ECONOMIC AND FINANCIAL PERFORMANCE OF REPRESENTATIVE SMALL SCALE DAIRY PRODUCTION UNITS TO 2027 †

[DESEMPEÑO ECONÓMICO Y FINANCIERO DE UNIDADES REPRESENTATIVAS DE PRODUCCIÓN DE LECHE EN PEQUEÑA ESCALA HASTA 2027]

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SUMMARY

Background: Small-scale dairy systems are vital in rural communities and strategic for livelihoods an economic development. **Objective:** To estimate the economic and financial viability of small-scale dairy Representative Production Units (RPU) in the high plateau of the State of Mexico using a Monte Carlo simulation. **Methodology:** Net yields were estimated for a 5-year planning horizon via simulated values for the distribution of input and product processes, establishing 2022 as the base scenario. A stochastic modelling approach was used to determine the economic and financial outlook considering the cost of two sources of labor for the simulations: (1) Cost of family labor (FL); and (2) Cost of external hired labor (EL). **Results**: A panorama of economic viability was evidenced. However, a lack of financial wellbeing was also determined. When FL was factored in, net income was estimated in $17.99 thousand USD in 2023 and $26.35 thousand USD in 2027. On the other hand, considering EL resulted in a net income of $9.88 thousand USD in 2023 and $16.31 USD in 2027. The Net Present Value in 2027 was calculated at $-161.84 thousand USD and $-191.27 thousand USD, with FL and EL, respectively. While the RPUs were determined to be competitive, the level of risk was significant due to the high monetary value, limited degree of specialization of the RPUs, and the prevailing volatile scenario at the time. **Implications:** This study can enable decision-makers, on one hand, to analyze and design policies and differentiated strategies for small-scale dairy production systems. On the other hand, it can empower dairy farmers to assess scenarios of technical and productive intervention. **Conclusions:** The financial and economic weakening of the studied RPU could have negative implications in terms of public policy, labor, marketing, value chains, and the persistence of producers in such activity.
Key words: Planning horizon; Stochastic model; Livestock; Monte Carlo Simulation.

RESUMEN

Antecedentes: La lechería de pequeña escala es importante en las comunidades rurales y son elemento clave para la vida y desarrollo económico. **Objetivo**: Estimar la viabilidad económica y financiera de Unidades de Producción Representativas (UPR) conformadas por granjas lecheras de pequeña escala ubicadas en el altiplano del Estado de México, mediante el modelo de simulación Monte Carlo. **Metodología**: Se estimaron los rendimientos netos en un horizonte de planeación de 5 años a través de valores simulados para la distribución de insumos y procesos de producto, estableciendo como escenario base el año 2022. Se utilizó un enfoque de modelación estocástica para determinar las

† *Submitted September 21, 2023 – Accepted March 10, 2024. http://doi.org/10.56369/tsaes.5174*

ISSN: 1870-0462.
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perspectivas económicas y financieras considerando el costo de dos fuentes de mano de obra para las simulaciones: (1) Costo de la mano de obra familiar (FL); y (2) Costo de la mano de obra externa contratada (EL). **Resultados:** El panorama de viabilidad económica fue favorable. Sin embargo, también se evidenció una falta de bienestar financiero. Al considerar la FL, los ingresos netos se estimaron en $17.99 mil USD en 2023 y $26.35 mil USD en 2027. Por otro lado, al considerar EL se obtuvo un ingreso neto de $9.88 mil USD en 2023 y $16.31 mil USD en 2027. El Valor Actual Neto en 2027 se calculó en $-161.84 miles USD y $-191.27 miles USD, con FL y EL, respectivamente. Si bien se determinó que los RPU eran competitivos, el nivel de riesgo era significativo debido al alto valor monetario, el grado limitado de especialización de los RPU y el escenario volátil prevaleciente en ese momento. **Implicaciones**: El presente estudio permite, por un lado, a los tomadores de decisiones analizar y diseñar políticas y estrategias diferenciadas para los sistemas de producción de leche, y por el otro lado, permite a los productores evaluar escenarios de intervención técnica y productiva. **Conclusiones:** El debilitamiento de estas UPR tienen implicaciones negativas en términos de política pública, mano de obra, comercialización, cadenas de valor y la permanencia de los productores en la actividad.
Palabras clave: Horizonte de planificación; Modelo estocástico; Ganadería; Simulación Monte Carlo.

INTRODUCTION

The Mexican Network for Research in Agriculture and Food Policy (Agroprospecta) was established in 2008 with the primary aim of producing objective and timely economic analyses of public policies pertaining to Mexico. At that time, it was conceived as a tailored instrument designed to facilitate decision-making both for researchers and producers (UACH, 2010). However, the project ceased operations after a few years. Mexico, despite having a deficit in fluid milk production, yielded 13,110,518.22 thousand liters of milk in 2022. With a difference of less than 21,765.02 thousand liters in the projected volume for the year and country, and considering an average price of $0.50 USD per liter, a total of $10,883,237.55 USD fell short of the initial forecast. Various methodologies have been used to include risk into studies related with dairy farming. For example, Newton *et al*., (2015) used farm-level data to evaluate decisions and aggregate policy costs across different risk scenarios and policy design alternatives. Their findings suggest that premium rates could lead to budget outlays significantly exceeding those for comparable variable-rate insurance, subsidized at levels similar to revenue-based crop insurance policies. In the absence of adjusted gross income or production eligibility constraints, a considerable portion of benefits might accumulate among a minority of large-scale dairy farms.

The productivity of dairy cows can be influenced by various factors, including diseases (Azooz *et al*., 2020; Neculai and Ariton, 2022), increasing input costs (Posadas-Domínguez *et al.,* 2016, Posadas-Domínguez *et al*., 2018), nutrition, feeding strategies (Saínz-Ramírez *et al.,* 2021), and social factors such as generational transition (White, 2012; Salinas-Martínez *et al*. 2012) and social well-being (Santos-Barrios *et al.* 2019). However, it is always anticipated to meet or exceed planned objectives, without falling short of them.

In 2016, FAO highlighted the significance of agro-livestock farming systems in Latin America, which contributed between 50% and 80% of the total consumed products. These systems accounted for 80% of the inventory and generated around 30% to 40% of the total agricultural Gross Domestic Product (GDP). Small-scale dairy farms typically operate with limited inputs and reduced production levels (FAO, 2022). However, through strategies such as breeding, genetic improvement, animal health measures, and effective socio-economic management, there is potential for a different outlook. All agricultural systems are susceptible to various risk factors (Richardson, 2000). In the context of small-scale dairy farms, these risks include factors such as scale (Romo *et al*., 2014), technical factors (Montiel-Olguín *et al*., 2019a; 2019b), their role as a source of liquid income and a means for poverty reduction (Ruíz-Torres *et al*., 2021), strengthening of local markets, reliance on government economic support, use of agricultural by-products (Cortés-Fernández *et al*., 2023), and a source of family and hired labor (Ruíz-Torres *et al*., 2022).

Food production in Latin America predominantly depends on small-scale farms (FAO, 2022). However, approximately 30% of these farms successfully transition to a second generation, while only 10% to 15% reach a third generation (Camacho and Vega, 2023). In developing countries, the livestock sector comprises nearly 1 billion small-scale production units, contributing approximately 40% to the agricultural GDP and accounting for between 2% and 33% of household income.

Bovine production holds a total multiplier of 2.90, indicating that for every million USD earned within the sector, an economic spill of $1.9 million USD is expected in the rest of the Mexican economy. In this regard, the milk industry holds a political and strategic position as an independent sector (Sosa *et.al.* 2017) emphasizing the importance of assessing the application of support and transfers to the dairy industry. Stochastic modeling of agricultural systems serves as a tool to evaluate various risk factors and their potential effects on the future economic performance, financial viability, and sustainability of these systems (Jonasson *et al.* 2014). In 2010, Agroprospecta provided a comprehensive overview of dairy farms within a planning scenario extending from 2008 to 2018. The study included farms from diverse regions across the country, involving various production scales ranging from 20 to 2000 cows. The report by Agroprospecta unveiled a challenging landscape, indicating an unfavorable outlook by 2018 for 7 out of the 19 representative production units evaluated. Greater attention should be paid to environmental factors in efficiency analysis (Dios-Palomares *et al*., 2015). Zavala-Pineda *et al.* (2012), applied both Monte Carlo simulations and econometric models to assess the long-term economic viability of Mexican pig farms by comparing four scenarios: A base scenario; a hiring-in labor scenario; a purchased inputs scenario; and a zero subsidies scenario. Similarly, Posadas-Dominguez *et al*. (2016) evaluated the economic and financial viability of small-scale dairy farms in central Mexico. Callejas and Rebollar (2020) conducted an evaluation of competitiveness, profitability, and risk analysis in the cow-calf production system. Despite differences in methodology and production scale, their study emphasizes the importance of conducting a prospective analysis that extends beyond the economic, financial, and political spheres, to include the identification of improvement options and corrective measures based on the productive and technical activities within farms.

Posadas-Domínguez *et al*. (2016) highlight the strength of small-scale dairy systems, which rely on family labor, self-produced resources, and inputs for production. Furthermore, they suggest a promising economic and financial outlook even in the absence of government support.

To date, there has been limited focus on the economic and financial viability of small-scale dairy systems in Mexico, and the scientific literature on this subject is scarce. However, there are some international studies available primarily focused on intensive milk production. Therefore, the objective of this study was to evaluate the economic and financial performance of Representative Production Units (RPUs), consisting of small-scale dairy farms with an average herd size of 15 cows in the high plateau of Central Mexico, over the planning horizon of 2023-2027. It is proposed that there is no difference in the economic and financial viability resulting from the utilization of family labor in small-scale milk production systems over a planning horizon of five years.

MATERIALS AND METHODS

Description of the Representative Production Units (RPUs)

The RPUs included in this study were located in the municipality of Aculco in the State of Mexico. The analyzed locality was: El Tixhiñú (99° 52' 31'' W and 20° 06'54'' N), at an altitude of 2,400 meters, with average annual rainfall of 700 to 1,000 mm and an average annual temperature of 14ºC (INEGI, 2018). Aculco has gained reputation for its milk production, along with other dairy products such as cheese and yogurt.

Figure 1. Location of the municipality of Aculco in the State of Mexico.

The RPU was constructed using a panel technique (Miller and Salkind, 2002). It consisted of average herds of 15 milking cows, representing 30 farmers in the study area. The panel comprised six farmers, along with two experts specializing in agricultural economics and animal science, and a representative from the local dairy farmers' association.

The herds were primarily Holstein, with a production level of 3,760.81 l per cow per year. These herds contributed with 10.77% of the annual milk production in the State of Mexico (SADER, 2021). The average rural price in 2022 per liter of milk was $0.44 USD. Farms had an average of 9 lactating cows with two milkings per day, 4 heifers and 2 calves. The RPUs mainly cultivate corn and forage crops using both irrigation and rainfed methods. Government subsidies such as PROCAMPO offer an annual subsidy of $72.63 USD per hectare.

In the RPU, the labor force is predominantly family-based, investing 4,380 ± 230.85 hours per year in both the herd and the irrigation and rainfed crops, receiving a fixed wage of $8.90 ± 2.70 USD per day of work. Additional periodic labor is hired for 4 days at a rate of $19.55 USD per day (in all cases). All economic and financial data were sourced directly from the assessed farm's accounting records.

The model

A stochastic simulation approach was used to evaluate the economic and financial viability, incorporating probability distributions as described by Zavala-Pineda *et al*. (2012) and Posadas-Domínguez *et al*. (2016). Historical data for the probability distributions were sourced from SIACON (2022), spanning a period of 42 years, from 1980 to 2022. The national macroeconomic sub-model drew data from the official Mexican Government information, while the macroeconomic international variables were sourced from the IMF and USDA. The model projected the economic and financial viability of the RPUs, providing insight into the trends of macroeconomic variables. To reduce estimation errors, trends in regional variables were estimated for the period 2023-2027. The model operates on an annual basis at a strategic level, generating pro-forma reports that include essential data for estimating key output, variables including net cash income, final cash reserves, change in net real capital, Net Present Value (NPV), and Rate of Return over Assets (RRA). The financial reports are generated through functional equations that establish the links between milk production, sales, input production, input purchase, capital operations, consumption, and financing activities. These reports support decision-making at both farm and policy levels.

Per Richardson et al. (2000), empirical multivariate probability distributions (MVE) were established for each variable within the analyzed RPU. Historical data from the past ten years allowed the estimation of MVEs. Subsequently, the MVEs were employed to simulate stochastic projections for the next five years, utilizing 500 iterations with the software applied by Richardson (2008). The mathematical expression of the model was: $\tilde{Y} = \bar{x} + SD*SND$. Where: $\tilde{Y}$= net income, $\bar{x}$= mean, SD= standard deviation, and SND= normal standard deviation.

The model was validated via 500 iterations, searching stochastic confidence intervals for net income to account for future risk. Figure 2 shows a simulation of the net income as percentiles measuring risk relative to mean income. The deviation from the mean value was measured in percentiles (from 5% to 95%) and the economic performance was categorized as follows: favorable (green), moderate (yellow), and unfavorable (red). The economic performance of the RPU was considered favorable when the average probabilities of ending with negative cash reserves and experiencing a loss of capital (equity or real net capital) were less than or equal to 25%. Conversely, if the probability of these events ranged higher than 25% to less than or equal to 50%, the financial performance was considered moderate. Exceeding a 50% probability indicated an unfavorable economic performance for the RPU.

Stochastic variables of the model

The RPU input prices and crop yields for the base year were directly sourced from producers through surveys. To simulate the cost of crops and milk, a Multivariate Empirical Distribution (MVE) was utilized (Richardson 2006). The probability distribution parameters were estimated using a Latin hypercube, employing a sampling procedure for generating pseudo-random numbers. This estimation method ensures that the coefficient of variation (CV) and the mean for the simulated random variables are equal to those of the historical variables (Richardson 2008). To estimate the parameters for a Multivariate Empirical (MVE) distribution, Richardson (2000) approach was applied.

Economic and financial viability indicators

The analyzed indicators were: Total Income in $USD (TI), Total Costs in $USD (TC), Net Income in Cash in $USD (NIC), Reserves in Cash % (RIC), Net Present Value in $USD (NPV), Internal Rate of Return % (IRR), Rate of Return on Assets % (RRA), and Cost to Benefit ratio % (C/B). The indicators were calculated according to Richardson’s (2000 and 2006) approach.

Model assumptions

The analysis considered the following assumptions: (1) scale of production; (2) productivity; (3) farm infrastructure capacity and utilization; (4) technical coefficients held constant during the planning horizon 2023-2027; (5) level of technology held unaltered; (6) discount rate established at 11.1 % (the reference discount rate in Mexico); (7) subsidies; (8)the number of farmers in the activity remained constant to prevent new dairy units or farms from affecting the results; (9) outflows considered a salary rate of $8.90 USD per day (FL); and (10) external hired labor (EL). Economic values were converted to USD with a currency exchange rate of 19.4143:1 USD: MXN as per Banco de Mexico (December 30, 2022).

RESULTS

Economic viability

Table 1 presents the economic performance of the RPUs throughout the planning horizon from 2022 to 2027.

Total income rose by 41.39%, expenses by 13.56%, and net income by 66.73%, demonstrating a competitive production system. When FL was not considered as a permanent labor source, income saw a notable decline due to the employment of EL, involving two employees. Transitioning from a net income of $26,000 USD in 2027 with FL to $3.55 thousand USD with EL led to losses in 2023. Consequently, the return on assets dropped from 2.26% to 0.47%, and final cash reserves decreased from $40,000 USD to $8.27 thousand USD over the simulated years.

Figure 2 shows the net cash income performance throughout the planning horizon, according to the risk evaluation. The economic panorama appears to be viable in 2027.

The cost structure was primarily composed of FL, representing 40.83% of total costs, followed by feed at 37.73%, and dairy cattle production at 15.19%. Other items accounted for a minimal proportion of the costs. Including EL into the simulation resulted in a shift in the cost structure, with EL, feed, and dairy cattle production representing 56.10%, 22.66%, and 9.12% of the total costs, respectively.

Financial viability

In the evaluated RPU, the Net Present Value (NPV) remained negative regardless of the labor source, with monetary values of $-161.84 thousand USD and $-191.27 thousand USD, for FL and EL, respectively. The Internal Rate of Return (IRR), Cost/Benefit ratio, and Real Rate of Return were estimated at 6%, 1.34, and 2%, respectively, when FL was considered, and 4%, 1.42, and 2%, when EL was included in the simulation. Incorporating family labor improved the financial viability of the RPU, as the opportunity cost of FL is lower compared to EL. Accounting for FL also reduced financial risk. The labor cost range increased by up to 66% when FL was utilized, in contrast to 58% when EL was employed.

Table 1. Economic viability of small-scale dairy Representative Production Units (Thousand USD).

	2022	2023	2024	2025	2026	2027
Total income	30.20	32.76	34.90	37.90	40.05	42.70
Total expenditure	14.39	14.77	15.14	15.52	15.98	16.35
Net income	15.81	17.99	19.76	22.37	24.07	26.35
Return on assets (%)	1.28	1.54	1.70	1.97	2.09	2.26
Ending cash reserves	2.75	7.08	12.52	19.95	28.82	40.13
Net capital	646.51	670.83	696.81	725.44	756.14	789.98

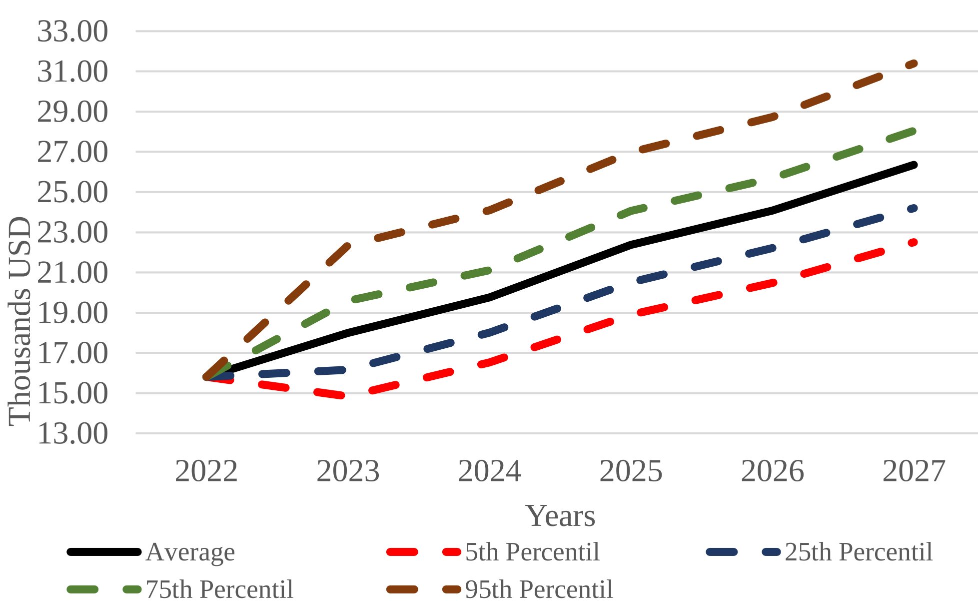

Figure 2. Representative Production Units net cash income performance according to percentile and risk simulation.

DISCUSSION

At the international level, Mexico holds the 16th position for cow milk production. Within the country, the livestock sector ranks third in the national GDP of the food industry, closely followed by dairy product manufacturing, contributing 10% (CANILEC, 2021). The main shift in the global dairy sector's structure will result from increased production volumes, particularly encouraged by developing economies (OECD-FAO, 2022). However, it is important to note that this change will primarily be driven by an increase in livestock populations rather than productivity advancements. The dairy sector in Mexico has shown steady growth since 2010. In 2010, milk production totaled 10,676.691 million liters, while in 2021, production increased to 12,842 million liters (SADER, 2021). Official statistical data reveals that milk production in Mexico demonstrated an average annual growth rate of 3.07% from 1980 to 2022, mainly attributed to sectoral advancements in other states. Conversely, the State of Mexico witnessed a negative annual rate of -1.80%. However, Aculco grew at an average rate of 11.07% from 2006 to 2022 (SIACON, 2022). The State of Mexico government identifies dairy farming as a vital sector of its economy, which is mainly composed by household dairy farms. The top-ranked municipalities in milk production are Texcoco, Zumpango, Aculco, Jilotepec, Teoloyucan, and Polotitlán.

According to Ojeda *et al.* (2016), small-scale dairy farms are prevalent across Mexico, incorporating agricultural activities such as maize, oats, and forage cultivation alongside dairy production, often operating within a family-based framework. The family unit serves as the main labor force and productive asset, constituting a key strength of these systems (Posadas-Domínguez *et al.,* 2018). Consequently, a significant portion of the cost structure is expected to be attributed to labor (both FL and EL). Posadas-Domínguez *et al.* (2016) identified FL as the main intangible accountable asset in small-scale dairy farms. Within such systems, the probability of obtaining a negative final net capital increased from 17.50% to 26.40%, while competitiveness decreased from 0.79 to 0.07 (Posadas-Domínguez *et al.,* 2014), Family labor, although not factored into the cost structure, constitutes an important contribution by the household members to mitigate adverse economic outcomes (Ruíz-Torres *et al*., 2022).

Statistical data from CEPAL (2022) indicates that small-scale dairy farms have the capacity to create and maintain between 4 and 17 jobs for every 100 liters of milk collected, processed, and commercialized. The number of jobs created depends on the level of processing, as dairy products are tailored to match consumer preferences. Thus, fluctuations in milk demand in the examined region can have a direct impact on the entire sector. The data from CEPAL incorporates the entire production chain, including primary, secondary and tertiary sectors, and indicates an increase in the added value of milk at every link of the production chain. The studied RPU produced an average of 33,847.29 liters per year, equivalent to 92.73 liters per day. With these figures, the RPU falls short of meeting the minimum milk production required to generate enough jobs to sustain the system.

In addition to milk production, the municipality of Aculco relies on the transformation and tourism sectors, drawing in visitors who purchase derivative products. FAO (2021) highlights the dairy sector's potential as a sustainable, equitable, and powerful driver of economic growth, food security, and poverty reduction. However, there is currently a lack of policies aimed at generating synergy between the primary and tourism sectors.

Wolf (2012) emphasized the importance of accounting for the risk inherent in milk and food prices, stressing the role of cooperatives in enabling risk management strategies for farmers who may not consider these risks. Cooperatives can facilitate such risk mitigation by providing contracts in smaller increments compared to future contracts and offering options contracts through commodity exchanges.

In the assessed region, milk production is a vital primary activity, prompting producers to anticipate strategic scenarios in face of sudden economic and political shifts that could directly impact them. It is imperative for small-scale dairy systems to engage in strategic planning for production through consultancy services, aiming to gather production data such as cow age, daily milking frequency, lactation duration, and other relevant metrics. This process is aimed towards improving livestock genetic quality and optimizing resource management. Notably, family labor emerges as a key variable negatively influencing the profitability of production units (Jiménez *et al*., 2014).

In the local context, economic and financial uncertainty is directly evident in the financial indicators of the RPU. The negative NPV may be attributed to the prevailing reference rate during the study of 11.1%, while the IRR and RRR were 6% and 2%, respectively. The 11.1% interest rate in Mexico during the study period posed a significant challenge for small scale dairy farmers, since the NPV did not translate into sufficient profits for the RPU. High interest rates from banks and government institutions, paired with limited access to credit, exacerbate the risk for dairy farmers in meeting their financial obligations (Brue *et al.,* 2010). According to Brue *et al.* (2010) the interest rate represents the market-determined price that borrowers must pay for using money over a specified period. Producers could only afford a maximum real rate of 2%.

While dairy farmers possess a substantial number of live assets and appear to be better positioned to improve their socioeconomic status compared to non-dairy farmers (Banda *et al.* 2021), the rate that small-scale dairy farmers could sustain in the present study was merely 2%. Posadas-Domínguez *et al.* (2016) reported a more favorable financial scenario with a discount rate of 10%. In their study, the average production per cow was 5,190 l, whereas in the present study, the yield was 3,760 l. The difference in production volume has been proved to limit the financial benefits of the analyzed systems. Similarly, Posadas-Domínguez *et al.* (2018) identified increased competitiveness in dairy systems yielding over 6,000 l per cow annually, as well as when the cost of family labor was not considered. Equipped with an understanding of potential future risks and uncertainties, dairy farmers can proactively implement suitable systems, thereby minimizing financial repercussions. A current low level of risk aversion additionally reinforces the adoption of an anticipatory strategy (Yanore *et al*., 2023

Given the anticipated price volatility in the near future (OCDE/FAO, 2022), it is imperative to adjust the findings of studies like the present one, which evaluates the economic and financial standing of RPUs, to effectively inform intervention strategies for policy development. The cyclicality of milk production correlates with factors such as feed prices and fluctuations in global trade. Small-scale farms face considerable obstacles in maintaining viability due to limited market access, often being marginalized from the more lucrative segments of the globalized market (Álvarez, 2021).

NPV is a crucial financial indicator, serving as a valuable tool for policymakers. Widely utilized in investment evaluation, NPV calculations optimize decision-makers' utility by favoring investments with the highest net profitability. (Shortall *et al.,* 2016). Since 2007, Olynk and Wolf have applied NPV to ascertain the optimal reproductive scheme for dairy herds. Yanore *et al.* (2023), introduced the notion of present biased farmers, proposing that such farmers demonstrate a time preference characterized by a (quasi-) hyperbolic pattern rather that an exponential one. They derive higher utility from cash flows received in the present compared to future ones. For present biased farmers, adopting an anticipation-based strategy may prove advantageous. Wolf and Karszes (2023) noted that during the 2010-decade, financial performance among US dairy farms followed a cycle of boom or bust, while maintaining relatively stable solvency positions driven by long-term asset and liability values. However, during periods of poor performance, a significant rise occurred in the proportion of farms falling below critical thresholds for liquidity and debt repayment capacity.

This study evaluates the economic and financial viability of small-scale dairy farms in the high plateau of central Mexico, projecting outcomes in a planning horizon until 2027. The findings of our analysis consistently reveals positive economic performance across the entire study period. The inclusion of family labor resulted in a rise in Net Income, increasing from $17.99 Thousand USD in 2023 to $26.35 Thousand USD in 2027. However, when considering external hired labor, the economic performance showed a different trajectory, with figures shifting from $9.88 Thousand USD to $16.31 Thousand USD. Both scenarios resulted in negative Net Present Values, indicating significant risk levels despite the competitive nature of the RPUs. This risk stemmed from factors such as high monetary value, limited specialization of the RPUs, and the prevailing volatile economic conditions.

The proposed methodology is not limited to small-scale systems in the high plateau of the state of Mexico. It enables the assessment of the economic and financial viability of any milk production system, regardless of its scale or technological level. This involves monitoring changes in productivity and considering corresponding inputs for the specific system under evaluation.

CONCLUSION

The economic and financial scenario of the evaluated RPU was favorable, with lower risk evident when family labor was utilized as opposed to hired labor. Within the RPU production scale, assets such as cows and infrastructure constituted a considerable portion of the investment and savings for small-scale dairy farmers. The weakening of such systems could imply adverse implications for public policy, as they serve as an area of opportunity for family labor, particularly in regions where producers lack alternative employment opportunities. Moreover, small-scale dairy systems use agricultural by-products as feed inputs, effectively reducing production costs. These systems also play a crucial role in consolidating local markets and developing short marketing circuits, thereby stimulating the local economy and serving as a consistent source of income. Milk producers in the state of Mexico have a strong relationship with the milk processing and cheese sector. Thus, a lack of awareness regarding the economic status of small-scale dairy systems could impact the future viability of the analyzed system, ultimately affecting the cheese industry in the state of Mexico.

Acknowledgements
The authors wish to thank the dairy producers from Aculco who kindly provided the information for this study.

Funding. This study was financed by the research project 6498/2022CIB of the Universidad Autónoma del Estado de México and CONAHCyT México via a doctoral scholarship granted to Vianey González-Hernández.

Conflicts of interest/competing interests. The authors declare no conflict of interest.

Compliance with ethical standards. The Ethics Committee of the Universidad Autónoma del Estado de México (México) approved the research protocol and information-gathering tools. Prior to participation, the owners of the dairy farms that conformed to the analyzed RPU were provided information about the overall aim and expected outcome of the present research. Due to the nature of the study, no animals were used to obtain data.

Data availability. The datasets analyzed in the current study belong to a panel of dairy producers and are not publicly accessible but are available from the corresponding author upon reasonable request.

Author contribution statement (CRediT). V. González-Hernández: Investigation, Writing-Original draft; **N. Callejas-Juárez:** Methodology, Data curation; **N. A. Rogers-Montoya**: Writing – Original Draft, Writing –Review & Editing; **C. G. Martínez-García**: Visualization; **J. A. Salinas-Martínez**: Supervision; **F. E. Martínez-Castañeda:** Conceptualization, Writing-Original draft, Funding acquisition, Supervision.

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