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Factors affecting exit intentions from dairy farming in the Pampas region of Argentina.

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ABSTRACT: This article examines the factors which explain exit from dairy farming in the Pampas region of Argentina. A representative sample of dairy farms was used, of which 12 % indicated their intention to exit in the next five years. High technical efficiency and the existence of a successor reduce the likelihood of exit dairy farming; while age of farmer, hired labor, and climate risk exposure are positively associated with exit intentions. The small dairy farms are more prone to exit than large ones, albeit with a smaller marginal effect.

Factores que inciden en la intención de salida de la actividad lechera en la región pampeana de Argentina.

RESUMEN: Este artículo examina los factores que explican la salida de la producción lechera en la región pampeana de Argentina. Se utilizó una muestra representativa de unidades productivas, de las cuales el 12 % indicó su intención de salir en los próximos cinco años. La eficiencia técnica y la existencia de un sucesor reducen la probabilidad de salida, mientras que la edad del productor, la mano de obra contratada y la exposición al riesgo climático se asocian positivamente con la intención de salida. Las unidades productivas pequeñas son más propensas a salir que las grandes, aunque con un menor efecto marginal respecto de otras variables.

KEYWORDS/ PALABRAS CLAVE: Stochastic frontier model, binary choice model, technical efficiency, economic viability. / Modelo de fronteras estocásticas, modelo de elección binaria, eficiencia técnica, viabilidad económica.

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1. Introduction

Following a global trend (MacDonald *et al.*, 2020; Eurostat, 2015; Dairy New Zealand, 2020a), the primary dairy sector in Argentina is undergoing continuous structural change, with the number of operations decreasing at a rate of 1.8 % per year since 2003 (OCLA, 2022). At the same time, there is an increase in the size of the farms that remain in business. This is reflected in the growth of average daily production, increasing from 1,558 to 3,030 liters in the period 2002-2021 (OCLA, 2022). In this context, the public debate discusses the role that scale plays in the exit decision and whether the decrease in the number of dairy farms also has socioeconomic and/or productive explanations.

The dairy sector is an important economic activity in Argentina, with more than 10,000 farms located almost exclusively in four provinces of the "Pampas" region (Buenos Aires, Córdoba, Entre Ríos and Santa Fe), producing 11.5 billion liters of milk per year (Dirección Nacional Láctea de Argentina, 2022). The milk production area is relatively homogeneous, with a temperate climate, annual rainfall of 750 - 1,100 mm (from West to East), and flat and fertile soils.

The average farm size on which milk is produced in Argentina is 190 hectares. Approximately 120 hectares of the 190 are used for milk production, and the remaining is used for other activities, such as heifer rearing and beef production from the dairy herd. Milk production is based on open grazing of semi-permanent pastures, mostly alfalfa-based, complemented with corn silage, and energy and protein concentrates (e.g., corn grain, soybean expeller, among others). Each of these sources of food represents 46, 25, and 29 % of the average diet, respectively. Some dairy farms have more intensive systems, with higher stocking rates and individual feed consumption levels. Systems such as dry lot or free-stall represent approximately 10 % of dairy farm units (Gastaldi *et al.*, 2020).

Traditionally, the exit of firms has been explained by (i) the characteristics of the farm, (ii) the farm operator, and (iii) the environment in which the farms operate, including land quality and climate (Quiggin *et al.*, 1986). In addition, the literature (see, for example, Bragg & Dalton (2004) and Bennett *et al.* (2006)) points out to the importance of efficiency in the decision to exit dairy farming and farm survival.

Given the importance of the subject and the lack of empirical evidence about this phenomenon in Argentina, this article presents an analysis of a cross-sectional dataset of a sample of dairy farms located in the Pampas region. We examine the factors that explain intentions to exit dairy farming with the aim to contribute to the policy debate regarding the future structural features of dairy farming in the country.

The remainder of this paper is organized as follows. A brief review of the literature on the decision to exit farming to support the selected explanatory variables is presented in section 2. Section 3 presents the methodology with the econometric specification for the frontier model for efficiency estimation and the logit model. The underlying data are described in section 4, and the empirical results are presented and discussed in section 5, with final remarks and conclusions in the last section of the manuscript.

2. Review of the literature

There is a large body of literature regarding the long-term trend towards a reduction in the number of farms. This trend matches perfectly with another long-term trend, the increasing average size of the farms, particularly in the context of commercial agriculture (Sumner, 2014).

One explanation for these trends is the cost advantage associated with size. In the context of a competitive dairy economy, where all farms face the same milk price, the inverse relation between farm size and production cost results in proportionally higher costs for smaller farms that cannot adequately remunerate their resources and are therefore forced to exit production. This is the "policy problem" that exists in most countries around the viability of small dairy farms.

Empirical evidence of the relation between size and cost is supported in many dairy regions worldwide. For example, Short (2004) reported that in the United States, dairy "operations with more than 500 cows had significantly lower total operating and ownership costs, indicative of the economics of size experienced by larger operations". Evidence from other regions of the world, such as Europe and Oceania, points to the same conclusions (Pieralli *et al.*, 2017; Dairy New Zealand, 2020b). For Argentina, Gastaldi *et al.* (2020), based on data from a national survey of dairy farms, showed a direct relation between herd size and economic performance.

In addition to the analysis of production costs, some studies have shown a direct relation between farm size and technical efficiency (TE), providing additional support for the viability problem. For example, Mosheim & Lovell (2009) found significant economies of scale in their study of more than 600 dairy farms across the U.S. with data from the year 2000. In addition, they pointed out that inefficiency was a key issue to be considered in the analysis of economies of scale and cost of production.

The relationship between the survival of dairy farms and factors such as scale and technical and cost efficiency was also studied by Tauer & Mishra (2006), who analyzed a cross-sectional sample of 755 U.S. dairy farms in the year 2000. They found that, although the frontier cost decreases with farm size, the higher cost of production of many small farms was more related to efficiency than technology.

A different strand in the literature to the "size – efficiency – viability" approach, consists in modeling the exit decision as a dependent variable of a set of explanatory variables -through a binary choice model-, as it is the case of Quiggin *et al.* (1986), who addressed the issue of exit in the Australian dairy industry using this approach.

For example, Peerlings & Ooms (2008), through a probit model, studied farm growth and exit and its interaction in Dutch dairy farming and its relations with Common Agricultural Policy reform. They found that the decision to exit dairy farming is largely determined by household characteristics such as farmer age and household size. These results are similar to those found by Zorn & Zimmert (2022), who analyzed dairy farm exit decisions in Switzerland.

Carter-Leal *et al.* (2018) also explore stay-exit intentions of small livestock-farms located in southern Chile using a large set of explanatory variables organized in three groups of theories: life-cycle, exit barrier, and efficiency theory. In the latter they included farm size and some dummy variables to indicate, for example, whether farm income was enough to cover expenses, the importance of off-farm income, and the presence absence of livestock and crop production on the farm, among others.

Ribas *et al.* (2006), incorporate the effect of efficiency in the analysis of exit intention, but in this case through a unique proxy variable such as the individual cow productivity. Similarly, Ifft & Yi (2019) used a Markov chain model to investigate the variables that explain the exit of New York (United States) dairy farmers and found that efficiency-related variables such as return on equity are negatively associated with dairy farm exit.

Bragg & Dalton (2004) studied a sample of 64 dairy farms in Maine (US) using a two-step procedure. First, they used an equation to explain dairy farm efficiency, measured as return on variable costs (ROVC). A binary choice logit regression model was then fitted to estimate the probability of an exit decision, resulting in four significant explanatory variables. Two of them (age of the operator and level of off-farm income) were positively correlated with exit decisions, and the other two (predicted ROVC and diversification of farm income) were negatively correlated.

Dong *et al.* (2016) used another approach, in which efficiency and herd size were considered jointly with other structural variables to predict the exit intentions of dairy farmers in the US. First, they estimated TE through a stochastic production frontier (SPF) model in which they accounted for the endogeneity of feed and labor inputs through the use of output and input prices. The TE estimation was then incorporated into a probit model of exit intentions. They concluded that the most efficient farmers expand their herds and are therefore less likely to exit the least efficient ones. In addition, they found that farms with no successors where the farmer is aged and educated are more likely to exit.

Pieralli *et al.* (2017) examined the impact of TE and output price volatility on the optimal exit timing for milk producers in western Germany. They developed a real options model that explicitly accounted for production efficiency and found that more efficient farms were less prone to exit the activity. Moreover, a small deviation from optimal production does not lead to an immediate exit decision, because poor efficiency can be partially compensated by other factors that determine the optimal exit trigger.

Finally, in Argentina, using a case study methodology, Rossler *et al.* (2013) studied the reasons for the exit decision of 30 dairy farmers who abandoned production between 1990 and 2012 in Santa Fe province (Argentina). Adverse rainfall events were the primary factor chosen by farmers to explain their decisions to leave the activity. Secondly, they mentioned problems associated with hired labor. Economic performance and farmers' age were also chosen to explain the decision to exit farming. According to this study, approximately 37 % of dairy farmers exiting dairy production remained in the farming sector, but in oilseed and crop production (mainly soybean, wheat, and corn).

3. Methodology

This paper is empirically oriented, and it aims to fill the gap in the national and regional literature about the reasons that explain the perceived problems of the smaller dairy farms to remain in business. The proposed methodological approach proceeds in two steps such as in Bragg & Dalton (2004) and Dong *et al.* (2016). First, we estimate TE, and then use a logit model to analyze the decision to exit dairy farming. In this model, we included TE in addition to the other selected explanatory variables, based on the theoretical framework previously developed.

TE was estimated with the SPF model (Aigner & Chu, 1968; Aigner *et al.*, 1977; Battese & Corra, 1977; Battese & Coelli, 1995). The stochastic frontier model assumes that each firm potentially produces less than it might due to a degree of inefficiency. In the SPF model, production is defined as a function of a given set of inputs with a stochastic error term:

$$y_i = f\ (X_i, \beta)\varepsilon_i \exp(v_i) \qquad [1]$$

where y is output for farm i, $i \in \{1,2, \dots, N\}$, X_i is a vector of inputs including a column of ones, β is the corresponding vector of parameters. ε_i is the level of efficiency for firm i, which must be between 0 and 1. If $\varepsilon_i = 1$, the firm is achieving the optimal output with the technology embodied in the production function $f\ (X_i, \beta)$. When $\varepsilon_i < 1$, the firm is not making the most of the inputs X_i given the technology embodied in the production function $f\ (X_i, \beta)$. Because the output is assumed to be strictly positive, the degree of TE is assumed to be strictly positive. Finally, a statistical noise v_i, due to measurement error or unobserved factor out of the operator´s control. We choose a Cobb-Douglas specification, then the log form of the model is as follows:

$$\ln(y_i) = \beta_0 + \sum_{j=1}^{k} \beta_j \ln(X_{ij}) + v_i - u_i \qquad [2]$$

where there are k inputs in the production function and $u_i = -\ln(\varepsilon_i)$, under the assumption that $u_i \geq 0$, then $0 < \varepsilon_i \leq 1$. To estimate such model, a distribution must be assumed for the inefficiency term. In this paper, u_i was considered to be independently half-normally distributed:

$$u_i \sim N^+(\mu, \sigma_u^2) \qquad [3]$$

Battese & Coelli (1995) showed that TE for each observation can be computed as the ratio of the observed output to the corresponding stochastic frontier output y^*:

$$TE_i = \exp(-u_i|v_i - u_i) \quad [4]$$

Complementarily, the relation between scale and efficiency was analyzed through variance analysis. We used herd size and land area as proxies for size organized into 3 categories (33rd percentile).

Following Bragg & Dalton (2004), in the second step the exit intention from the dairy activity was analyzed through a logit model (Amemiya, 1985). Logit models are based on the theory of random utility of individuals' decisions (McFadden, 1973). We also tried a probit specification with the same results (see appendix A).

In logit models, the individual derives utility from the different available alternatives. However, the utility is not directly observable. Instead, what is obtained is the final choice made by the individual, which reveals the alternative with the highest utility. Thus, the dependent variable is a dummy variable that indicates the option reporting the highest level of utility to the individual.

Random utility models consider utility has a deterministic component that is a function of the individual's observable characteristics and a random component. In the logit model, logistic distribution for the error term is assumed. This model estimates the probability that each individual will choose an option between two available alternatives conditional on their observable characteristics.

The logit specification assumes that:

$$P_i = \frac{1}{1 + \exp(-W_i'\gamma)} \quad [5]$$

where P_i represents the probability of the exit decision occurring for firm *i*. The model is used to fit a binary dependent variable. The assigned value is 1 if the producer expects to exit dairy activity in the next 5 years and is 0 if otherwise. This decision is explained by W_i , a vector of explanatory variables, and γ, a vector of unknown coefficients defining a utility index (Griffiths *et al.*, 1993). Therefore, the logarithm of the odds-ratio $\left(\frac{P_i}{1-P_i}\right)$, and an error component, is:

$$L_i = \ln\left(\frac{P_i}{1 - P_i}\right) = Z_i = \gamma_0 + \sum_{j=1}^{k} \gamma_j \ln(W_{ij}) + \xi_i \quad [6]$$

Given that the model is nonlinear, its parameters do not have the usual interpretation as marginal effects. To obtain the explanatory variables' marginal effects, the differential of the model for the variable of interest must be calculated (see Maddala (1983) for a detailed description). In this model, the marginal effects depend on both the values of the estimated parameters and the values of the explanatory variables. Hence, the marginal effects are usually reported for some cases of interest, like average values of the explanatory variables.

Finally, classical goodness-of-fit measures are not relevant in logit models (Hagle & Mitchell, 1992; Tardiff, 1976; Yazici *et al.*, 2007); instead, the model's predictive capacity is measured by (i) the proportion of total observations correctly classified by the model, (ii) "sensitivity" (true positive rate), which is the proportion of observed 1's that were predicted to be 1's, and (iii) "specificity" (true negative rate), which is the proportion of observed 0's that were predicted to be 0's.

As a final point about the proposed two-step methodological approach, we should mention the following caveat, regarding possible issues of "confoundedness" arising from simultaneity of TE and exit decisions causing a sort of spurious association. A recent paper using the same type of two-step approach (Dalheimer *et al.*, 2022) propose a methodology of "lag identification" which allow for the verification of the robustness of the estimation.

The same approach wouldn't be applicable in our case since we rely on cross-sectional data. Instead, we may argue that the presence of any degree of simultaneity between TE and the exit intention is very unlikely, since efficiency as measured in the survey is the consequence of decisions taken in the past and therefore could be considered as exogenous from the viewpoint of the exit decision.

4. Model specification and data used

A cross-sectional survey of milk producers, carried out by the National Institute for Agricultural Technology (INTA) through on-site interviews[1] during the July 2018-June 2019 production season (Gastaldi *et al.*, 2020) was used for the analysis. It collected technical and socioeconomic variables for 194 dairy operations located in the Pampas region of Argentina, which houses more than 95 % of dairy farms in the country.

The data set includes a variable called "stay-exit intention", which was obtained by asking the farmer about his/her intention to remain in milk production within a 5-year horizon. The 12.2 % value for "exit" obtained for the sample is consistent with the annual exit rate of 1.8 % recorded in recent years in Argentina, which provides additional support for the quality of the survey.

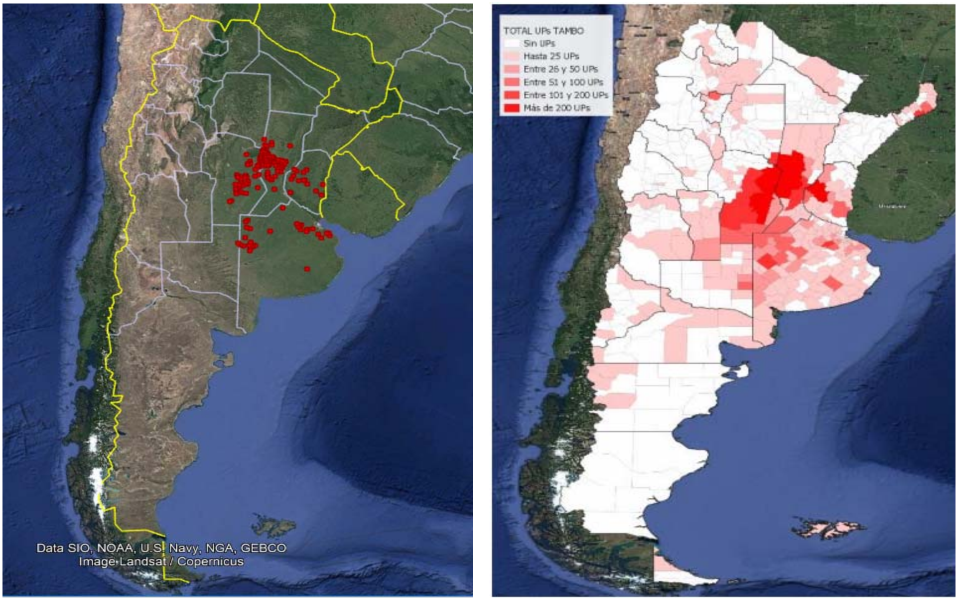
The sample size was about 2 % of the dairy farm population in the area. Sample selection was performed through an ad hoc procedure that started with the information provided by the Ministry of Agriculture, Livestock, and Fisheries for the whole population of dairy farms in the region. This information contained the geographical distribution of the dairy units and volume of milk production, which was used to draw the first approximation to the sample. In addition, many dairy companies participated in the process, collaborating with the final selection of farm units to be surveyed. Another aspect of INTA's dairy farm survey that should be highlighted is the process of ex-post validation through consultation with different participants in the dairy chain, which supports the representativeness of the sample and the data.

[1] The questionnaire contains questions about the structure of the whole agricultural business (that is, other activities in addition to dairy) and more specific details regarding milk production, such as use of capital, human resources, technology, animal health and feeding strategies, production level and revenues and costs.

To support the validity of the data used for the analysis, Figure 1 shows the geographical distribution of the sample of dairy farms (a) and its comparison with the geographical distribution of the total population of dairy farm units (b). In addition, Table 1 provides complementary information about the distribution of dairy farm units by province and the size distribution (in liters of milk per day), for both the sample and the whole population.

FIGURE 1

Geographical distribution of dairy farms in the sample (a) compared to the population density of dairy farms in Argentina (b)



Google Earth

senasa

a) Dairy farms sample.

b) Population density of dairy farms in Argentina

Source: a) Own elaboration; b) Senasa (2021).

TABLE 1

Dairy farm sample compared with population data, by geographic location and daily milk production

Province, Argentina	Milk production (liters/day)	< 2,000	2,000 to 3,999	4,000 to 9,999	≥ 10,000	Total
Buenos Aires	Sample (%)	8	4	5	2	18
	Population (%)	10	5	4	2	20
Córdoba	Sample (%)	15	9	10	1	35
	Population (%)	16	11	6	1	34
Entre Ríos	Sample (%)	6	1	1	0	8
	Population (%)	5	1	1	0	7
Santa Fe	Sample (%)	14	14	10	1	39
	Population (%)	24	11	4	1	39
Total	Sample (%)	43	28	26	3	100
	Population (%)	55	27	15	3	100

Source: Gastaldi *et al.* (2020).

INTA's dataset was complemented with rainfall data downloaded from the Climate Hazards Center of the University of California[2], considering the geographic coordinates for each dairy farm or the nearest city. Precipitation data was used in the stochastic frontier model to control for the rainfall pattern of 2018-2019 period that may have affected milk production performance (Donald *et al.*, 2015). A rainfall variable was included in the logit model, based on the evidence presented in Rossler *et al.* (2013) regarding the importance of climate conditions in exit decisions. In this case, the yearly average rainfall for the period January 1981 to December 2020 and its coefficient of variation were used.

Table 2 presents the selected variables for the SPF and the logit models, with a brief statistical description.

TABLE 2

Model specification and statistical description of variables

Variable	Detail	Unit	Mean	SD
Stochastic production frontier model (SPF)				
Dependent variable				
MILK	annual milk sales for the period July 2018-June 2019	liter	1,196,886	1,095,532
Independent variables				
Production function				
HA_COW	land used by dairy cows	hectares (ha)	136	78

[2] Data is available from the website https://iridl.ldeo.columbia.edu/SOURCES/.UCSB/.CHIRP/.

Variable	Detail	Unit	Mean	SD
COW	total number of cows (milking and dry cows)	head	194	140
VO_VT	proportion of milking cows over total cows	%	81.2	---
LABOR	labor availability (1 equivalent = 2,400 hours/year)	equivalent	4.72	2.49
GRAIN	use of grain and commercial concentrates	kilograms (kg)/year	381,850	433,171
SILAGE	use of silage and hay	kg/year	416,242	431,305
MIX_FEED	dummy for mixed feed, as partial or total mixed ration	%	0.60	---
AGRON	dummy for the use of continuous agronomic advice	%	74.01	---
PP_ANOM	annual rainfall (18/19) less long-run averages (1981/2020)	millimeters (mm)	104	47
PP_ANOM^2	squared of PP_ANOM	mm		
PP_JAS	accumulated rainfall in July – September 2018	mm	101	32
PP_OND	accumulated rainfall in October – December 2018	mm	289	34
PP_JFM	accumulated rainfall in January – March 2019	mm	442	56
PP_AMJ	accumulated rainfall in April – June 2019	mm	156	36
Logit model (LG)				
Dependent variable				
EXIT_DAIRY	dummy for the intention to exit within the next five years	%	12.2	---
Independent variables				
Dairy farm efficiency				
TE	technical efficiency	%	Estimated by SPF	
Farmer characteristics				
AGE	farmer´s age	years	55	13
OFF_INC	dummy for off-farm income	%	42.3	---
UNIV_AGRO	dummy for a university degree in agricultural sciences	%	22.7	---
UNIV	dummy for non-agriculture university degrees	%	12.7	---

Variable	Detail	Unit	Mean	SD
Potential successor				
NON_SUCC	indicates the absence of a succession	%	45.0	---
SUCC_EXIT	the successor has the intention to close the dairy farm	%	15.3	---
SUCC_STAY	the successor has the intention to remain in dairying	%	39.7	---
Labor characteristics of the dairy farm				
HIRED_LABOR	proportion of hired labor	%	60.5	27
Land area and ownership				
HA_BUSINESS	total area of the farm (crop and livestock production)	ha	445	637
HA_DAIRY_FARM	milk production area	ha	186	128
RENTED_LAND	the proportion of rented land on the dairy farm	%	51.5	41
The climate risk exposure of the dairy farm				
PP_HIST	annual average rainfall for the period Jan 1981 – Dec 2020	mm	883	84
PP_HIST^2	squared of PP_HIST	mm		
PP_CV	coefficient of variation of annual rainfall	%	17.5	0.02
Risk factors assessment by the farmer				
R_CLIMATE	dummy for climate variability as the main risk factor	%	38.6	---
R_PRICE	dummy for milk price volatility as the main risk factor	%	20.1	---

Source: Own elaboration.

The average dairy farm in the sample produces almost 1.2 million liters of milk per year (plus some livestock sales, mainly cull cows) and uses 136 hectares (only for milking and dry cows). Each dairy farm has its own milking parlor, mainly of the parallel and herringbone types.

Most of these dairy farms are owned by a single farmer (64 %), although there are dairy farms whose ownership is shared by more than one person or shareholders. Some of these agricultural firms have other independent farms with their own milking parlors, where milk is also being produced. The average number of dairy operations (or independent dairy farms with their milking parlors) per agricultural firm was 1.2 units (79 % had only one dairy farm, 14 % had two dairy farms, 3 % had three dairy farms, and the rest had more than three dairy farms). In addition, these firms generally engage in other non-dairy agricultural activities, such as grain and livestock production.

The feeding pattern for a typical dairy farm in the sample included a combination of grain and/or concentrate, corn silage, and direct grazing of alfalfa-based pastures. All dairy farmers produce their own pastures and silage, whereas commercial concentrates are purchased from outside the farm. In the case of dairy farms that use grains (63 % of the cases, mostly corn), around half buy the grain, while the other half produce it on the farm.

The farm is mostly organized as a family business, with the owner (55 years old on average) and other family members providing managerial and operating labor, while most of the milking labor is hired from non-family members (providing 39.5 and 60.5 % of the total labor availability, respectively). Only 2 % of the sample were dairy farms without any kind of family labor.

5. Results

5.1. Stochastic frontier model estimation

The empirical results for the estimation of the frontier model are summarized in Table 3. Five observations were lost due to missing data in some of the explanatory variables.

TABLE 3

Empirical results of the stochastic production frontier (SPF) model for dairy farms in Argentina

SPF model[1]		Number of obs[2]	189	
Dependent variable		**Wald chi2 (7)**	**2891.1**	
ln Milk		**Prob > chi2**	**0.0000**	
Independent variables	**Coef**	**SD**	**Prob > z**	
Production function				
ln HA_COW	-0.010	0.045	0.826	
ln COW	0.725	0.075	0.000	***
VO_VT	0.884	0.273	0.001	***
ln LABOR	0.059	0.046	0.199	
ln GRAIN	0.229	0.045	0.000	***
ln SILAGE	0.119	0.030	0.000	***
MIX_FEED	0.044	0.026	0.097	*
NON_AGRON	0.051	0.033	0.118	
PP_ANOM	0.001	0.001	0.343	
PP_ANOM2	0.000	0.000	0.087	***
PP_JAS	0.000	0.001	0.565	
PP_OND	0.001	0.001	0.126	

SPF model[1]		**Number of obs[2]**	**189**	
Dependent variable		**Wald chi2 (7)**	**2891.1**	
ln Milk		**Prob > chi2**	**0.0000**	
Independent variables	**Coef**	**SD**	**Prob > z**	
PP_JFM	-0.001	0.000	0.074	*
PP_AMJ	0.000	0.001	0.440	
Constant	5.133	0.455	0.000	***
/lnsig2v	-4.441	0.527	0.000	***
/lnsig2u	-2.809	0.428	0.000	***
sigma_v	0.109	0.029		
sigma_u	0.245	0.052		
sigma2	0.072	0.020		
lambda	2.262	0.079		

[1] An alternative estimation was made with a Translog specification. The results do not differ from those obtained with the Cobb-Douglas specification and many degrees of freedom are lost with a small sample. The Akaike Information Criterion (AIC) for the Cobb-Douglas was -79.70, while in the Translog model was -68.28. Thus, it was decided to continue with the Cobb-Douglas form. For completeness, the effects calculated with the Translog specification are shown in the appendix.
[2] Although the number of observations in the sample is relatively small, it doesn't generate a multicollinearity problem in the SFA estimates. Considering the variance inflation factor (VIF) only "PP-rains" and "COW" variables had values greater than 10.
** Statistically Significant at the 0.05 level, *** Statistically Significant at the 0.01 level
Source: Own elaboration.

Most coefficients are significant at the 1 % critical level. Because a Cobb-Douglas function is used, these coefficients represent the elasticity between the dependent variable and each input.

Milk production was more sensitive to VO_VT and COW variations and these inputs have the highest partial elasticities (0.88 and 0.72), in agreement with the literature for dairying in Argentina (Pace *et al.*, 2016; Bravo-Ureta *et al.*, 2008; Moreira *et al.*, 2004). An increase in the number of cows while maintaining the amount of land implies a higher stocking rate, which improves grazing efficiency, animal management, and production (Macdonald *et al.*, 2008; Baudracco *et al.*, 2011). In addition, more milking cows over total cows implies more milk production with the same herd, which is also indicative of managerial efficiency.

The third variable of importance (given the size of the elasticity coefficient) was GRAIN, which represents the annual use of grain (mostly corn) and commercial concentrates on the dairy farm, indicating the positive effects of additional energy intake on milk production. The use of SILAGE also produces a positive effect, as in the case of GRAIN, but somewhat lower, as was found by Pace *et al.* (2016), showing the difference in the energy concentration of both types of feeds. A positive effect of a more intensive feeding pattern over the TE was also found in New Zealand dairy farms (Ma *et al.*, 2018).

Feed management was another factor affecting TE, and farmers that used supplementary feeds (silage, grain, etc.) with an adequate diet balance through mixed rations (MIX_FEED) had a higher performance. Similar results were reported by Donald *et al.* (2015) for Wisconsin's dairy farms, but in this case, the mixed ration positively affected only the TE of dairy farms with lower TE levels.

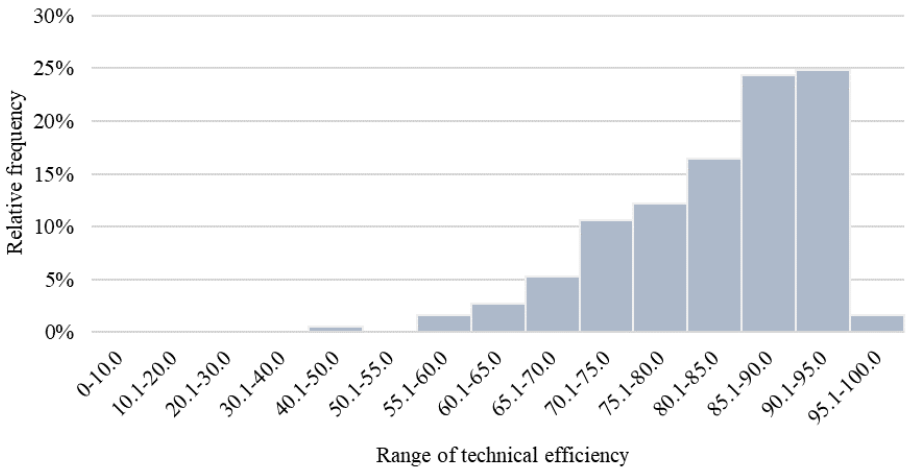
Finally, the rainfall anomalies recorded during the year were statistically significant, but only the quadratic term. This means that when anomalies are greater than a critical level, milk production begins to decrease.

In addition to annual precipitation anomalies, we found that the amount of summer rainfall had a negative impact on milk production. This can be explained by the strong positive association between rainfall and humidity during summer, and excessive humidity can have negative effects on the comfort and production of cows, as noted in the Ministry for Primary Industries of New Zealand (2023) and Gaviglio *et al.* (2021). In general, the results reported above reflect the importance of precipitation as an external factor affecting the performance of dairy farms.

The average TE for the sample was 83.1 %, varying between 42.05 % and 96.5 %, as shown in Figure 2. This value is lower than the 87.8 % reported by Pace *et al.* (2016) for 2014/2015, using a similar statistical specification but with a smaller sample size. The same type of analysis conducted in Uruguay, for example, shows that TE in dairy farms of this country had an average TE around 83.6 % during the period 2005/06 to 2016/17 (García-Suárez *et al.*, 2019).

FIGURE 2

Distribution of relative frequencies of technical efficiency in Argentine dairy farms



Source: Own elaboration.

The average TE values for the smallest (≤ 120 cows), medium (121 – 210 cows) and largest (> 210 cows) farms were 0.80, 0.84, and 0.85, respectively. Variance analysis showed that only smaller farms were significantly less efficient (p-value 0.0136). This is in line with other studies, such as Mosheim and Lovell (2009), who found a significant positive relation between TE and herd size in the US when the herd was greater than 200 cows.

5.2. Logit model estimation

Following the two-step approach explained in the methodology section, the TE estimate for each dairy farm is one of the independent variables used in the logit model to explain dairy exit intentions within the next five years, as presented in Table 4.

The goodness-of-fit of the model is indicated by a pseudo $R^2 = 39.65$ %, similar to other papers reviewed in the literature (see Carter-Leal *et al.* (2018)). Regarding predictive capacity, 88.36 % of the observations were correctly predicted by the model. However, the sensitivity (correctly predicted exit cases) was only 34.78 %, possibly because the share of the sample declaring exit intention was low (12 %). The specificity of the model (proportion of correctly predicted zeros) was 95.78 %.

TABLE 4

Empirical results of the logit model. Factors that affect the intention to exit the dairy activity

LOGIT MODEL		**Number of obs**		**189**		
Dependent variable		**LR chi2(22)**		**55.5**		
EXIT_DAIRY		**Prob > chi2**		**0.0000**		
		Pseudo R^2		**0.3965**		
	Coef	**SD**	**Prob > z**		**dy/dx[1]**	
Dairy farm efficiency						
TE	-7.423	2.993	0.013	**	-0.504	***
Farmer characteristics						
ln_AGE	4.682	1.840	0.011	**	0.318	***
OFF_INC	0.173	0.657	0.793		0.012	
UNIV_AGRO	1.616	0.751	0.031	**	0.137	**
UNIV	-0.225	0.833	0.787		-0.013	
Potential successor						
SUCC_NON	level	level	level		level	
SUCC_EXIT	0.926	0.829	0.264		0.092	
SUCC_STAY	-1.770	0.835	0.034	**	-0.102	**

LOGIT MODEL		**Number of obs**		**189**		
Dependent variable		**LR chi2(22)**		**55.5**		
EXIT_DAIRY		**Prob > chi2**		**0.0000**		
		Pseudo R^2		**0.3965**		
	Coef	**SD**	**Prob > z**		**dy/dx[1]**	
Labor characteristics of the dairy farm						
HIRED_LABOR	3.324	1.627	0.041	**	0.226	**
Size of the agricultural business						
HA_BUSINESS	-0.001	0.001	0.430		0.000	
HA_DAIRY_FARM	-0.015	0.005	0.002	***	-0.001	***
RENTED_LAND	-0.341	0.760	0.654		-0.023	
The climate risk exposure of the dairy farm						
PP_HIST	-0.188	0.056	0.001	***	-0.013	***
PP_HIST2	0.000	0.000	0.001	***	0.000	***
PP_CV	39.237	23.829	0.100	*	2.662	*
Worry risk factors assessment						
R_CLIMATE	1.645	0.780	0.035	**	0.112	**
R_PRICE	0.573	0.887	0.518		0.039	
Constant	64.524	23.546	0.006	***		
Sensitivity Pr(+ D)	34.78%					
Specificity Pr(-~D)	95.78%					
Correctly classified	88.36%					

[1] Average marginal effects – Model VCE: OIM.
* Statistically Significant at the 0.10 level, ** Statistically Significant at the 0.05 level, *** Statistically Significant at the 0.01 level.
Source: Own elaboration.

The most important effect (measured by the size of the parameter estimate and also because it is statistically highly significant) is the variable TE, suggesting that efficiency is in itself a prerequisite to stay in business. The average marginal effect was around -0.504 and represented the change in the probability of exit (that is, the farmers who answered positively to the question of whether they plan to leave the activity within the next five years) for a unit change in TE keeping the rest of the variables constant.

This result is in agreement with that of Dong *et al.* (2016), who explain that the most efficient farms are better prepared to stay in business. Other literature also show that exit decisions depend on efficiency but are represented through proxy variables such as productivity and return over variable costs, among others (Bragg & Dalton, 2004; Foltz, 2004; Ribas *et al.*, 2006; Carter-Leal *et al.*, 2018; Ifft & Yi, 2019; Mishra *et al.*, 2010).

For the AGE variable (55 years old on average), the results show a positive effect on exit intention, in line with most papers reviewed in the literature (Dong *et al.*, 2016; Bragg & Dalton, 2004; Ribas *et al.*, 2006; Peerlings & Ooms, 2008; Mishra *et al.*, 2010; Ifft & Yi, 2019; Quiggin *et al.*, 1986; Ahmad *et al.*, 2020; Zorn & Zimmert, 2022), which supports life-cycle theory indicating that older producers are more likely to exit. This point is relevant considering that about 22 % of dairy farmers in Argentina are over 65 years of age.

The effect of education variables on intention to exit is ambiguous in the literature. For example, Mishra *et al.* (2010) found a negative relation between level of education and the likelihood of exit, while Bragg & Dalton (2004) found a positive effect. In this case, following the study by Carter-Leal *et al*. (2018), we divided the education variables into nonagricultural and agricultural degrees. While the first was not significant, we found that the "agricultural science degree" variable was positively and significantly correlated with exit.

These results may be explained by the fact that agricultural graduates know the productive and economic possibilities of the farm better than others, according to the available resources. If the farm is not profitable, then they might prefer to switch to a different agricultural activity or to another job such as consulting, rather than remaining in dairy farming. In fact, our result regarding the effect of education on exit decisions is in line with the idea presented by Carter-Leal *et al.* (2018), about more educated farmers increasing their own knowledge to improve access to off-farm employment, rather than adopting management-intensive systems to improve farm efficiency.

The presence of a successor was only statistically significant if he/she intended to stay in the dairy business (SUCC_STAY). In this case, the exit probability is reduced, with an average marginal effect of –0.102. A similar relation was reported by Dong *et al.* (2016) and Ribas *et al.* (2006). In other words, having a successor is a crucial factor that reduces the intention to leave, but according to our analysis, only if this potential successor has the intention of keeping the dairy alive; otherwise the result is the same as having no successor at all.

Within the group of variables representing the organization and structure of the farm business, we found that hired labor (HIRED_LABOR) was positively related to exit intention, a result that is in line with the experience of many small and medium-sized farmers who complain about the increasing difficulties in dealing with hired labor (Rossler *et al.*, 2013). A similar impact was found, for example, in Ifft & Yi (2019), but in this case, the authors used a hired labor expense variable.

The size of the dairy farm (HA_DAIRY_FARM) also had a statistically significant coefficient, with a negative sign (in agreement with Breustedt & Glauben, 2007, Ribas *et al.*, 2006, Peerlings & Ooms, 2008). Kimhi & Bollman (1999) suggest that farm size positively contributes to farm survival because larger farms are more likely to provide the farm operator and their family with a reasonable and sustained income. In our case, the marginal effect of HA_DAIRY_FARM on exit intention was low;

therefore, although this variable is important, it would not be the more relevant to explain exit intentions.

Exposure to climate risk was represented by average precipitation (PP_HIST) and its variability (PP_CV). The mean annual precipitation had a non-linear relation with the exit intention, which gets higher as annual precipitation moved away from an optimal value of 928 mm. In other words, rainfall patterns that are too wet or too dry imply a greater risk that farmers do not always want to face, becoming a factor that can determine their exit from dairy production.

Regarding rainfall variability (PP_CV), the coefficient is positive, which means that an erratic rainfall pattern is another factor explaining exit intention, in line with Rossler *et al.* (2013), who mentioned that the occurrence of adverse weather events was the main reason behind exit decisions in the period from 1990 to 2012 for dairy farms located in the central region of Santa Fe province, Argentina.

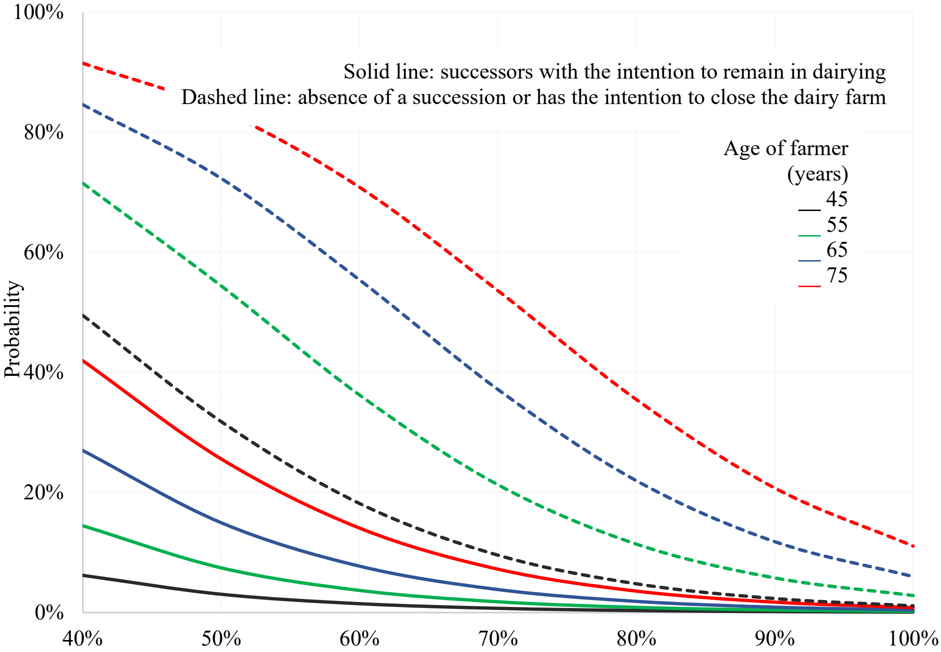
Dairy production in Argentina is mainly based on direct grazing (Lazzarini *et al.,* 2019). These open-air production systems are generally more affected by rainfall variability than intensive systems such as free-stall, where cows are indoors and fed through a total mixed ration system. Therefore, rainfall is a key variable for Argentina dairy production, which is also affected by other climate events, such as heat (Gastaldi *et al.,* 2014, Chang-Fung-Martel *et al.,* 2017).

The argument in the public debate stresses the importance of market risk in explaining the exit decisions of dairy farmers. Our research shows that price risk, as perceived by farmers does not have a significant effect on exit. Rather, climate-related risks are the more important factors behind exit intentions.

As a synthesis of the results, we would argue that TE, farmer ages, existence of successor, structure (size and labor) and climate are the key factors explaining exit intentions in dairy farming. Regarding to the first three variables, Figure 3 presents the probability of exit dairy farming intention for different TE ranges and farmer´s age (AGE); differentiating according to the existence of a potential successor to stay in dairy activity (SUCC_STAY) in contrast to the other two categories NON_SUCC or SUCC_EXIT.

FIGURE 3

Probability of exit intention according to farmer´s age, the technical efficiency of the dairy farm and the existence or not of a successor to the company



Source: Own elaboration.

The interpretation of Figure 3 is straightforward. For example, a 65-year-old farmer (blue lines) and 50 % efficiency, with a successor (solid line) who wants to stay in the dairy activity, would have a 15 % probability to exit the business within the next five years. In contrast, the same 65-year-old farmer, without having a potential successor (blue dashed line), would have 72 % probability of declaring the intention to leave the activity.

Figure 3 is also useful for determining the marginal effect of having or not a potential successor for the same age and efficiency level. For example, if the farmer is 65 years old (blue line) and his farm has a TE of around 80 %, having a successor with the intention of continuing with dairy activity reduces the probability of an exit decision by 20.1 percentage points. This value was obtained from the difference between the two blue lines (solid and dashed lines).

In the methodology section, we warned of the potential issue of confoundedness arising from the simultaneity of TE and exit decisions. Another related point, not previously discussed, concerns the existence of measurement errors from efficiency estimates and the potential problems it may create in the second step of the estimation. As an empirical answer to this situation, we may point towards the comparative results of the logit and probit estimations (see Appendix A), which do not change the overall impact of the variable, thus signaling the robustness of the estimate.

6. Conclusions

This research article explores the reasons behind the "exit intention" of dairy farmers in the Pampas region of Argentina, using a cross-sectional data set from 2018/2019. The results show that the main factors explaining farmers' exit intentions from dairy farming in Argentina are (i) TE, (ii) farmer characteristics, (iii) structural characteristics of the farm (size and labor organization), (iv) presence of an interested successor, and (v) precipitation features for each location and climate risk perception.

Our findings are consistent with the literature on the decision to exit dairy operations and have important policy implications. First, we confirm the prevailing view from the policy debate that small farms would be more prone to exit dairy activity; therefore, the current trend towards larger operations in the dairy sector is likely to continue.

However, our results also show that size is not the main determinant of exit. Therefore, at least for Argentine conditions, we may argue that the shrinking of the dairy farm population is not a problem of just the smaller farms, although, other things being equal, it is likely that smaller dairy farms will be more likely to exit the activity. In other words, the "get big or get out" does not necessarily hold.

Given the cross-sectional nature of the data we used, we could not test whether milk price is an important determinant of the exit decision, as argued mainly by farmer representatives. However, we tested the effect of milk price variability, measured by farmers' perception of price risk, and found that it was not a relevant predictor of the decision to exit. Therefore, it is difficult to justify the introduction of price support or price levelling schemes on the grounds of a "small farm problem".

In contrast to price, climate risk and rainfall variability are more strongly associated with the exit intentions of dairy farmers. From a policy perspective, it makes sense to promote instruments that may increase resilience to extreme rainfall events, such as risk-transfer tools and other forms of financial support. Of course, improvements in basic infrastructure such as roads and channels (given the flat terrain prevailing in the Pampas) should have a positive impact on the decision of dairy farmers to stay in farming.

From a policy perspective, one of the keys to reduce the rate of exit from dairy farming should point towards the improvement of TE, for example, through the promotion of technical support services. Here, improvement in the access to finance for small farmers through the banking system or more specific forms of financial support (i.e., rotatory funds managed by farmer organizations) is another alternative that should be explored, particularly in Argentina, where persistent high inflation generates a strong bias against the development of capital markets. In the case of smaller farmers, these problems are compounded by the traditional issues of information asymmetries that plague the relationship between small farms and lending operators (Hoff & Stiglitz, 1990).

Given the combined importance of variables such as age, presence of successors, and desire to continue a career in farming, public policies should generate conditions to promote rurality and family attachment to agricultural and dairy production to facilitate the interest of younger family members in the dairy industry. In particular, Dong *et al*. (2016), for the case of the United States, signal the importance of public programs that work to "reduce asset transfer frictions in agriculture, for example, by offering beginner farmer programs where activities often include facilitation of matches between prospective entrants and farmers without successors".

These results should contribute to improve the policy debate about the survival of the small dairy farmers, which has been normally dominated by considerations of fairness (of markets, processors or retailers alike) rather than efficiency or structural factors, which seem to be the key factors explaining the decision to remain or exit the dairy activity.

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Appendix A

In the table, the marginal effects corresponding to the following models are shown:
CD-Logit: Cobb-Douglas production function plus Logit model.
T-Logit: Translog production function plus Logit model.
CD-Probit: Cobb-Douglas production function plus Probit model.
T-Probit: Translog production function plus Probit model

Models	CD - Logit	T - Logit	CD - Probit	T - Probit
Variables	Marginal Effects			
TE	-0.5036***	-0.5597***	-0.5133***	-0.5678***
ln_AGE	0.3177***	0.3036**	0.3042***	0.2907**
OFF_INC	0.0117	0.0111	0.0079	0.0065
UNIV_AGRO	0.1370**	0.1340**	0.1300*	0.1288*
UNIV	-0.0130	-0.0137	-0.0068	-0.0094
SUCC_EXIT	0.0923	0.1069	0.1008	0.1151
SUCC_STAY	-0.1017**	-0.0984**	-0.0991**	-0.0963**
HIRED_LABOR	0.2255**	0.2306**	0.2324**	0.2357**
HA_BUSINESS	-0.0000	-0.0000	-0.0000	-0.0000
HA_DAIRY_FARM	-0.0010***	-0.0010***	-0.0010***	-0.0010***
RENTED_LAND	-0.0231	-0.0280	-0.0251	-0.0279
PP_HIST	-0.0128***	-0.0123***	-0.0132***	-0.0127***
PP_HIST2	0.0000***	0.0000***	0.0000***	0.0000***
PP_CV	2.6620*	2.6541*	2.8343*	2.8028*
R_CLIMATE	0.1116**	0.1042**	0.1163**	0.1072**
R_PRICE	0.0389	0.0434	0.0367	0.0399