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Impact of Cooperatives on Technical Efficiency and Technological Change in Dairy Farming in the State of Minas Gerais. Brazil

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Impact of Cooperatives on Technical Efficiency and Technological Change in Dairy Farming in the State of Minas Gerais, Brazil¹

Brazil is the third largest milk producer in the world (FAO, 2018). In that country, the state of Minas Gerais stands out, representing more than a quarter (1/4) of milk production (IBGE, 2023). According to data from the 2017 Agricultural Census, similarly to Brazil, Minas Gerais also features a scenario of productive concentration: farms with more than 100 hectares represented 15% of total agricultural establishments. And this percentage of farms produced around 37 billion liters of milk in 2017, representing 42% of total production in Minas Gerais (IBGE, 2023)

Improving the economic indicators of small producers is still a challenge. In this way, cooperatives are a possibility for the 85% (establishments with more than 0 to less than 100 hectares) to achieve productive gains similar to the other establishments. Cooperatives can act to strengthen the production of small producers and interaction with the market since marketing channels are often characterized by market failure (Hellin; Lundy; Meijer, 2009; Neves et al. 2021). Considering the relevance of dairy farming to Minas Gerais, as well as the role advocated for cooperatives, this paper aims to identify the effect of the participation of milk producers from Minas Gerais in cooperatives on productivity components: technical efficiency; and technological change, captured as a change in the frontier due to cooperative membership.

We combined two methods, Propensity Scores Matching (PSM) and Stochastic Production Frontier (SPF), to analyze the behavior of the production function of those milk producers in Minas Gerais who are members of cooperatives and those who are not members. Therefore, first, we used the Propensity Score Matching (PSM) model to select a sample of non-members (control group) comparable to those who are members (treated group), to control biases related to observable characteristics. Then, the Stochastic Production Frontier (SPF) model was used to measure the levels of technical efficiency, separately, for each of the producers' groups. Third, we estimated the metafrontier to provide a comparison of the impact of cooperative membership on technological levels, providing a common reference technology for dairy farmers who are members of cooperatives and non-members. This made it possible to estimate metatechnology indexes (MTRs). We used primary data in the research, coming from the "Educampo Leite/Sebrae-MG" Extension Program in the state of Minas Gerais, from 2018 (SEBRAE, 2023). This information relates to the farms (*e.g.* input expenses, distance to the city, area, capital) and their owners (*e.g.* age, experience, education) (refer to Table 1 and Table 2 for descriptive statistics).

Table 1 Variables used in the research, “Educampo Leite/Sebrae-MG” Program, Minas Gerais, Brazil, 2018

Variables	Unit	Description
Gross Income	BRL/Year	Gross income from dairy activity
Hired labor	BRL/Year	The sum of expenses with hired labor and expenses with the family labor

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Specific Expenses	BRL/Year	Spending on feed and supplements in dairy farming
Land	BRL/Year	The sum of the capital stock in forage and capital stock in land
Capital	BRL	The sum of the capital stock in improvements and capital stock in machinery
Animal Stock	BRL	Capital stock in animals
General expenses	BRL/Year	The sum of accessories and expenses in general: artificial breastfeeding, leasing, rent, administrative expenses, expenses with technical assistance, energy and fuel, laboratory tests, hormones, milking material, medicines, freely ingested minerals, others, milk quality, repairs and machine repairs, reproduction, breeding outsourcing, vaccines, and forage.
Age	Years	Farmer's age
Experience	Years	Length of time as a dairy producer (years)
Elementary school	Share	Farmer with Elementary School Degree
High school	Share	Farmer with High School Degree
College	Share	Farmer with College Degree or more
Distance to the city	Kilometers	Distance from the farm headquarters to the nearest municipality center

Source: Own elaboration.

Table 2 Descriptive Statistics of Dairy Farms served by “Educampo Leite/Sebrae-MG Program”, Minas Gerais, Brazil, 2018

Variables	All observations		Coop farmers		Non-Coop farmers	
	Average	Std. Dev	Average	Std. Dev	Average	Std. Dev
Gross Income	1194872.20	1103790.68	1176819.52	1123456.20	1224759.40	1075991.84
Hired labor	149038.71	137051.78	144549.02	137179.84	156471.63	137281.55
Specific Expenses	398953.49	380116.34	388488.22	374810.48	416279.34	390238.22
Land	1451911.00	1896098.64	1570348.18	2203042.70	1255831.66	1216931.75
Capital	565767.59	470310.09	544942.23	440464.93	600245.13	516672.67
Animal Stock	715605.60	620732.68	738009.32	665252.37	678514.98	540557.04
General expenses	415255.99	389347.78	399366.90	394346.13	441561.25	381652.46
Age	54.38	12.76	55.01	12.33	53.33	13.45
Experience	21.07	12.50	21.68	13.15	20.05	11.33
Elementary school	0.24	0.43	0.19	0.39	0.32	0.47
High school	0.36	0.48	0.36	0.48	0.34	0.48
College	0.31	0.46	0.36	0.48	0.23	0.43
Distance to the city	15.63	10.40	16.49	10.88	14.19	9.45
Obs.	239		149		90	

Source: Research Results.

In general terms, factors linked to the farm and the farmer's condition were important in explaining being a member of cooperatives. Thus, "Age", "Experience", and "Distance from the farm to the nearest city" were positively related to participation in a cooperative. The variables "Capital" and "General Expenses" were inversely linked to membership in cooperatives. In other words, the more capitalized and the greater the expenses, the less likely it is to be a member of cooperatives (Table 3).

Table 3 Results of the Probit Model for dairy farmers served by the “Educampo Leite/Sebrae-MG” Program, Minas Gerais, Brazil, 2018

Variables	Probit
log Hired Labor	-0.232 (0.340)
log Expenses	0.0424 (0.353)
log Land	0.0853 (0.102)
log Capital	-0.399* (0.220)
log Animal Stock	1.185*** (0.333)
log General Expenses	-0.785* (0.433)
Age	0.125** (0.0506)
Age ²	-0.00110** (0.000443)
Experience	-0.0392 (0.0301)
Experience ²	0.00101* (0.000562)
Distance to the city	0.0174** (0.00877)
Elementary school	-0.278 (0.321)
High school	0.277 (0.319)
College	0.598* (0.345)
Constant	-2.846 (2.256)
Chi ²	40.981
Obs.	239
AIC	305.627
BIC	357.774

Notes: Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01
Source: Research Results.

The average Technical Efficiency (TE) was higher for the group of cooperative members, which also presented the highest TE relative to the metafrontier (Table 5). However, there was a small difference to the group of non-member producers. The average TE's concerning the boundaries of each group were 0.922 and 0.839, for the groups of cooperative members and non-members, respectively. This indicates that both groups have the potential to increase their dairy production under their existing production technologies. In this way, the technical efficiency of the members of cooperatives was greater compared to non-member producers.

Table 4 Results of the models of the treatment and control groups and the Metafronteira for dairy farmers served by the “Educampo Leite/Sebrae-MG” Program, Minas Gerais, Brazil, 2018

	All observations	Coop farmers	Non-Coop farmers	Metafrontier
	y=log Gross Income			y=y meta
log Hired Labor	0.0452* (0.0266)	0.0426 (0.0340)	-0.0123 (0.0277)	0.00119 (0.00412)
log Expenses	0.602*** (0.0319)	0.574*** (0.0422)	0.520*** (0.0374)	0.518*** (0.00514)
log Land	-0.00223 (0.00904)	-0.0000346 (0.0115)	-0.00938 (0.0211)	-0.00617*** (0.00208)
log Capital	-0.0182 (0.0186)	-0.0312 (0.0248)	0.0142 (0.0231)	0.00713** (0.00337)
log Animal Stock	0.125*** (0.0285)	0.165*** (0.0367)	0.135*** (0.0510)	0.135*** (0.00561)
log General Expenses	0.231*** (0.0366)	0.241*** (0.0458)	0.312*** (0.0531)	0.313*** (0.00711)
Constant	1.366*** (0.152)	1.241*** (0.208)	1.692*** (0.200)	1.613*** (0.0243)
Usigma Constant	-4.930*** (1.149)	-4.511*** (0.767)	-3.114*** (0.156)	-5.035*** (0.0978)
Vsigma log Animal Stock	0.325 (0.362)	0.634 (0.589)	-11.31** (4.772)	
log Expenses	-0.856*** (0.303)	-1.276*** (0.461)	9.225** (4.453)	
Constant	1.985 (2.779)	3.080 (4.055)	21.32* (11.73)	-11.40*** (0.833)
Chi ²	9709.473	5123.106	336097.761	537300.552
Obs.	239	149	90	239
AIC	-313.746	-176.632	-111.422	-823.319
BIC	-275.505	-143.589	-83.924	-792.031

Notes: Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Source: Research Results.

However, when we compare the results of the metafrontier TE, we identify that the group of non-member producers has a smaller difference to the metafrontier. This shows that non-member farmers are more tech-savvy. Average MTRs demonstrate that dairy farmers produce 9.09% (cooperative members) and 9.87% (non-members) of their potential production outputs with existing technologies. This means that non-member producers are at a higher technological level than cooperative members.

Table 5 Technical Efficiency (TE) and Metatechnology Ratio Estimates for dairy farmers served by the “Educampo Leite/Sebrae-MG” Program, Minas Gerais, Brazil, 2018

	Average	Std Dev	Min	Max
All Dairy Farmers				
Technical Efficiency (TE)	0.936	0.021	0.803	0.973
Metatechnology Ratio	0.938	0.045	0.838	0.999
TE Metafrontier	-	-	-	-
Coop Members				
Technical Efficiency (TE)	0.922	0.032	0.742	0.974
Metatechnology Ratio	0.909	0.030	0.838	0.998
TE Metafrontier	0.838	0.040	0.690	0.957
Non-Coop Members				
Technical Efficiency (TE)	0.839	0.087	0.667	0.999
Metatechnology Ratio	0.987	0.007	0.969	0.998
TE Metafrontier	0.828	0.086	0.665	0.994

Source: Research Results.

We note that joining cooperatives positively affects technical efficiency and, potentially, the income of the analyzed dairy farmers in Minas Gerais. Thus, our results lead us to believe that small non-member producers can benefit from joining a cooperative to improve their productive efficiency through better management of productive activity and access to the market. However, there is space for cooperatives to help their members with the technology of their activities, potentially making them less arduous and more attractive to future generations of milk producers.

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