source: Author's graphic using collected CAFO data and USDA, NASS 2019b
Note: Milk cow data from March to June of 2013 is missing due to a limitation of NASS funding at the time. Those monthly data are linearly interpolated to construct figure.

Figure 4.7 Cumulative CAFO Milk Cows and USDA Estimated Change in Texas Cow Herd (two axes)



Source: Author's graphic using collected CAFO data and USDA, NASS 2019b
Note: Milk cow data from March to June of 2013 is missing due to a limitation of NASS funding at the time. Those monthly data are linearly interpolated to construct figure.

Texas experienced major growth of its dairy industry in the past 20 years. The data collected from dairy CAFO permit public notices appears to at least follow a similar growth pattern. In periods of extreme growth of the Texas cow herd, there are more proposed increases of CAFO milk cows. In periods of less growth or even decline in the Texas cow herd, there are fewer or no proposed expansions and new facilities. Similarities in the patterns of the cow herd and additions of CAFO milk cows suggest that CAFO permits could be useful in determining future periods of growth.

Chapter 5

Economic Theory and Methodology

5.1 Economic theory background

More accurate predictions of dairy cow numbers should lead to a more accurate forecast of the supply function of milk according to economic theory behind the supply curve. Economic theory suggests that supply curves can be shifted due to determinants of supply. These non-price factors include changes in productivity, the number of sellers, prices of inputs, and expectations of future prices by producers. In the case of the fluid milk supply curve, a change in productivity could be increased production per cow, which would shift the supply curve out. Increases in feed prices or other inputs would cause an inward shift of the supply curve. Similarly, an increase or decrease in the number of milk cows could cause an outward or inward shift of the supply curve, respectively. The CAFO permits used as leading indicators could help create a more accurate picture of the supply determinant that is number of milk cows.

5.2 Description of analysis variables, methods, and approach

This section introduces the variables utilized in analysis and describes their part in the modeling approach. All of the variables used in analysis are transformations of monthly values for USDA milk cows in Texas, USDA Margin Protection Program (MPP) estimation of milk margin above feed costs, and milk cows on CAFO public notice. They are used in Ordinary Least Squares (OLS) regressions to test the hypothesis that the CAFO permit variable is useful in predicting the future number of cows.

The monthly values for USDA Texas milk cows are transformed to year-over-year values. Each monthly observation is its respective value of milk cows less the value of milk cows in that month of previous year. For example, the value for January of 2008 is the number of milk cows in Texas in January of 2008 less the number of milk cows in Texas in January of 2007. This variable is transformed to year-over-year to account for the year to year change in the data and to address possible autocorrelation.

The USDA calculates a monthly milk margin above feed costs for use in its MPP. This variable was used by Bozic et al. (2012) to understand the lags between producer net income and livestock gross margin insurance for dairy cattle. This margin is used to control for determinants of supply like changes in input prices. It is transformed into a three-month moving average with the intuition that a dairy producer is more likely to change production capacity due to a three-month period of high or low prices. The three-month moving average is calculated by averaging a respective month's margin with the two preceding months. Producers' inability to react immediately to changes in the margin cause need for lags of this variable. The two lags implemented are a six-month lag and a twelve-month lag. The lags imply that Texas dairy producers might be more likely to react to the three-month average margin six months or even twelve months in the future.

Cows on CAFO permit public notice by month is the dataset described in section 4.3. In this analysis, cows on CAFO public notice are transformed into a six-month moving sum. Therefore, the value of the observation for June of 2008 includes a sum of all cows that were on CAFO public notice from January to June of 2008. The summation levels out the effects of scenarios like many public notices for large dairies going on public notice in the same month. With this transformation, the effects of one CAFO permit are smoothed out over the course of a six-month period as that one permit affects six different summation values in the dataset. This is especially necessary since facilities will not be on the same construction timeline. It may take one producer a few months to add 1,000 cows, while another producer may need one year to add those same 1,000 cows. Lag transformations are also needed for this variable. Producers cannot begin building new facilities until the permit is approved. To allow for this gap in time between cows being on CAFO public notice and appearing in the Texas milk cow herd, lags of six and twelve months are implemented in these models for the CAFO variable. The combination of the six-month moving sum and the six-month lag allows the model to react to cows that were on CAFO public notice six to twelve months ago as opposed to the current month. Table 5.1 defines and provides descriptive statistics for the variables used in analysis. The descriptive statistics for the two different lags of both the margin and CAFO variables are extremely similar due to the fact that they only differ in the value of six, monthly observations.

Table 5.1 Definitions and Descriptive Statistics of OLS Regression Analysis Variables

Variable	Definition	Units	Mean	SD	Minimum	Maximum
YOYCOWS	Year-over-year TX milk cows	Number of cows	15,656.05	16,811.82	-20,000	48,000
$MARGIN3MA_{t-6}$	Three-month moving average of MPP milk margin above feed costs lagged six months	$ / cwt of milk	8.45	2.60	2.69	14.92
$MARGIN3MA_{t-12}$	Three-month moving average of MPP milk margin above feed costs lagged twelve months	$ / cwt of milk	8.53	2.61	2.69	14.92
$CAFO6MS_{t-6}$	Six-month moving sum of cows on CAFO public notice lagged six months	Number of cows	37,548.89	58,234.74	-565	277,683.33
$CAFO6MS_{t-12}$	Six-month moving sum of cows on CAFO public notice lagged twelve months	Number of cows	39,444.24	58,297.68	-565	277,683.33

Notes: 157 observations for all variables from June 2006-June 2019

Four OLS models are used to test the hypothesis using the statistical software SAS. Their mathematical formulas are outlined below as equations 5.1, 5.2, 5.3, and 5.4. Each model is run with 157 observations from June of 2006 to June of 2019. The first observation is June of 2006 because it is the first available observation for the twelve-month lag of the six-month moving sum of CAFOs that were first collected from January of 2005. The final observation included is June of 2019 because it is the last value for the six-month lag of the six-month moving sum of CAFOs.

(5.1) $YOYCOWS_t = \alpha_0 + \alpha_1 MARGIN3MA_{t-6} + \varepsilon_0$

(5.2) $YOYCOWS_t = \beta_0 + \beta_1 MARGIN3MA_{t-6} + \beta_2 MARGIN3MA_{t-12} + \varepsilon_1$

(5.3) $YOYCOWS_t = \gamma_0 + \gamma_1 MARGIN3MA_{t-6} + \gamma_2 MARGIN3MA_{t-12} + \gamma_3 CAFO6MS_{t-6} + \varepsilon_2$

(5.4) $YOYCOWS_t = \delta_0 + \delta_1 MARGIN3MA_{t-6} + \delta_2 MARGIN3MA_{t-12} + \delta_3 CAFO6MS_{t-6} + \delta_4 CAFO6MS_{t-12} + \varepsilon_3$

This chapter described the economic theory justification for the four OLS regression models used in this thesis.

Chapter 6

Results and Discussion

6.1 Results

The results of the four OLS models are shown in Table 6.1. The Durbin-Watson test showed that the models had evidence of autocorrelated errors. Therefore, Newey-West heteroskedasticity and autocorrelation robust standard errors are calculated and used for analysis. Statistical significance of parameter estimates is consistent throughout the four models. The six-month lag of the margin variable is statistically significant at the one percent level in all models. The six-month lag of the CAFO variable is the other statistically significant variable. It is statistically significant at the five percent level in model 5.3 and the one percent level in model 5.4. The twelve-month lags of both variables are not found to be statistically significant in any models.

Table 6.1 Parameter Estimates, (Newey-West Standard Errors), and Hypotheses Test Results for Four Regression Models

Dependent: YOYCOWS	(5.1)	(5.2)	(5.3)	(5.4)
Intercept	-9,233 (8,436)	-12,120 (12,314)	-12,488 (11,551)	-13,052 (11,725)
$MARGIN3MA_{t-6}$	2,946.92*** (946.7)	2,791.14*** (903.4)	2,771.34*** (872.9)	3,005.80*** (952.9)
$MARGIN3MA_{t-12}$		492.84 (1,184.0)	296.29 (1,120.3)	197.34 (1,116.5)
$CAFO6MS_{t-6}$			.0589** (.0278)	.0834*** (.0316)
$CAFO6MS_{t-12}$				-.0378 (.0293)
Adjusted R-Squared	.203	.203	.239	.243
No. Observations	157	157	157	157

Notes: Standard errors in parenthesis
Standard errors are corrected for autocorrelation with the Newey-West method
Estimates YOYCOWS from June 2006-June 2019
*P<.10, **P<.05, ***P<.01

6.2 Discussion

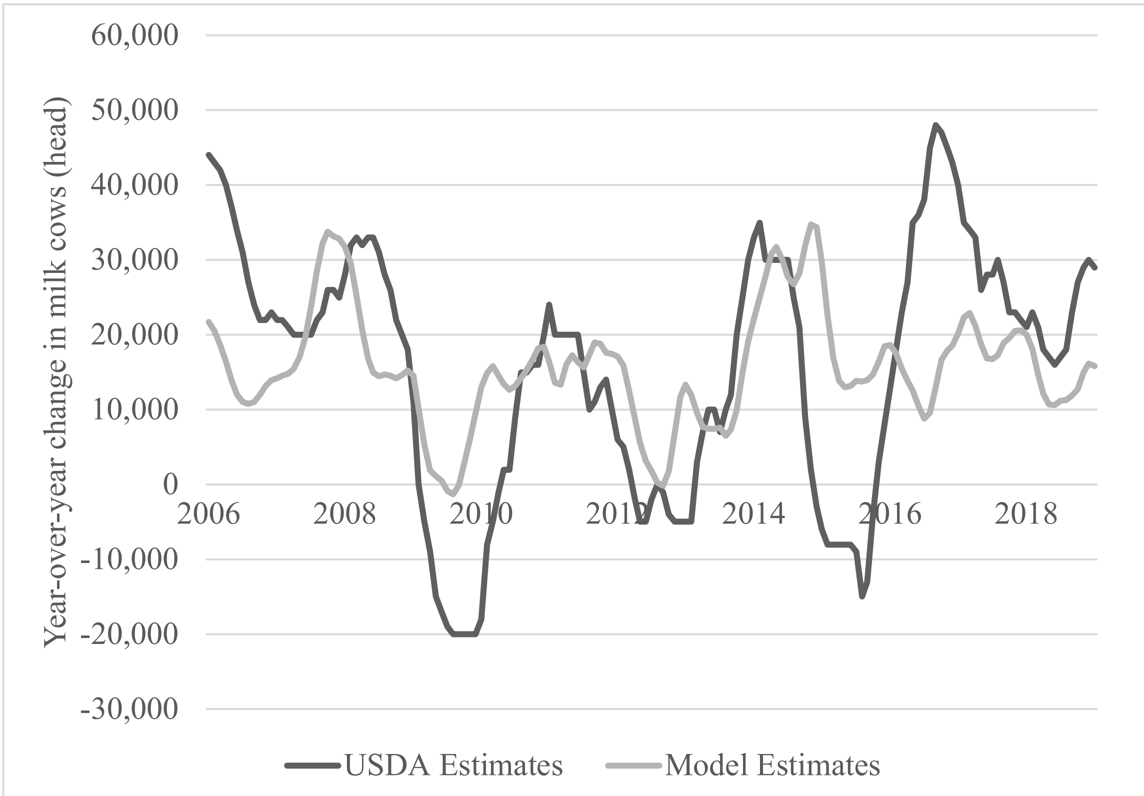
The statistical significance of the CAFO variable lagged six months suggests CAFO permits on public notice in Texas could have some predictive power in the year-over-year change of the Texas milk cow herd. The results also suggest that Texas dairy producers are reactive to milk margin above feed costs as expected. Although both variables are statistically significant, the milk margin variable arguably explains more of the variation than the CAFO variable. Using the parameter estimates from model 5.3, a one dollar per hundredweight increase in the three-month moving average of milk margin above feed costs would be expected to result in approximately a 2,771 head increase in year-over-year change in milk cows in Texas six months later, all else equal. The mean value of the same variable is expected to result in a 23,414 (8.45 × 2,772) head increase in the year-over-year change in milk cows in Texas six months later. Meanwhile, the mean value of the CAFO variable only predicts a 2,106 (37,549 × .0561) head increase in year-over-year change in milk cows in Texas. The CAFO variable does appear to add some predictive power. However, the economic significance of its addition to the model is not as powerful as milk margin above feed costs.

Another takeaway from this modeling approach is that producers in Texas appear to respond in a six-month period of time. This is shown by the significance of parameter estimates with a six-month lag and the lack thereof with parameters lagged twelve months. A relatively quick response to the margin and after CAFO application is not surprising in a state like Texas that requires less of its facilities compared to states with more variable climates.

One problem with this model is that it does not reach the lowest year-over-year changes in milk cows. It is much better at estimating increases in the milk cow herd than declines. Figure 6.1 depicts this with a graph of estimated year-over-year values of milk cows from model 5.3 versus USDA estimates. The parameter estimates are all positive, and variables are positive in almost every observation. The only negative values for variables result from the rare occasion of a negative CAFO permit as discussed in section

4.2. These factors make it difficult for the model to estimate year-over-year declines in cows. Possible models to help fix this problem are discussed in the last chapter.

Figure 6.1 Model Estimates Versus USDA Estimates for Year-Over-Year Change in Texas Milk Cows



Chapter 7

Summary and Implications

7.1 Implications

This research suggests that CAFO permits on public notice do have some predictive power about the Texas milk cow herd six to twelve months into the future. Yet, the economic significance of its abilities cannot match that of milk margin above feed costs. This is intuitive since producers are sensitive to the current price of milk and the feed inputs used to produce that milk. The CAFO permits could be implemented into forecasting methods. However, their added value compared to their added cost required to gather notices and construct a dataset would need to be evaluated. Models and methodology of implementing CAFO permits into forecasts would also need to be state specific. Differences in the permitting process and public notices from state to state require individualized assumptions to create datasets. Some states are also more accepting of large CAFO permit facilities than others. These differences in the dataset construction and overall state approach to CAFO permits would require that models be created unique to each state.

7.2 Limitations of this research

The main limitations of this research stem from the ambiguities of constructing a data set from public notices. In Texas, public notices are the most complete and publicly accessible form of documentation on CAFO permit capacities. However, their intent is to inform the public of what could or will be happening at a CAFO facility as opposed to current or historical information. For this reason, many CAFO public notices do not provide adequate information to determine the precise change in capacity by animal type for which a facility has applied.

There are two scenarios when this issue is the most common. Public notices usually do not specify if applications for first time CAFOs are for new or existing facilities. Even if the notice does specify new or existing facility, it still does not state the current capacity of an existing facility. Missing information on current capacity for these new permits inhibits a precise calculation of intended change in milk cow head. The second scenario occurs when existing CAFOs are applying for expansions. Public notices for expansions typically state the current animal capacity and the requested capacity broken down by animal type. For example, "applying to expand an existing dairy facility from 3,000 head to a maximum of 4,000 head of which 3,000 head are milking cows" could be the statement on a public notice. In this scenario, it also is not possible to conclude how many milk cows a facility intends to add to its herd.

Furthermore, farmer behavior impacts the accuracy of this dataset. Facilities that apply for these permits may not add any additional cows or may only add a fraction of what they originally intended. Timelines of expansions and construction also vary amongst applicants. Moreover, communication with Charles Schneider of the CAFO team at TCEQ revealed that farmers have been known to apply for a capacity far above their current plans with the mentality that it will make the process simpler if they decide to expand more in the future.

One other aspect this dataset is incapable of capturing is expansion of facilities under the CAFO threshold and dairy cows leaving the Texas herd as farms go out of business. Public notices are not generated for CAFOs selling cows. Likewise, this methodology does not track farms under the CAFO threshold. In a state such as Texas with a larger average farm size this may be less significant because only about 13% of all milk cows in Texas reside on a farm with less than 1,000 cows.

A more accurate and conclusive dataset could be constructed with the same collection process if public notices contained more information. The addition of current capacity of milk cows and proposed capacity of milk cows on every CAFO public notice would provide enough information to determine the intended increase of milk cows for a facility. With this information, the reader would be able to conclude if a facility is increasing from 0 to 1,000 milk cows or 2,000 to 5,000 milk cows. This information should already be available to the permitting authority or easily attained through contact with the permittee. Limitations due to farmer behavior and CAFO regulations would not be cured with this change, but that cannot be expected of a permitting process with a purpose of protecting water quality. The CAFO public notices have the potential to accurately reflect the intentions of facilities to build and expand by only slightly altering the way in which a public notice is written. Accurate information on farmers' capacity intents would be a practical expectation of a figure to extract from the CAFO permitting process. Farmers' intents to add cows would also be a new addition to current statistics on dairy farms. The state and federal regulatory process generally invites public comments while the regulation is being studied in its draft form. The CAFO permitting process is periodically renewed and comments regarding this type of data could be submitted for greater clarification in the permits.

As discussed in the second chapter, an initial attempt was made to collect data from other states in the manner in which was done for Texas. The limitations discovered during this process led to focusing on one state for this initial project. These limitations included lack of publicly available historical data, inabilities to calculate change in head from animal capacity data provided, and other accessibility and interpretation problems. Further attempts to do this on a state-by-state basis should develop a flowchart for each state similar to Figure 4.3. Then an interview should be done with an individual responsible in that state for CAFO data to understand the CAFO process fundamental to interpreting and collecting permit data. This process would establish confidence in the data and allow its use as a possible indicator.

Another limitation of this research is the omission of variables that would likely have explanatory power. These variables were omitted from the model because of a lack of datasets to represent them. Milk processing capacity and weather would be two of these variables. Milk processing capacity in Texas could have added explanatory power to the models as farmers and processors work through expansions together to maximize plant capacity. Processing capacity data could be especially powerful in Texas over the time period when Hilmar Cheese and Southwest Cheese were building and expanding. The model is also missing weather incidents that affected the state herd size like the snow blizzard that killed over 35,000 cows. This model is limited by the omission of variables such as these, but they are omitted because data on these factors is difficult to quantify.

Timing and impact of weather incidents are difficult to estimate, and processing capacity data is typically kept private by companies.

7.3 Suggestions for future research

A modeling approach that allows for more predictive power in periods of milk cow decline would be desirable. The CAFO permit public notices are not designed to inform about milk cow or dairy farm exits. They can give some sign of stagnant periods of time with no new permit applications. However, the addition of a variable that allows for decline in milk cows could be helpful. One idea for this would be the addition of a variable for the total dairy farm net income. The minimum value for milk margin above feed cost is positive. Farm net income would take on negative values at times and better allow the model with positive parameter estimates to predict declines in the number of milk cows. This research did attempt to do this with quarterly values of net income per cow for Texas dairy farms, but the results were not reported because the degrees of freedom was substantially lower with only quarterly values. An addition of a variable like this is probably even more important when looking at expanding this model to include other states that have not been in as steady of growth periods as Texas.

It would also be interesting to evaluate the predictive power of CAFO permits in a cross-sectional model including the top dairy states. Texas was selected for this research because it was thought to be one of the best states for a model like this to work. A cross-sectional model with top dairy states would give insight into just how valuable CAFO permits could be in the broader U.S. dairy industry.

The data collected in this research used a process of manually collecting permits from different websites over time. Such a process is tedious but extremely valuable in understanding where the data comes from and how it is collected. A better process for future data collection would be to use web scraping or web harvesting methods from websites' hypertext markup language. Web scraping software would allow the computer to collect CAFO data from these permitting websites to construct a database. This may work better in some states than others due to the variability in content and format of public notices. While other state public notices for CAFO permits were being collected for this research, it was learned that the differences that exist across state permitting processes require not only different collection methods but different assumptions when building a dataset. Each state used would need to be evaluated separately to ensure the assumptions are most logical for its rules and processes.

This research shows major dairy growth in Texas through USDA cow estimates and even larger intents to build and expand from the CAFO permit data. The lower cost environment in Texas due to labor availability, less costly facilities, and further lower input prices compared to many other states is assumed to play a big role in the boom in the Texas dairy industry. This suggests the hypothesis that cows are moving to areas where dairy farms can survive with lower milk prices. Research to test this hypothesis could be a valuable addition to milk forecasting literature by aiding predictions of the geographical movement of cows throughout the U.S. in a similar way to this CAFO research.

7.4 Summary

This thesis was a discussion of the predictive power of CAFO permits in the Texas dairy industry over the last thirteen years. The results suggest that there is statistical significance to including a CAFO permit variable in a model of Texas milk cows. The economic significance of CAFO permits in a forecasting model and feasibility of implementation are less certain. Nevertheless, it is the first known research to construct a dataset from individual CAFO permits, and the results imply that there could be value in continuing research of this kind. There is evidence from this research that CAFO permits could have value in forecasting models in the future, especially in time periods of dairy industry growth.

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