Colegio de Postgraduados

Milking to 2030: economic and sustainability prospective of the Mexican dairy sector

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ABSTRACT

Objective: This study aims to assess the productive and economic performance of the Mexican milk sector, particularly focusing on small and medium-scale dairy farms, and examining pessimistic, base, and optimistic scenarios.

Design/methodology/approach: Employing a statistical univariate method with time series analysis (ARIMA), we analyzed productive efficiency and price behavior in Mexican dairy systems. Deterministic and stochastic estimations for production volume, milk price, and cattle inventory from 2021 to 2030 were established using confidence intervals to construct pessimistic (lower interval), base (mean), and optimistic (upper interval) scenarios.

Results: The evaluated period witnessed an estimated 10.27% increase in production, equivalent to 576 million liters of milk, with an average annual growth rate of 1.0922%. Milk prices displayed an upward trend, with average prices of \$0.66, \$0.69, and \$0.72 under pessimistic, base, and optimistic scenarios, respectively. In 2030, a 22% price increase compared to 2021 was observed. Considering a base price of \$0.45 USD per liter in 2030, costs under pessimistic, base, and optimistic scenarios were \$1,658.21, \$1,756.43, and \$1,855.31, resulting in profits of \$1,160.75, \$1,229.50, and \$1,022.45 from milk sales. Cattle inventory exhibited an upward trend, paralleling milk volumes and prices.

Limitations on study/implications: The study's use of a univariate method may incompletely capture market dynamics complexity, potentially underestimating the impact of external market forces and global economic conditions on milk prices.

Findings/conclusions: To secure forecasted milk volumes in base and optimistic scenarios, maintaining and enhancing good management practices is crucial. Additionally, addressing the imperative to augment production efficiency and improve environmental sustainability and animal welfare is essential.

Keywords: Deterministic and stochastic; Productivity; ARIMA; Livestock.

Image by Wolfgang Ehrecke at Pixabay

INTRODUCTION

In 2016, highlighted the importance of small-scale agricultural and livestock systems in Latin America which contributed with between 50% and 80% of the total consumed products (FAO, 2016). Small-scale farms accounted for 80% of the inventory, generating 30% to 40% of the total Agricultural Gross Domestic Product (GDP). Such activities are based on low input levels and reduced production levels (FAO, 2022). However, with tools such as breeding, genetic improvement, animal health, milking hygiene, nutrition, animal welfare, and an effective socio-economic management, the outlook could be promising.

In Mexico, the dairy cattle population is distributed as follows: 85% belong to semi-intensive household systems, 12% to tropical systems, and 3% to intensive systems (INEGI, 2018; Loera and Banda, 2019).

The main factors that have an impact in milk production and the development of dairy cattle replacements are genetics, environmental conditions, management (Espinoza, 2012), and feeding strategies (Sainz-Ramírez *et al.*, 2021a). Additionally, dairy farms are exposed to a variety of risks stemming from a limited knowledge in disease prevention, management, and control. Such risks could reduce not only milk yields, but also fertility and the longevity of dairy cows. For example, reports worldwide losses from mastitis amounting to more than 40 billion USD per year (Azooz *et al.*, 2020). Since the latter health problem affects the mammary gland, a significant decrease in production is expected with and impact in milk quality, animal welfare, livestock performance, milk disposal, and antimicrobial use in the production unit, which increase operation costs (Neculai-Valeanu and Ariton, 2022). A complex panorama is also expected for dairy systems when considering global factors such as climate change and stricter environmental policies, resulting in a reduction of grains and forages that could affect the capacity to sustain livestock production (Sánchez *et al.*, 2020) and supply chains.

While (OECD/FAO, 2021) indicates that agricultural production will decrease in the next decade compared to the current one (1.4% per year *vs.* 1.7% before), the main increase in agricultural, livestock, and fishery products will stem from low and middle-income countries, driven by an increase in productivity, investment in agricultural infrastructure, research, and development. In this sense, it is essential to identify the elements of the productive and economic structures that could allow the evaluation, within a planning horizon, of the performance and productive efficiency reflected in economic improvements of the involved systems. Therefore, the objective of this study was to determine the productive and economic performance of the milk sector in Mexico, with an emphasis on small and medium-scale dairy farms and considering a pessimistic, base, and optimistic scenarios.

MATERIALS AND METHODS

The study aimed to analyze the productive and economic aspects of the Mexican milk production system from 2022 to 2030, focusing on variables such as production volume, fluid milk price, and dairy cattle inventory. To achieve this, a univariate time series model, specifically Autoregressive Integrated Moving Average (ARIMA), was employed.

The ARIMA models consisted of autoregressive (AR) and moving average (MA) components, integrating an order of differentiation (d) to ensure stationarity (Kirchgassner, 2007). Stationarity, crucial for the Box-Jenkins methodology (Box *et al.*, 2015), was tested using the Dickey-Fuller (D-F) test: H: Yt∼I(1); H1: Yt∼I(0) (Dickey and Fuller, 1979).

The interactive Box-Jenkins method was then applied to estimate deterministic univariate time series (Box *et al.*, 2015).

In detail, the AR component captured the autoregressive behavior of the time series, while the MA component modeled the moving average. The order of differentiation referred to the transformation needed to make the original time series stationary.

Stationary processes, indicating relatively constant mean and variance, were fundamental for developing ARIMA models. The D-F test confirmed stationarity, allowing for trend estimation and model fitting.

The risk simulation process involved determining 12 types of distributions for data, with subsequent fitting of the best-suited distributions for production volume, dairy cattle inventory, and fluid milk price. Normal distributions were employed for the former two, while a geometric distribution was used for the latter.

Forecasted production volume and price series were simulated using normal and geometric distributions, respectively. Regression models were developed, considering factors such as lags and information criteria for model selection.

Economic analysis focused on fluid milk prices for the entire country from 2022 to 2030, utilizing SIACON-NR (2022) data. Risk factors were determined by establishing confidence intervals from the minimum and maximum series values, constructing pessimistic, base, and optimistic scenarios.

Monetary values were expressed in US Dollars ($USD) using an exchange rate of 1 USD: 19.8030 Mexican Pesos (MXN) as of December 7, 2022. The study included small and medium-scale dairy farms, representing 85% of the dairy cattle inventory and embodying the semi-intensive milk production system in Mexico.

The impact of scenarios on income and profit was calculated, considering the average price paid to the producer as gross income and deducting 70% of total costs, as suggested by relevant literature (Martínez-García *et al.*, 2015; Posadas-Domínguez *et al.*, 2014; Posadas-Domínguez *et al.*, 2018).

Additionally, calculations were performed to determine milk volumes per production unit, per cow per year, and per cow per day, assuming a lactation length of 305 days. This comprehensive approach aimed to provide a robust analysis of the economic and production dynamics within the Mexican milk sector.

RESULTS AND DISCUSSION

The deterministic forecast for 2030 milk volume, represented by the model P_t=94,291.30+0.213 $P_{(t-1)}$+0.051 $P_{(t-2)}$, indicated a clear increasing trend. Figure 1 illustrates the behavior of milk production up to 2030, projecting a 10.27% increase from 2021, equivalent to 1,154 million liters. The average annual growth rate was 1.0922%, with volumes for pessimistic, base, and optimistic scenarios at 11,701, 12,394, and 13,091 million liters, respectively.

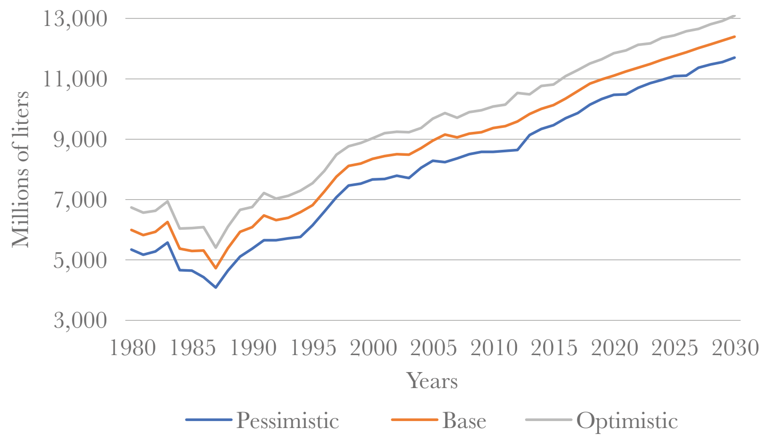

Figure 1. Evolution of the volume of milk produced from 1980 to 2030.

The dairy cattle inventory forecast for 2030, modeled as P_t=27,345.724+0.122 $P_{(t-1)}$+0.164 $P_{(t-2)}$, is depicted in Figure 2. In 2021, the inventory was 2,798,370 cows, producing 3,744; 4,017; and 4,268 liters per cow per year for pessimistic, base, and optimistic scenarios. The estimated inventory in 2030 was 3,142,872 cows, with respective yields of 3,723, 3,944, and 4,166 liters, translating to 12.21, 12.93, and 13.66 liters of milk per cow per day.

The deterministic forecast for 2030 fluid milk price, expressed by P_t=0.082+0.195 $P_{(t-1)}$+0.003 $P_{(t-2)}$+0.230 $P_{(t-3)}$, demonstrated an overall increasing trend (Figure 3). Average prices per liter in pessimistic, base, and optimistic scenarios were \$0.41 USD, \$0.45 USD, and \$0.48 USD, respectively. A forecasted 22% price increase in 2030 compared to 2021 resulted in projected revenues per cow per year of \$1,658.21 USD, \$1,756.43 USD, and \$1,855.31 USD for pessimistic, base, and optimistic scenarios, respectively. Corresponding profit from milk sales and net income varied accordingly.

When considering a base price of \$0.45 USD in 2030, the expected revenues were estimated in \$1,658.21 USD, \$1,756.43 USD, and \$1,855.31 USD per cow per year, under

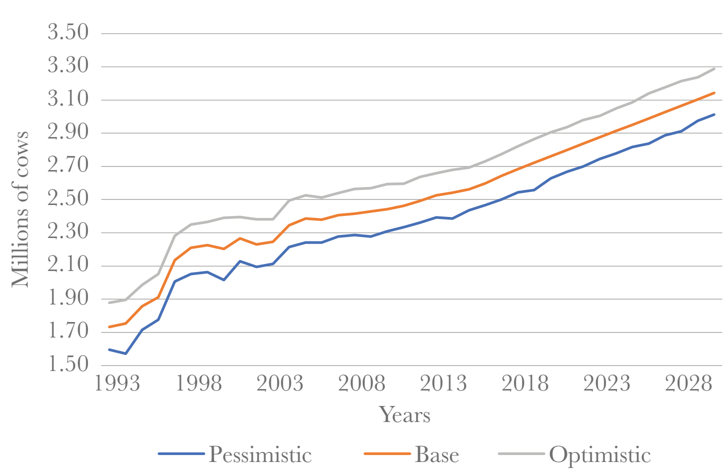

Figure 2. Evolution of the dairy cattle inventory from 1993 to 2030.

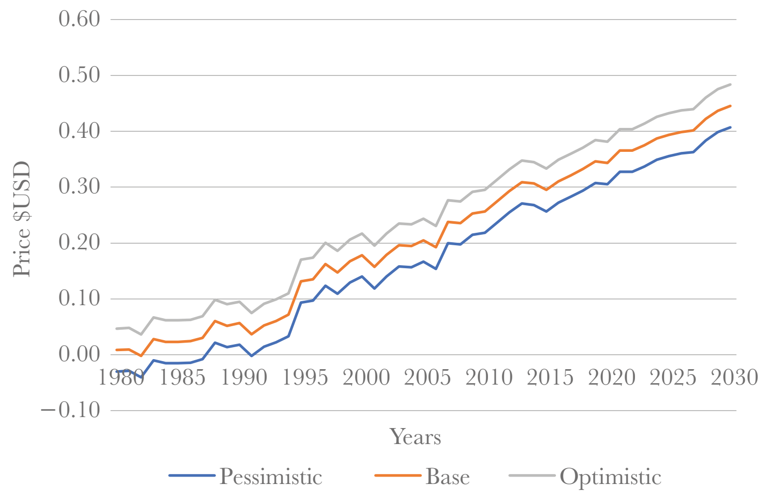

Figure 3. Evolution of price per liter of fluid milk from 1980 to 2030.

the pessimistic, base, and optimistic scenarios, respectively, with a profit from milk sales of $1,160.75 USD, $1,229.50 USD, and $1,298.71 USD, and a net income of $497.46 USD, $526.93 USD, and $556.59 USD, for the respective scenarios.

Milk production in developing regions exhibits significant variability due to diverse infrastructures, technologies, and environmental conditions, with Central America showing lower milk yields per cow compared to North America and Western Europe (FAO/GDP, 2019). While the study projects an increase in production levels in Mexico, aligning with trends in developing countries, this growth is attributed to larger herd sizes rather than improved productivity (OECD/FAO, 2022; Britt *et al.*, 2018). The projected surge in global population emphasizes the importance of enhancing milk production efficiency, considering that dairy farming requires less land for protein production compared to other livestock and agricultural systems.

Dairy farming in Mexico faces challenges like limited access to resources and increasing demand for animal products, operating under diverse environmental conditions (Bennett *et al.*, 2022). A comprehensive evaluation of resource availability is crucial for sustainable dairy production (Bosire *et al.*, 2019). Strategies involving breeding, superior animal selection, and improved farm management are essential for efficiency improvements (Hayes *et al.*, 2013). However, Mexico's current focus on external phenotypic characteristics in cattle selection neglects genetic trend estimations, raising concerns about genetic dependence on foreign material (Domínguez *et al.*, 2003; Toledo *et al.*, 2014).

Small and medium-scale herds in Mexico, predominantly Holstein, may benefit from evaluating alternative genotypes like Jersey for better adaptation to diverse conditions (Larios-Sarabia *et al.*, 2020). However, a declining trend in genetic progress for certain breeds, as identified in previous studies, highlights the importance of restructuring national genetic improvement programs (Boichard *et al.*, 2015; Larios-Sarabia *et al.*, 2020). While global dairy systems move towards specialization and mechanization, this study emphasizes the need to balance resilience and efficiency, considering climatic factors (Cole *et al.*, 2020).

Nutritional management significantly influences milk production, with efficient practices and technologies improving productivity (Hazard, 2004). However, grazing systems, predominant in small-scale herds, pose challenges in effective health control and technology incorporation (Sainz-Ramírez *et al.*, 2021b; Moscovici *et al.*, 2021). Addressing these challenges, along with focusing on environmental sustainability and efficient resource use, is essential for the future of dairy farming in Mexico (Medeiros *et al.*, 2022).

The discussion emphasizes the role of genetics, feeding practices, and management improvements in addressing the uncertainties faced by dairy farmers, such as low milk prices and restricted access to resources (Maltz, 2020). Despite the trend of larger, more efficient farms globally, this phenomenon doesn't necessarily apply to small-scale Mexican dairy farms (Posadas-Domínguez *et al.*, 2014).

Strategies to address challenges include incorporating advancements in breeding, nutrition, and management practices, focusing on disease prevention and improving calf raising facilities (Roland *et al.*, 2016). While milk quality regulations exist, further enhancements in chemical components through feeding strategies must be balanced with economic considerations (Sainz-Ramírez *et al.*, 2021a; Posadas-Domínguez *et al.*, 2018).

The discussion delves into the complexities of the dairy sector in Mexico, considering factors like trade liberalization, price volatility, and environmental impact (Ángeles *et al.*, 2004). The cyclical nature of milk production and its correlation with variables like feed prices and world trade variations highlight challenges for small-scale dairy farms in a globalized market (Navarrete-Molina *et al.*, 2019).

Addressing water scarcity emerges as a critical factor for sustainable dairy farming, suggesting strategies like raising replacements and growing feed inputs in less arid regions (FAO, 2022). The impact of urban growth on rural areas and migration trends among younger generations underscores the need for comprehensive strategies that involve the small and medium-scale dairy sector in shaping the future (Bullock and Crane, 2021; Moreno-Ramos, 2021; Ruiz-Torres *et al.*, 2017).

In conclusion, the projected upward trend in production volume and estimated prices for the semi-intensive milk production system in Mexico necessitates a focus on efficiency improvements, sustainable practices, and strategic planning for the challenges posed by global trends and local conditions. The citations provide a robust foundation for the discussed insights

CONCLUSIONS

The applied methodology estimates milk volume, price, and dairy cattle inventory behavior until 2030, utilizing historical data. Ensuring forecasted milk volumes requires maintaining good practices, enhancing production efficiency, and improving sustainability and animal welfare. Strategies such as implementing milk quality-based pricing, exploring flexible financing for producers, and state investments can mitigate price risks. While reducing dairy cattle inventory seems risky, this study suggests it's feasible in an optimistic scenario without compromising production volumes, challenging conventional strategies in Mexico's fluid milk deficit.

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