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ANIMAL PRODUCTION

Adoption of beef cattle traceability at farm level in São Paulo State, Brazil

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ABSTRACT: *This paper aimed to identify the determinants of beef traceability adoption at farm level in São Paulo State, Brazil. A sample survey of 32 farmers who adopted the European Union certified traceability and 52 other farmers who did not adopt traceability provided data to test hypotheses on determinant factors. Three binomial logit models were used in the analysis. Results suggested that capital-intensive livestock production system, high scale production, access to specialized information and high level of human and social capital play significant role in the adoption decision.*
Key words: *traceability, certification, technology adoption, agriculture, beef cattle.*

Adoção da rastreabilidade de bovinos de corte no estado de São Paulo, Brasil

RESUMO: *O artigo tem como objetivo identificar os determinantes da adoção da rastreabilidade por pecuaristas no estado de São Paulo, Brasil. Uma amostra de 32 produtores que adotaram a certificação da rastreabilidade para a União Europeia e 52 que não adotaram a rastreabilidade forneceu dados para testar hipóteses a respeito de fatores determinantes. Três modelos logit binomial foram utilizados na análise. Os resultados sugerem que o sistema de produção pecuária intensiva, a elevada escala de produção, o acesso a informação especializada e a rede de relacionamentos desempenham papel significativo na decisão de adoção.*
Palavras-chave: *rastreabilidade, certificação, adoção de tecnologia, agricultura, pecuária.*

INTRODUCTION

Problems with food contamination and the Bovine Spongiform Encephalopathy epidemic in Europe have raised concern about quality and food safety in the beef industry since the 1990s. These fostered the adoption and diffusion of regulations, certification schemes and management innovations in global agrifood chains.

The European Union (EU) demanded traceability to access its fresh beef market. Food safety regulation was adjusted in Brazil in order to meet this requirement and sustain trade with the EU. In 2002, traceability became operational in the country by means of the Brazilian System of Identification and Certification of Bovine and Bubaline Origin (SISBOV), a voluntary system coordinated by the Ministry of Agriculture, Livestock, and Supply. In order to export fresh beef to the EU, the export industry has to obtain cattle from farms that are not only certified in the SISBOV but also listed in the Trade Control and Expert System (TRACES), which was created by the EU for veterinary health control. TRACES is a management tool for sanitary requirements on intra-EU trade and importation of animals, semen and embryo, food, feed and plants.

The practical aspects of the adoption of traceability, assuming the SISBOV requirements, involved the adoption of a set of management tools and technologies. SISBOV certified farms to adopt technologies for animal identification, storage of records and inventory controlling. Hardware and

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software information technologies are necessary, as well as labor training. As a return for their investment, farmers expect to receive premium prices from beef export companies.

The number of Brazilian farms in the SISBOV was still low in 2015: 1, 628 farms, accounting for 0.5% of the number of farms with more than 50 head of bovines (BRASIL, 2015). Considering the observed low diffusion of this certification, one can raise the following question: why had some farmers adopted it while many other did not? Thus, the aim of this empirical study is to identify factors determining the adoption of SISBOV certification at farm level.

Theoretical approach relies on the literature of technology adoption in agriculture. Technology adoption is influenced by a set of factors. Some of them may speed up, while other may slow down or even prevent diffusion (SUNDING & ZILBERMAN, 2001). BOCQUET et al. (2007) described two approaches for the study on technology adoption and diffusion. In the first, the diffusion of an innovation can be either fostered or hampered by exogenous determinants. Investigations on this approach tried to identify these factors. In the second approach, a concept of complementarity (MILGROM & ROBERTS, 1990) is brought into the analysis. It is assumed that an innovation is adopted as part of the firm's overall strategy. Therefore, other organizational and technological practices are jointly adopted (BOCQUET et al., 2007). Empirical studies use both approaches to identify determinants of technology adoption (VICENTE, 2002; BOCQUET et al., 2007; MONTEIRO & CASWELL, 2009; CANAVARI et al., 2010; GALLIANO & OROZCO, 2011; LIAO et al., 2011; DILL et al., 2015; VINHOLIS et al., 2016). A review on these studies pointed out factors related to farmer and farm characteristics. In this paper, we tested the effect of factors related to information, human capital, access to credit, risk aversion, farm size and production system on the decision of farmers to adopt certification. The next section presents the econometric logit model, the sample of farms, and the variables used in the analysis. The third section presents and discusses the results of the models. Final remarks are presented in Section 4.

MATERIALS AND METHODS

A logit model for discrete choice dependent variables was used in the empirical analysis. Several empirical studies on technology adoption have used logit models, some of them performed to test hypotheses on the adoption of traceability system and information technologies (MONTEIRO & CASWELL, 2009; GALLIANO & OROZCO, 2011; LIAO et al., 2011). The dependent variable is the dichotomous choice, adoption/non-adoption, which is explained by a set of independent variables. In this article, it is assumed that a farmer decides to adopt, or not, the traceability and its SISBOV certification after taking into consideration a set of factors, which are represented by independent variables.

The model can be described as

$$y_i^* = \beta' X_i + u_i \quad i = 1,\dots,N \tag{1}$$

where y_i* is defined as a latent not directly observed variable, and X_i is a set of explanatory variables. The observed variable, y, is a dummy, assuming y_i=1 if farmer *i* has adopted and y_i=0 if farmer *i* has not adopted. The observed values of *y* are assumed to be related to *y**:

$$yi = 1 \text{ if } yi^* > 0 \tag{2}$$

$yi = 0$ *otherwise* and

$$Pr(y_i = 1) = Pr(y_i^* > 0) = Pr(u_i > -\beta' X_i) = 1 - F(-\beta' X_i) = F(\beta' X_i) \tag{3}$$

where *F* is the assumed cumulative symmetric distribution function for *u*. Maximum likelihood procedures are used to estimate parameters β. A logit model is obtained if a logistic cumulative distribution is assumed:

$$\Pr(y_i = 1) = \frac{e^{\beta X}}{1 + e^{\beta X}} \tag{4}$$

The 'odds ratios', e^{β}, were calculated to identify the effect of changes in the explanatory variables on adoption. An odds ratio greater than 1 means a positive effect of the respective explanatory variable on adoption, while an odds ratio smaller than 1 means a negative impact.

A survey questionnaire was designed to collect data from a sample of 32 certified and 52 counterfactual non-certified farms. Certified farms were randomly selected from a population of 137 farms of the State of São Paulo; all of them were listed in TRACES. Sampled farms are mostly located in the main regions of beef cattle raising of the state of São Paulo: Araçatuba (19); Presidente Prudente (17); Ribeirão Preto (12); Bauru (13); São José do Rio Preto (13); other regions (10). Personal interviews were conducted in 2011 with the decision makers; most of them were the farmers themselves, their relatives or managers. Counterfactual non-certified farms were selected in the neighborhood of the sampled certified farms. This sampling technique decreased the cost of the survey and reduced the variance of characteristics of the environment, such as topography, climate, water availability and soil.

The dependent variable of the model equals 1 if the farmer is certified and 0 if he/she is not. Table 1 presents the definition of the independent variables used to test hypotheses on six factors determining adoption: information, human capital, access to capital, risk aversion, scale, and complementarity. The expected effects of all independent variables are in the last column of table 1. They are in accordance with the literature review on technology adoption (FEDER et al., 1985; MILGROM & ROBERTS, 1990; VICENTE, 2002; BOCQUET et al., 2007; MONTEIRO & CASWELL, 2009; CANAVARI et al., 2010; GALLIANO & OROZCO, 2011; SOUZA FILHO et al., 2011; DILL et al., 2015; VINHOLIS et al., 2016).

Access to information is central in epidemic models of technology adoption. This seminal approach emphasizes the key role of information to speed up technology diffusion. Four variables were used in the model to assess the role of information: Internet, extension, association and informal group. The Internet Web has been largely used to disseminate information. Therefore, this variable is used in the model to test the effect of the access to specialized newsletters through the Internet. The effect of the access to private paid extension services was also evaluated. The variable association was introduced in the model to test the effect of membership of an association and attendance at its meetings and events, as they are means to access information. Finally, participation in informal network, such as regular meetings of farmers to discuss joint strategies, was likewise tested.

Two variables were included to test for human capital: education and experience. In the literature, it is assumed that the higher the level of education and experience, the higher individuals' ability to process information, as well as perceive and respond to opportunities arising from the market. Education was measured by the number of years of formal schooling, while experience identifies if the farmer has previously undertaken another certification.

A special attention was given to the role of previous adoption of feedlot in the adoption of SISBOV certification. It is supposed that cost and effort in adopting traceability is lower for farmers who already run a high capital intensive production system, such as feedlot, because of complementarity. Feedlot systems are better equipped with information technology than less intensive production systems adopted in beef farms in Brazil, thus adoption of traceability is just one additional step forward. Therefore, the role of complementarity could be tested.

Finally, the model provides an evaluation of the effect of farmers´ risk aversion behavior on adoption by means of a psychometric test. The variable risk aversion, which ranges from 8 to 40, is the 'Harm Avoidance' dimension of the test validated by ADAN et al. (2009). It is supposed that an individual's attitude towards risk is an intrinsic characteristic and a key variable in decision-making on the adoption of a new technique, even when its potential results are widely known. Several aspects associated with the adoption of technologies, such as the expectation of input

Table 1 - Variables to test hypotheses on factors determining adoption.

Factor	Variable	Variable definition	Expected effect
Information	Internet	If the farmer has access to paid specialized newsletter by internet = 1, = 0 otherwise.	(+)
	Extension	If the famer has access to private paid extension service = 1, = 0 otherwise.	(+)
	Association	If the farmer is member of an association and attend its meetings and events =1, = 0 otherwise.	(+)
	Informal group	If the farmer is member of informal groups of farmers = 1, = 0 otherwise.	(+)
Human capital	Education	Farmer's years of formal schooling.	(+)
	Experience	If the farmer has previously adopted other certification = 1, = 0 otherwise.	(+)
Access to capital	Credit	If the farmer had access to credit in the previous year = 1, = 0 otherwise.	(+)
Risk aversion	Risk Aversion	Score ranging from 8 to 40, measuring *Harm Avoidance* dimension of TCI-56 test (ADAN et al., 2009).	(-)
Scale	LogSize	Natural logarithm of the number of hectares of the farm.	(+)
Complementarity	Feedlot	If the farmer adopts feedlot = 1, = 0 otherwise.	(+)

and sale prices, are subject to subjective evaluation by the farmer, mainly in the presence of incomplete information. These aspects pose potential risks in the process of technology adoption. The model of ADAN et al. (2009) describes seven dimensions for explaining individual differences in behavior. The 'Harm Avoidance' dimension is used as a proxy for risk aversion (EKELUND et al., 2005).

The empirical approach consisted of providing eight statements to be assessed by famers. For each statement, the farmer can choose an answer from five options from a Likert scale ranging from 1 (definitively false) to 5 (definitively true). A 'Risk aversion' indicator was then constructed for each farmer as a summation of the points established in his/her eight answers. Six respondents refused to evaluate the statements, so the Logit Model 2 was performed with 78 observations.

RESULTS

Table 2 presents the mean and standard deviations of the independent variables, according to both certified (adopters) and non-certified farms (non-adopters).

Table 3 presents the odds ratios of these variables in three logit estimations using stepwise method. All estimations have been undertaken using Statistica 10.0. Model 1 consists of variables related to information and human capital. Model 2 includes variables related to risk aversion, scale and complementarity. Model 3 includes variables related to social interaction and access to credit. The likelihood ratio was used to test the hypothesis that all coefficients in the models were equal to zero. The chi-square in Model 1 was 21.53. With four degrees of freedom, the critical value at 5% significance level was 9.49. In Model 2, the chi-square was 33.30, and in Model 3 it was 52.83. The critical value at 5% significance and four degrees of freedom was 12.59, so the joint hypothesis that all coefficients of each model are equal zero was rejected. Three models predicted correctly 70%, 77% and 84% of results, respectively. Odds ratios (e^{β}) were transformed by the formula $[(e^{\beta}-1)*100]$, which shows, in terms of percentage points, the effect of a unit change in the independent variable on the probability of adoption.

Results of Model 1 are consistent with the theoretical framework on diffusion and adoption of innovation, with the exception of variable *Extension*. Odds ratios of the variables *Experience, Internet* and *Education* are significant at 1%, 5% and 10% levels, respectively. Therefore, we can accept that information and human capital play an important role in the adoption of SISBOV certification. Farmers who have had (i) experience with another certification, have (ii) access to paid information and have (iii) more years of schooling are more likely to adopt SISBOV certification.

Previous experience in the field related to a new technology increases the likelihood of adoption, as shown in the literature review. The adoption of SISBOV certification requires the adoption of management tools for production control and compliance with inspections, which are similar to those required by other certifications. Prior experience can reduce the time and cost of implementation of SISBOV. This result confirms other empirical studies, such as the

Table 2 - Mean and standard deviation of variables, certified and non-certified farms.

		------------------Certified farms-----------------		----------------Non-certified farms--------------	
	N	mean	s.d.	mean	s.d.
Internet	84	0.56	0.50	0.25	0.44
Education	84	16.38	1.70	15.00	2.91
Experience	84	0.50	0.51	0.13	0.34
Association	84	0.38	0.49	0.06	0.24
Informal group	84	0.63	0.49	0.23	0.43
Extension	84	0.59	0.50	0.46	0.50
Credit	84	0.59	0.50	0.77	0.43
Risk aversion	78	22.77	6.41	22.91	6.60
LogSize*	84	8.19	1.65	6.81	1.44
Feedlot	84	0.41	0.50	0.06	0.24

*The geometric mean of the size of farms is 11.6 hectares, for adopters, and 2.1 hectares, for non-adopters.

Table 3 - Estimates of the Logit Model.

Variable	----------------Model 1-----------------			-------------------Model 2-----------------			----------------Model 3-----------------		
	Odds Ratio	Std. Error	*P*	Odds Ratio	Std. Error	*P*	Odds Ratio	Std. Error	*P*
Intercept	0.023	2.270	0.098	0.008	3.228	0.137	2.728	0.690	0.146
Experience	2.239*	0.300	0.007	1.919***	0.333	0.050	1.306	0.408	0.513
Internet	1.695**	0.264	0.046	1.405	0.319	0.287			
Extension	0.937	0.272	0.812						
Education	1.266***	0.140	0.093	1.232	0.162	0.199			
Risk aversion				1.054	0.051	0.301			
Feedlot				2.672**	0.395	0.013	5.179*	0.495	0.001
LogSize				1.000**	0.000	0.040	1.000***	0.000	0.057
Informal group							2.515**	0,379	0.015
Association							2.829**	0.472	0.028
Credit							0.271*	0.429	0.002
N		84			78			84	
Chi^2		21.53			33.30			52.83	
Log-likelihood		-45.05			-35.76			-29.41	
Nagelkerke R^2		0.308			0.470			0.635	
Prediction (%)		69.83			77.49			84.25	

Note. Coefficients significant at 1%*, 5%**, and 10%***

adoption of EurepGAP traceability in the production of pears in Portugal (MONTEIRO & CASWELL, 2009).

The odds ratio of *Internet* was significant, showing positive impact on the likelihood of adoption of SISBOV certification. Use of the Internet Web to diffuse information has been growing in recent years in rural areas. Agricultural newsletters with experts´ analyses can reach farmers quickly, while providing information on price, domestic and international markets, new technologies, as well as online courses. Access to high quality information provides advantages to the potential adopter. This result corroborates the empirical study of DILL et al. (2015). The level of farmers' education is high, with mean of 16 and 15 years of schooling for both adopters and non-adopters (Table 2). In Model 1, the odds ratio of *Education* is significant at 10% level and shows a positive effect on the probability of adoption. This result confirms other empirical studies (VICENTE, 2002; MONTEIRO & CASWELL, 2009).

The odds ratios of variables *Risk Aversion*, *Feedlot* and *Size* were tested in Model 2. The odds ratios of *Size* and *Feedlot* are significant at 5%, while the odds ratio of *Risk Aversion* is not statistically significant. This model shows that the probability of adoption significantly increases when farmers raise cattle in *Feedlot* system as a strategy of fattening. This result confirms the complementarity of SISBOV certification and high capital-intensive production system, such as Feedlot. The latter is not only a capital-intensive production system but also managerial-intensive. Management of feedlot systems involves many managerial tools, skills and information technologies that are necessary for the adoption of traceability and its certification. The setup cost and effort required to implement traceability is smaller for adopters of capital-intensive production systems. Moreover, this production system has a more complex cost structure, narrow profit margin and greater risk price. It could benefit from joint adoption with SISBOV certification, since farmers can get premium prices for traced cattle.

The odds ratio of *LogSize* shows that the probability of adoption significantly increases when size increases. This result confirms other empirical studies (SUNDING & ZILBERMAN, 2001; VICENTE, 2002; BOCQUET et al., 2007; GALLIANO & OROZCO, 2011). In agriculture, the size of the farm is a key factor in explaining the adoption of technologies. Larger farms, with greater access to credit and information, are in better position to deal with risk and to test new practices (SOUZA FILHO et al., 2011). Size is also associated with economies of scale (GALLIANO & OROZCO, 2011). As SISBOV certification requires fixed costs, such as the certification fees and software, larger firms are in better position to reduce unit cost.

In Model 3, the odds ratios of *Informal Group*, *Association* and *Credit* were tested for statistical significance. The odds ratios of *Informal Group* and *Association* are significant at 5%, and show positive impact on the adoption. These results are consistent with the theoretical framework on the importance of information, as well as the aforementioned sources of information for technology adoption. The odds ratio of *Feedlot* became significant at 1% level, and the odds ratio of *Size* is statistically significant at 10%. These results show that social capital, in addition to size and intensity of capital significantly increases the likelihood of adoption of SISBOV certification.

The positive impact and significance of the odds ratio of *Association* confirm other studies (FEDER et al., 1985; MONTEIRO & CASWELL, 2009; DILL et al., 2015). However, being a member of an association does not ensure access to key information and other benefits of association. The result shows that the likelihood of adoption increases when farmers attend association meetings and events, where information can be disclosed and exchanged among peers. Membership of informal groups, as shown by the odds ratio of variable *Informal Group*, has similar effect.

The odds ratio of *Credit* is statistically significant at 1% level, but with the opposite expected impact, as seen in other studies. In fact, most SISBOV certified farmers run livestock activity by means of their own financial resources, which can explain this result.

CONCLUSION

The analysis suggested that the probability of adoption SISBOV certification by farmers in the State of São Paulo is positively associated with scale of production and capital-intensive production system. The latter requires management tools and information technology, which are also required in the adoption of traceability and SISBOV certification. In addition, previous experience with other certification and participation in farmers´ association and informally organized groups increase the probability of adoption. Farmers with these characteristics also have a high level of formal education and are able to access information through many sources, including paid sources. This profile differs from most Brazilian farmers, which helps to explain the low diffusion of SISBOV certification and traceability so far.

The dataset refers to a single innovation and state, which limits the generalization of results to other regions of the country. In addition, the cross-sectional nature of the data hinders unambiguous detection of causalities. Thus, the findings are just the confirmation of associations between traceability adoption and other variables in a given point in time. Future research should aim at conducting a dynamic analysis, incorporating longitudinal information.

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REFERENCES

ADAN, A. et al. A reduced temperament and character inventory (TCI-56) psychometric properties in a non-clinical sample. **Personality and Individual Differences**, v.46, n.7, p.687-692, 2009. Available from: <http://dx.doi.org/10.1016/j.paid.2009.01.023>. Accessed: Oct. 01, 2015. doi: 10.1016/j.paid.2009.01.023.

BOCQUET, R. et al. Complementarities in organizational design and the diffusion of information technologies: an empirical analysis. **Research Policy**, v.36, n.3, p.367-386, 2007. Available from: <http://dx.doi.org/10.1016/j.respol.2006.12.005>. Accessed: Oct. 08, 2015. doi: 10.1016/j.respol.2006.12.005.

BRASIL. MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO (MAPA). **Sistema brasileiro de identificação e certificação de bovinos e bubalinos (SISBOV)**. Available from: <http://www.agricultura.gov.br/animal/rastreabilidade/sisbov>. Accessed: Oct. 01, 2015.

CANAVARI, M. et al. Traceability as part of competitive strategy in the fruit supply chain. **British Food Journal**, v.112, n.2, p.171-186, 2010. Available from: <http://www.emeraldinsight.com/doi/pdfplus/10.1108/00070701011018851>. Accessed: Oct. 05, 2015. doi: 10.1108/00070701011018851.

DILL, M.D. et al. Factors affecting adoption of economic management practices in beef cattle production in Rio Grande do Sul state, Brazil. **Journal of Rural Studies**, v.42, p.21-28, 2015. Available from: <http://www.sciencedirect.com/science/article/pii/S0743016715300206>. Accessed: Sep. 25, 2015. doi: 10.1016/j.jrurstud.2015.09.004.

EKELUND, J. et al. Self-employment and risk aversion—evidence from psychological test data. **Labour Economics**, v.12, n.5, p.649-659, 2005. Available from: <http://dx.doi.org/10.1016/j.labeco.2004.02.009>. Accessed: Oct. 16, 2015. doi: 10.1016/j.labeco.2004.02.009.

FEDER, G. et al. Adoption of agricultural innovations in developing countries: a survey. **Economic Development and Cultural Change**, v.33, n.2, p.255-298, 1985. Available from: <http://www.jstor.org/stable/1153228>. Accessed: Oct. 01, 2015.

GALLIANO, D.; OROZCO, L. The determinants of electronic traceability adoption: a firm-level analysis of French agribusiness. **Agribusiness**, v.27, n.3, p.379-397, 2011. Available from: <http://onlinelibrary.wiley.com/doi/10.1002/agr.20272/full>. Accessed: Oct. 08, 2015. doi: 10.1002/agr.20272.

LIAO, P.A. et al. Why is the food traceability system unsuccessful in Taiwan? Empirical evidence from a national survey of fruit and vegetable farmers. **Food Policy**, v.36, n.5, p.686-693, 2011.

Available from: <http://www.sciencedirect.com/science/article/pii/S030691921100087X>. Accessed: Oct. 08, 2015. doi: 10.1016/j.foodpol.2011.06.010.

MILGROM, P.; ROBERTS, J. The economics of modern manufacturing: technology, strategy, and organization. **American Economic Review**, v.80, n.3, p.511-528, 1990. Available from: <http://www.jstor.org/stable/2006681>. Accessed: Oct. 01, 2015.

MONTEIRO, D.M.S.; CASWELL, J.A. Traceability adoption at the farm level: An empirical analysis of the Portuguese pear industry. **Food Policy**, v.34, n.1, p.94-101, 2009. Available from: <http://dx.doi.org/10.1016/j.foodpol.2008.07.003>. Accessed: Oct. 01, 2015. doi: 10.1016/j.foodpol.2008.07.003.

SOUZA FILHO, H.M. et al. Condicionantes da adoção de inovações tecnológicas na agricultura. **Cadernos de Ciência & Tecnologia**, v.28, n.1, p.223-255, 2011. Available from: <https://seer.sct.embrapa.br/index.php/cct/article/view/12041>. Accessed: Oct. 08, 2015.

SUNDING, D.; ZILBERMAN, D. The agricultural innovation process: research and technology adoption in a changing agricultural sector. In: GARDNER, B.; RAUSSER, G.C. **Handbook of agricultural economics**. Amsterdam: Elsevier, 2001. p.207-261.

VICENTE, J.R. **Pesquisa, adoção de tecnologia e eficiência na produção agrícola**. São Paulo: Agência Paulista de Tecnologia dos Agronegócios (APTA), 2002. 153p.

VINHOLIS, M.M.B. et al. Complementarity in the adoption of traceability of beef cattle in Brazil. **Production Journal**, v.26, n.3, p.540-550, 2016. Available from: <http://dx.doi.org/10.1590/0103-6513.193615>. Accessed: Sept. 12, 2016. doi: 10.1590/0103-6513.193615.