TECHNOLOGY ADOPTION, PRODUCTION PERFORMANCE AND FACTORS DRIVING FARMERS´ DECISION MAKING PROCESS IN BEEF CATTLE FARMS IN URUGUAY

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Paper prepared for presentation at the 23rd ICABR Conference

"REGULATION & FINANCE OF INNOVATIONS FOR A SUSTAINABLE ECONOMY"

Ravello, Italy: June 4 – June 7, 2019

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Abstract

In 2016, the Sustainable Development Solutions Network (SDSN) project issued the first report with the Agricultural Transformation Pathways (ATP) for Uruguay and two other selected study cases. Beef is one of the main agri-food chains included in Uruguay´s first studies given is the country´s main export, production is the largest in terms of land used (12,6 million ha) and farms involved (44780). After setting Sustainable Development Goals (SDG)-consistent ATPs, the proposed "backcasting" methodology includes the identification of roadblocks to overcome to transition.

Using data from the National Cattle Farm Survey 2016 (1298 farms) this paper addresses the relationship between farm business orientation, farm size, technological level, and production performance. The objective is to understand the main constraints to the adoption of technology and the driving factors to consider in the design of future assistance programs.

Cattle farms were classified according to their livestock business main orientation. A Technological Index (TI) was developed and calculated for each farm using data of application of specific production practices, farm production efficiency indicators and the extension and type of improved pastures in the farm.

Results show a strong and increasing relationship trend between farm size, technological level, production performance and net income, particularly for cow-calf operations. Available facilities for specific technology implementation and excess stocking rate are some of the main factors constraining productivity. Small farmers´ view of cattle accumulation as a denotation of wealth and a secure readily available savings fund needs to be addressed in future programs seeking higher technology use and production.

Key Words

sustainable intensification, SDSN, development, technology adoption, livestock production

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1. Introduction

Understanding the relationship among the multiple factors driving farmers´ decision making process is crucial for policymakers and experts selecting the best pathway to overcome roadblocks and reach goals. This paper addresses the relationship between farm business orientation, farm size, technological level, production performance and economic return in the beef cattle production sector. The objective is to understand the main constraints to the adoption of technology and the main factors to consider in the design of future assistance programs.

Characterize livestock producers with respect to their quantity, size, productive orientation and geographical location is, in itself, an extremely complex task given the variability of conditions that are attributable to each individual producer and to livestock production systems in general. However, there are several works in this field and with over the years, new sources of information are used to come back and update the reality of livestock production.

Through the information generated by the National Cattle Farm Survey 2016 (NCFS), the present work proposes to review the situation of farmers in relation to the previously mentioned dimensions, but focusing on the degree of technological development that they exhibit in their production systems. The analysis of the NCFS allowed determining groups of producers (clusters) based on defined variables, establishing its relative frequency and, therefore, its importance (and productive incidence) in the national total. By combining this valuable source of information (NCFS) with productive and economic results obtained by simulation, the defined clusters were evaluated from the productive and economic point of view, aspects that were not contemplated in the survey. This survey generated a large volume of valuable information about different aspects of livestock production in the country. This article focuses mainly on those farms that include breeding in the production process (cow-calf operations and cow-calf operations that also include pasture fattening/finishing).

2. Background / Theory

The Agricultural Transformation Pathways (ATP) for Uruguay and two other selected study cases issued in 2016 in the frame of the UN´s Sustainable Development Solutions Network (SDSN) project made relevant advances in setting the desired and feasible goals and development objectives for 2030 (Schoowb *et al.*, 2016). Beef is one of the main agri-food chains included in Uruguay´s first studies given is the country´s main export, production is the largest in terms of land used (12,6 million ha) and farms involved (44780).

The so-called “backcasting” approach for “building a vision of the future we want” denotes a process in which a desired target is set for a future date, and then identifies the best pathway towards achieving that target by moving backward in time. Identification of sociological, political and technological roadblocks to overcome to achieve the desired ATP target is part of the SDSN initiative proposed methodology.

This paper aims to understand the relationship among the multiple factors driving farmers´ decision making process as crucial feedback for policymakers and experts selecting the best pathway for sector development. Particularly livestock business orientation, farm size, level of technology use and the resulting production and economic performance are studied to identify the key factors to consider in designing beef sector oriented technological, social and/or financial support programs.

Previous analysis showed a large number of farms with a very low level of technology use, particularly in the cow-calf component of the production process. In most cases, even the most basic and well-known practices, with no implementation incremental cash costs are disregarded.

Well accepted theory among experts is that for small farmers business economic return is not one of the main factors driving their decisions concerning technology adoption and production intensification, even when no incremental cash costs are involved for implementation. But no actual performance and production data was used to support this theory or to evidence farmers´ behavior.

3. Data / Analysis

The NCFS was carried out within the work agreement between the Central Bank of Uruguay (BCU) and the Ministry of Livestock, Agriculture, and Fisheries (MGAP). Due to its national character, in addition to the aforementioned institutions, it demanded the cooperative effort of other organizations including the National Agricultural Research Institute (INIA) (Bervejillo *et al.*, 2018).

The field survey began towards the end of 2016, continuing until winter 2017. The target population of this survey was constituted by livestock farms throughout the national territory. The sample base was the General Agricultural Census of 2011. The base population included: farms with livestock production (cattle or sheep) as their main activity; without commercial dairy production; and with at least 7 livestock units (UG)[1] on the farm.

The sample size was 1,506 cases (5.89% of the target population). The relative error is less than 1% to estimate the total cattle at the country level, with a 95% confidence (Bervejillo *et al.*, 2018).

For the analysis presented in this paper, farms with less than 50 hectares of land were discarded in order to avoid interference from atypical production situations (cropland with low stocking rate, temporary livestock stocking farms, small farmers grazing animals on local roads or public land, etc.). Following the criteria used by the MGAP, they were divided into three groups according to their land size: Small: 50 to 500 ha, Medium: 501 to 1250 ha, Large: more than 1251 ha

4. Findings

Predominant productive systems

By analyzing the composition of each farm cattle herd, plus the support of other variables surveyed, it is possible to identify the different production orientations on the farms. Six groups were classified according to their livestock business main orientation: cow-calf operations (CC), cow-calf operations and fattening of cull cows (CC + fattening cull cows), cow-calf and

[1] 1 Livestock Unit (UG) = 1 adult pregnant breeding cow 380 kg LW, or a steer 380 kg LW

backgrounding (CC+B), cow-calf and pasture fattening/finishing (CC+F), cattle pasture finishing only (F) and cattle backgrounding only (B). Table 1 presents the distribution of production systems combined with the size of the establishments as they were defined.

<TABLE 1>

It is evident the predominance of small farmers in the CC and CC+C. The CC+Fattening cows, CC+F and F the distribution is more homogeneous, although in all cases small farmers are still a bigger proportion.

Technological level in systems that include breeding processes

It is especially interesting to be able to obtain information about production management since other official sources do not provide such indicators. In this section, some key technological variables for the success of the systems that include the breeding process are analyzed, that is for farms with only cow-calf operation (CC) as for those that also include backgrounding (CC+B) or cattle finishing (CC+F).

The survey shows a large number of farms with very low technology level, not applying even the minimum basic management techniques recommended by the national research and extension agencies, even those that do not imply direct effective costs for their implementation. Example of some of these practices includes having a concentrated breeding period, the use of diagnosis of pregnancy, the use of the body condition score to group cows by feed requirements and the test of bulls before the season, among others. The absence of these technologies surely determines a very low production level (Table 2) and therefore, a poor economic return, both by animal and by unit of land.

<TABLE 2>

Figures 1 and 2 show the frequency of use of these basic technologies during the breeding process by the producers, according to their size. Figure 1 shows the close relationship between the size of the farm and the use of technology. While within the large farms (>1250 ha) only 5% of producers have a continuous breeding season, almost half of the small farms use this practice

(48%). Other techniques such as the use of the body condition score do not have such a clear relationship with the farm size.

<FIGURE 1>

Figure 2 presents the frequency of these practices in relation to the number of cows affected. Bars represent the percentage of the total cows of the survey that are included in each group. For example, in the case of the group with “no bulls testing”, 32% of the total cows have been served with bulls without test before the breeding season. Of this 32%, 12% were from small farms, 10% from medium and 9% from large size farms.

<FIGURE 2>

It is important to note that a third of the cows have been served with an untested bull and also have no pregnancy diagnosis. The percentage of cows that were not classified using a body condition score is also high (58%). It is believed that even when a formal numerical classification like the BCS (as it is asked in the survey) it is not performed by farmers, there is some kind of subjective grouping of the animals by their general condition.

Furthermore, farmers were grouped into four levels of technology use according to their business production orientation. For the CC, CC+B, CC+F, and F four technological levels were described (Basic, Adjusted, Improved and Advanced) based on use of specific production practices, production efficiency indicators and the extension and type of improved pastures on the farm. The farmers were assigned to one of the groups based on an algorithm developed including the previous variables. This Technological Index (TI) was intended as a proxy for the intensity of technology use by farmers. It was possible to classified almost 80% of the farmers using this methodology, while the rest had coherency problems with the data. The results of this classification are presented in Figures 3 and 4.

A clear association between farm size and technological levels is shown, similar to the tendency already shown in Figure 1 for some specific practices. Small farmers are more frequent in the Basic level of technology and their presence strongly decrease as the technological level increase. The trend is inverse in the case of the large farms with a higher percentage of farmers of this group in the levels of better technology. The trend is not clear for medium-size farms (Figure 3).

<FIGURE 3>

For the case of the complete cycle (Figure 4) it is observed a growing trend in the proportion of farmers of all sizes as the technological level increase. This uptrend continues up to the improved level for the small and large size farms, while remains up to the advanced level for medium-size farms. There is no appreciable clear trend for the other orientations.

<FIGURE 4>

5. Discussion / Conclusions

The NCFS data was a key tool to confirm (or refute) some of the hypotheses regarding the incidence of these variables in the livestock business sector in the country.

Animal overstocking in the farms is considered by experts one of the most important determinants of poor production performance, in particular on farms that rely on native pasture for animal feeding. The database was filtered to detect situations of high animal stocking rate on the CC and CC+F production orientations focusing on farms based on native pasture grazing.

The main livestock production extension agency has developed the concept of "Safe stocking rate" (Boné *et al.*, 2011) referring to "an average of the different stocking rates that a particular pasture land can support, through different seasons and several years, in a given period of time". According to this concept, "when a number of animals larger than the carrying capacity of the land are maintained for a long period of time (several years), an overstocking situation is generated so the natural equilibrium between the pasture composition and the animal production is broken, degrading the pasture and diminishing the capacity of feeding the herd on that pasture on the long run as a consequence".

In other words, the "safe stocking rate" can be defined like the one that, allowing an economically feasible livestock production, makes it possible to minimize risk when facing climate variability in an agricultural business such as a grazing livestock production, and even to deal with more extreme adverse events like droughts or very rigorous winters.

The probability that, at the time of the survey, the actual stocking rate (ASR) maintained by the farmers was above the adequate stocking rate represented by the “safe stocking rate” (SSR) was estimated through the difference between the probability distributions calculated by simulation of the two variables considered (ASR and SSR). This is equivalent to estimating the probability of (SSR-ASR) > 0. The real stocking rate of the farmers in the survey (Figure 5a) corresponds to its value at July 1st (winter), while the “safe stocking rate” refers to an annual average (Figure 5b). The result of the probability analysis (Figure 5c) reveals that there is a 73,6% probability that the actual stocking rate of the farms was above the stocking rate defined as "safe".

<FIGURE 5>

A high stocking rate generates a demand for forage larger than the amount that can be supplied by the pasture, so animals can not fulfill the requirements needed to produce as expected. On the long run, the continuous defoliation of the species of the pasture produces a significant deficit of reserves in the plants and as a consequence, the productivity of the plant communities are significantly reduced and the disappearance of valuable species occurs.

An adequate stocking rate is a first and fundamental measure to reduce vulnerability to climate change. Although the native grassland is resilient given its adaptation and the high number of species, the continuous overstocking seriously compromises the chances of facing, resisting and recovering from a situation of climatic stress.

Table 3 clearly shows that farms with the lowest level of technology use (Basic) have the highest winter stocking rates, decreasing significantly in the Adjusted level. This behavior is consistent with the theory that for the farmer cattle is not only a production asset but also a form of wealth accumulation. In particular, it has been said that small farmers perceive cattle as a secure readily available savings fund being the main cause of the excess stocking rate. If true, this is an important element to be taken into account for the purposes of communication with the producer and in the transfer and promotion of technological packages seeking a production increase.

<TABLE 3>

Productivity and economic performance

The NCFS does not provide information on the production performance, or data to perform a calculation estimate about it. Based on the use of modeling tools (Soares de Lima, 2009) and the farms´ technological level it was possible to estimate beef production for each farm size group and business production orientation.

Table 4 shows the beef production level per hectare, for each production orientation and technological level. The level of production is higher as the technological levels increase and for the production orientations that have a higher overall biological efficiency (F> CC+F> CC+B> CC).

<TABLE 4>

By averaging the production of each group and weighting by the total occupied land, an average production of 96 kg LW/ha is obtained. This "country average" figure is similar to the annual values reported by extension and consulting organizations obtained from livestock farms records.

The economic result for each group, by technological level, using average prices for the last 4 years, was also estimated through simulation. In this way, effects on benefits and additional direct costs of moving from one technological level to another, or eventually from one orientation to another are evident. Net revenue for each group is shown in table 5.

<TABLE 5>

There is an important jump in income when passing from the Basic to the Adjusted technological level, due to an adjustment on the factors of production, mainly adequating the animal stocking rate and the other associated variables already presented in table 2.

Lower response to intensification is observed in the cow-calf operations given this system is biologically more limited by “energy expensive” processes such as gestation or lactation. In the CC+B, technology intensification determines an acceleration of the males raising process, freeing more pasture for the herd to grow. The finishing only orientation (F) has the highest respond the technology intensification being the result of the incorporation of inputs (improved pastures, supplements) on the animal's individual performance and through an increase in stocking rate.

This article constitutes a first analysis in relation to the situation of livestock production in Uruguay from data from the NCFS. The results obtained highlight the importance of farmers characterization not only considering their productive orientation and size but also the use they make of the available technology. This information will support the development of possible technological trajectories to improve their income.

At the same time, this information is relevant for decision-makers on public policy and for the study of the policies potential impact. It serves as the basis for studying the effect of tools, policies, potential programs to increase production and income, as well as social support programs.

Additionally, the study of the particular characteristics of each group reveals the potential constraints for productive growth, allows to address the resources necessary to promote it and permits to analyze the returns to the private and public investment involved in the process.

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Appendices

Table 1. % of farmers by size and production orientation (% within each orientation)

Production orientation	Small	Medium	Large
Cow calf (CC)	85	13	2
CC + Fattening cull cows	47	36	17
CC + Backgrounding	78	16	7
CC + Finishing	50	25	26
Finishing only	67	24	9
Backgrounding only	61	37	2

Table 2. Some key technologies of the breeding process and their effects on production systems

Technology	Level	Direct effects	Effects on the production system
Stocking rate	High (overstocked)	Low weight gains, low body condition, delayed puberty, reduced native pasture productivity	Low adult weight, low weight of calves at weaning, heifers first breeding not until the age of 3 or more, low pregnancy rate, lower system carrying capacity due to less pasture dry matter production
Bull testing	No	Reproductive disease transmission and dissemination to the breeding herd	Low pregnancy rates, more miscarriages, abortions, low weaning rates
Breeding season	All year round	High weight variability among calves, requirements are not fulfilled by pasture availability	Calves lower sale price, complicated management due to higher weight and age heterogeneity
Pregnancy diagnosis	No	No differential management of pregnant and non-pregnant cows, pregnant cows kept until next breeding season, no cull cow sales	Lower herd efficiency and lower farm productivity
Body condition score (BCS) use	No	Not able to offer differential feeding to different requirements cattle categories	Lower pregnancy rates, lower calves´ weight at weaning, lower cull cows´ weight

Table 3. Stocking rate by production orientation and technological level (UG/ha at July 1st, 2016)

	CC	CC + B	CC + F	F	Total
BASIC	1,08	1,05	1,09	0,86	1,06
ADJUSTED	0,79	0,79	0,83	0,63	0,80
IMPROVED	0,89	0,96	0,90	0,81	0,90
ADVANCED	0,93	1,14	0,91	0,84	0,93
Total	0,96	1,01	0,94	0,80	0,93

Table 4. Calculated productivity by production orientation and technological level (kg LW/ha)

	Basic	Adjusted	Improved	Advanced
CC	44	77	89	98
CC + B	56	71	94	100
CC + F	58	84	105	130
F	90	116	171	239

Table 5. Net revenue by productive orientation and technological level (USD/ha)

	Basic	Adjusted	Improved	Advanced
CC	11	67	72	74
CC + B	23	52	87	81
CC + F	53	88	99	102
F	56	73	92	132

Figure 1. Frequency of farmers NOT using basic technologies during the breeding process (% of farmers within each size group) according to farm size

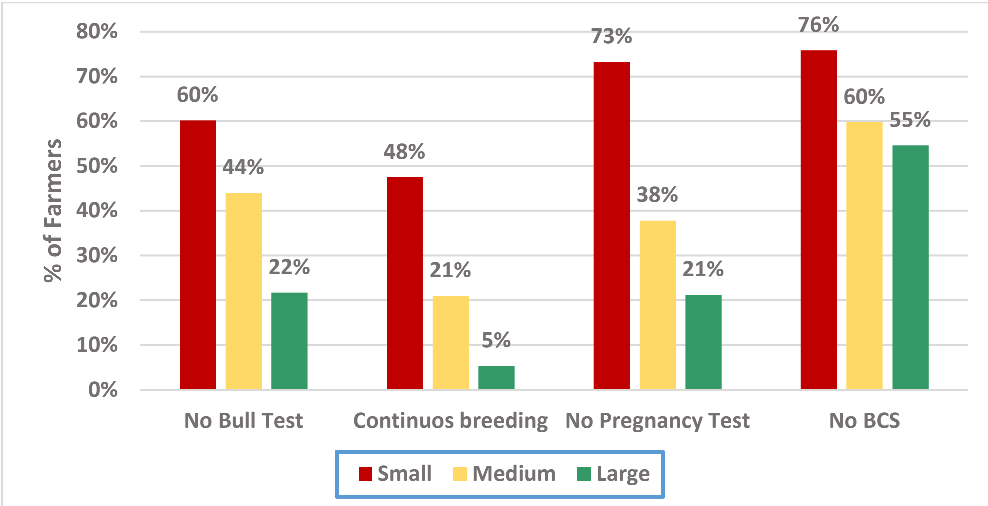

Figure 2. Frequency of cows NOT exposed to basic technologies during the breeding process (% of cows within each size group) according to farm size

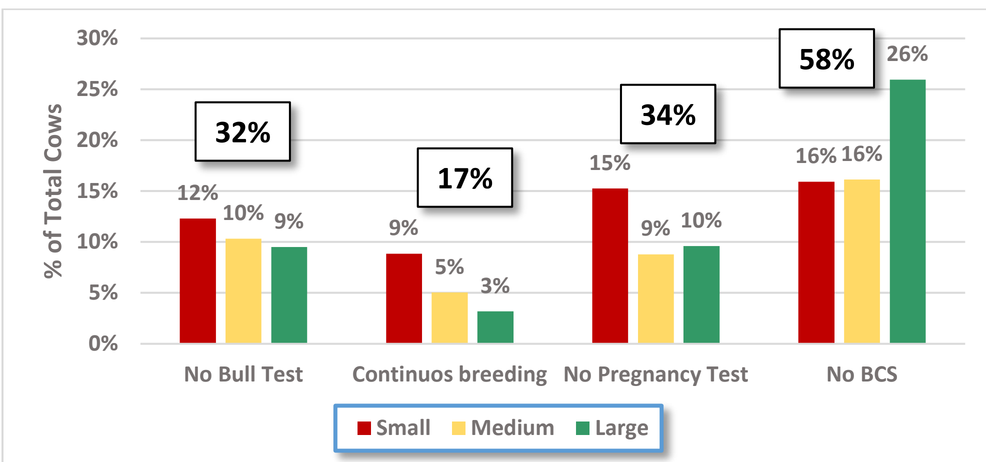

Figure 3. Farmers distribution (% of farmers within each size group) according to technological level and size for Cow-Calf operations

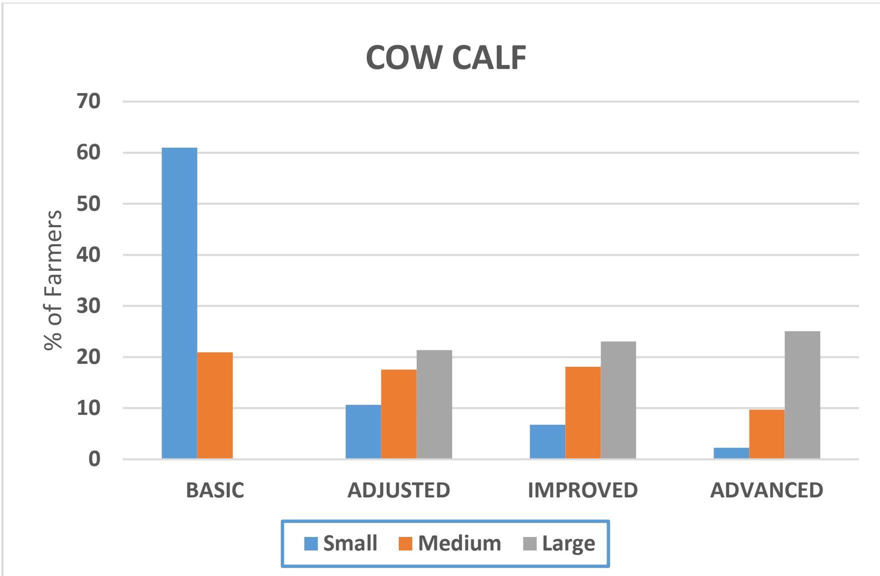

Figure 4. Farmers distribution (% of farmers within each size group) according to technological level and size for Cow-Calf + Finishing operations.

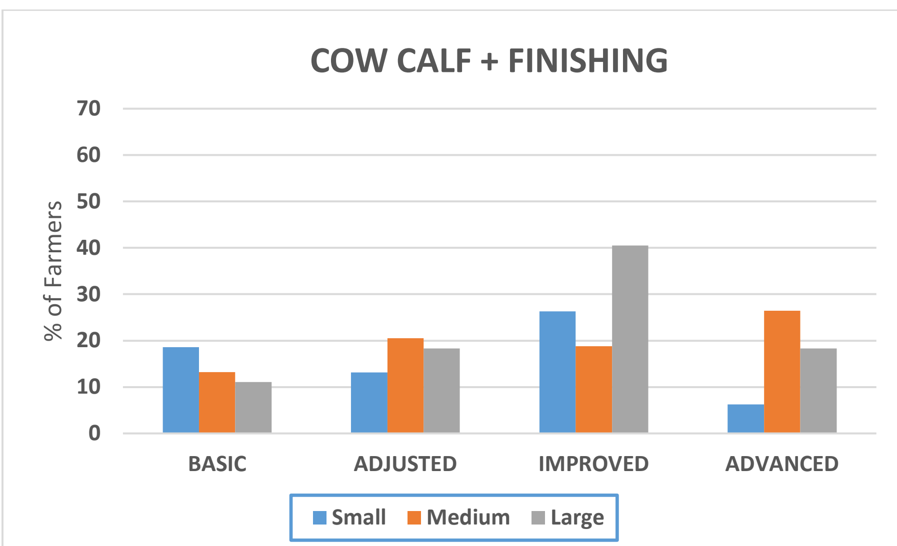

Figure 5. Stocking rate probability distribution (UG/ha): "safe" (A), actual stocking rate (B) and probabilistic analysis of animal overstock (C).