DETERMINANTS OF THE ADOPTION OF IRRIGATION TECHNOLOGIES BY CITRUS GROWERS OF THE STATE OF SÃO PAULO-BRAZIL

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The objective of this paper is to identify and analyze the factors determining the adoption of irrigation technologies by citrus growers located in the state of São Paulo, Brazil. Data was collected among a representative sample of 98 producers of four of the state's regions, comprising 34 adopters and 64 non-adopters of irrigation systems. The data were analyzed by using descriptive statistics and a logit model. The results showed that the factors that increase the likelihood of adoption of irrigation systems are the number of varieties of citrus grown, the composition of the agricultural income, technical assistance, and education level. Based on these results, public and private strategies were presented, aiming towards an increase in the use of irrigation systems in Brazilian citrus orchards.

Keywords: Technology adoption; irrigation; citrus producers.

1. Introduction

Brazil is the world´s largest producer of fresh orange and orange juice, and the state of São Paulo concentrates about 80% of the national production of both products (NEVES *et al.*, 2010). In 2014, Brazil produced more than 11 tons of fresh orange and about 1.0 million tons of orange juice (IEA, 2014; USDA, 2014). Thus, this sector is very important to the economy of the country because more than 90% of the orange juice produced is exported, and the main destinations include the European Union (EU) and the United States of America (USA) (CITRUSBR, 2013).

Since the mid 90´s there has been a significant reduction in the number of citrus growers in the state. According to Lupa (2008) and Conab (2013), the number of citrus growers fell from 35.883 in 1995/1996 to 10.100 in 2013, respectively. Many factors can be pointed as the cause of this significant reduction in the Brazilian citrus belt (São Paulo and Minas Gerais Triangle region), but it was mainly the increase in production costs associated with the low prices paid per orange box that reduced the grower's profitability, leading to the abandonment of the activity by many producers.

Given this situation, some factors have become very important for the permanence of the citrus producers in the activity. Among these is the need to increase production factor yields, which can reduce the production costs per orange box, thus increasing the grower's profitability. Adoption of irrigation systems is supposed to improve factor yields. This technology has presented positive results related to the increase of orange productivity (KOO & SMAJSTRLA, 1984; ZANINI *et al.*, 1998; SILVA *et al.*, 2009), which can reduce production costs and augment the profits of the citrus growers. Moreover, the use of irrigation can also improve the size, weight and juice content of the fruits (BARREDA *et al.*, 1984; PRADO *et al.*, 2007).

Providing water is very important for citrus plants in all stages of their development, but the most critical period happens during the flowering, until the fruit reaches one inch in diameter. The water stress at this stage can be very damaging to the production (COELHO *et al.*, 2004). In general, citrus fruits need from 600 to 1200 mm of well distributed water per year (BEM MECHLIA & CARROL, 1989). In Brazilian citrus orchards, the most common irrigation systems are sprinklers and drip irrigation. The latter is the most adopted among producers, since it is more efficient in the use of water (NEVES *et al.*, 2010).

In spite of the benefits of using irrigation systems, the adoption of such technologies is still very low among the citrus growers. It is estimated that, in 2010, 130.000 hectares of orange groves were irrigated in the Brazilian Citrus Belt (NEVES *et al.*, 2010), corresponding to approximately 21% of the total planted area of orange in the belt (IBGE, 2011).

Thus, considering that the percentage of diffusion of such systems is still low among the producers and that increasing the diffusion of these systems is desirable, due to its benefits to the crop and its profitability, the following research question can be raised: *which are the factors that could increase the diffusion of the irrigation systems in the citrus orchards*?

Considering the context exposed, the main objective of this study was to identify and analyze the determinants of the adoption of irrigation systems by citrus growers of the state of São Paulo, Brazil. In order to achieve this purpose, an empirical investigation was held among producers located within four of the state's meso-regions. The present study is relevant because, despite the importance of the adoption of irrigation systems in the citrus orchards, so far no study has been conducted regarding this subject in Brazil. Efforts towards understanding why some producers adopt irrigation systems, while many others do not, will help in the formulation of public policies and private strategies for the sector.

2. Conceptual Framework

2.1. Models of technology adoption in agriculture

Several empirical studies have analyzed the adoption of technology in agriculture, especially in developing countries, in which the majority of the population makes a living from agriculture. Adopting a new technology aims to increase the productivity of the crops, but they are rarely immediately adopted by all of the potential adopters, and a lot of effort has been made in order to understand this phenomena.

In this section, some of the technology adoption models found in the literature will be briefly described. Griliches (1957) conducted one of the first studies involving the adoption of innovation in agriculture. In his work, he analyzed the adoption of hybrid corn in the United States of America by using the epidemic model. The epidemic model considers technology diffusion as a process very similar to the spread of a disease, in which the frequency of contacts between adopters and potential adopters of the technology can affect the time and speed of its diffusion (GEROSKI, 2000).

Over time, the number of adopters increase as well as the information on the use of the new technology, reducing the risk associated with the adoption. This situation leads to an increase in the number of adopters and a decrease in the number of potential adopters. The cumulative frequency of adopters over time creates a technology diffusion curve with a sigmoid shape, called the “S” curve. However, this model has limitations, since there exists only one explanatory variable (the cumulative adoption) that works as a proxy for the internal mechanism of diffusion of word-of-mouth information, and it is based on aggregate data rather than individual data, which could best explain the adoption decision process (GEROSKI, 2000).

The probit model has a different approach. The individuals’ decisions are at the center of the analysis. The adoption of a new technology by the potential adopters occurs when a set of explanatory variables reaches a certain threshold level that can vary over time because of changes in the price of the technology and its technical parameters (SOUZA FILHO, 1997).

Compared to the epidemic model, this model made a significant advance because the information about the technology, such as its characteristics and profitability, are widespread, and the heterogeneity among the potential adopters determines the differences in adoption, being it a key element of this process (BOCQUET *et al.*, 2007). In agriculture, this model was used by David (1966) e Davies (1979) to analyze the adoption of a mechanical harvester in the USA.

The model considers the heterogeneity among potential adopters as a factor that impacts the decision of adopting a new technology, by calculating the probability of an individual to adopt. The outputs of the probit models are very similar logit models (which assumes a logistic distribution instead of a normal distribution), but the data from the logit model can be easier to interpret. In agriculture, these models have been widely used to study technology adoption.

2.2. Determinants of adoption of irrigation systems in agriculture

The review of the literature shows three groups of variables as determinants for the adoption of irrigation systems in agriculture. Most of the studies are concerned with the adoption of more efficient irrigation technology instead of less efficient ones, but they offer important information. The first group is based on the characteristics of the farmers and comprises variables such as educational level, farming experience, participation in farmers' organizations (cooperatives and/or associations), and agricultural income.

According to Bagheri & Ghorbani (2011), in Iran, the behavior of adopting microsprinkler irrigation was positively influenced by producers with higher education levels. The same result was obtained by Namara et al (2007), in India, in which the more highly schooled producers of leguminous plants and oilseeds had a greater probability to adopt drip and micro sprinkler irrigation, which are considered more efficient technologies in water saving. In general, it is expected for producers with higher education levels to be better informed about the existence and performance of different irrigation technologies (ABDULAI *et al.*, 2011).

Farming experience can be measured by the number of years that farmers work in agriculture or their age. Younger farmers in Iran are more willing to accept new irrigation technologies and more capable of seeing advantages in such systems (KALANTARI *et al.*, 2010). On the other hand, according to Abdulai *et al.* (2011), in Ghana, although the eldest vegetable producers seems to be more conscious about the adoption of new irrigation technologies, this only occurs until up to 33 years, when they begin to have less awareness on adoption. In Greece, the younger producers of olives as well as those with the higher levels of education are more likely to adopt new irrigation technologies (KOUNDOURI *et al.*, 2006).

Participation in farming organizations constitutes an important social network in which the producer can obtain information on new technologies. Vegetable producers in Ghana who participate in such organizations are more likely to adopt efficient irrigation systems (ABDULAI *et al.*, 2011).

The income of producers is also an important variable regarding the adoption of irrigation systems. Off-farm income, especially from non-agricultural activities, can stimulate the adoption of irrigation, as additional source of capital is available. However, the likelihood of adoption decreases when off-farm income becomes the main source of living (NAMARA *et al.*, 2007).

The second group of variables is based on characteristics of the farms and the agricultural production, such as the size of the farm, the diversification of the production, and the availability of water. According to Mohammadzadeh *et al.* (2014), apple producers from Iran with larger farm areas have more financial resources to install drip irrigation within their properties, instead of other types of systems. In this same country, the adopters of microsprinkler irrigation possess larger properties in comparison to non-adopters and producers who abandoned the use of irrigation (BAGHERI & GHORBANI, 2011).

Diversifying the production increased the likelihood of adopting integrated technologies of supplementary irrigation and water harvesting for producers of potatoes, wheat, and other commercial crops in China (HE *et al.*, 2007).

The third group of variables is related to systemic factors, such as access to rural credit and diffusion of information. When more credit is available for producers, the speed of adoption of drip irrigation by fruit and other crops producers in Spain is higher (ALCON *et al.*, 2011). In the same direction, according to He *et al.* (2007), in China, the higher the credit availability, the greater the probability of adoption of irrigation by farmers.

Adoption of irrigation systems is also affected by the availability of information, since it contributes to increasing the knowledge on new technology. In Spain, producers who obtain knowledge of the technology through specialized people in agriculture are more likely to adopt irrigation than those who obtain their information from other producers (ALCON *et al.*, 2011). In Ghana, the number of yearly extension visits was crucial for the adoption of irrigation technologies (ADEOTI, 2009).

3. Research Methodology

The information used in this study to identify the determinants of the adoption of irrigation technology by citrus producers was obtained by means of a structured questionnaire. Data collection was undertaken from January to October 2014 from a representative sample of 98 citrus growers, including 34 adopters of irrigation systems and 64 non-adopters. In total, the producers possessed 263 properties with citrus, mainly located in four regions of São Paulo: Araraquara, Campinas, Piracicaba and Ribeirão Preto.

Personal interviews were held, providing information on farmers and farm characteristics, as well as on the citrus production of 2013/14 crop season.

Descriptive statistics (mean, standard deviation and frequency) was used to discriminate the group of producers who adopted irrigation systems from the group of non-adopters. Since the two groups are considered independent, test of hypotheses were carried out by using Student's t-test for quantitative variables (continuous) and Chi-square test for qualitative variables (nominal).

Table 1 describes the hypothesis test performed for the quantitative and qualitative variables. All hypotheses were tested at a 5% and 10% level of significance, in which H_0 is rejected when p-value ≤ 0.05 and ≤ 0.10, respectively.

Table 1. Description of the hypothesis test performed for the quantitative and qualitative variables analyzed.

Type of variable	**Hypothesis**		**Description of the parameters**
	H_0	**H_1**	
Quantitative continuous	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_2$	μ_1: mean of the continuous variables for the sample of farmers who adopted irrigation systems. $\mu2$: mean of the continuous variables for the sample of farmers who did not adopt irrigation systems.
Qualitative nominal	$\rho_1 = \rho_2$	$\rho1 \neq \rho2$	$\rho1$: frequency of the nominal variables for the sample of farmers who adopted irrigation systems. $\rho2$: frequency of the nominal variables for the sample of farmers who did not adopt irrigation systems.

The literature review on adoption of irrigation systems as well as the results from these analyses were important to indicate some hypotheses on the determinants of the adoption of irrigation systems. The description of the variables, as well as the hypotheses on its impact on the adoption of irrigation systems, is described in Table 2.

Table 2. Description of the variables used to discriminate the group of adopters of irrigation systems from the non-adopters, and the hypotheses concerning the impact of the variables on the adoption of irrigation.

Variable	Description	Expected Signal of the impact on adoption
Citrus varieties grown **(VARIET)**	Number of varieties of citrus grown by the producers in the properties	(+)
Income **(INCOCITR)**	Percentage of the agricultural income obtained through citrus activities	(+)
Technical assistance **(TECHASSIST)**	The dummy (Yes/No) variable assumes value 1 for farmers who pay technical assistance; and 0 if otherwise	(+)
Education level **(EDUC)**	Number of years of formal education of the farmer	(+)
Citrus area **(CITRAREA)**	Percentage of the citrus area in the total area of the farm	(+)
Price received **(PRICE)**	Average price received per box of orange in the crop season of 2013/2014	(+)
Participation in farming cooperatives and/or associations **(PARTIORG)**	The dummy (Yes/No) variable assumes value 1 for farmers who participate in farming cooperatives and/or associations; and 0 if otherwise	(+)
Rural credit **(CREDRUR)**	The dummy variable assumes value 1 for farmers who obtained rural credit in crop season 2013/2014; and 0 if otherwise	(+)
Commercialization channels **(COMMERCHAN)**	The dummy variable assumes value 1 for farmers who sell 50% or more of the production to juice processor companies; and 0 if otherwise	(+)

Source: the authors (2015).

The second step consists of testing hypotheses on the determinant factors of the use of irrigation systems in citrus orchards. This logit model was chosen because it has been widely used to study technology adoption and it allows for the identification of the individual decision behavior.

In this model, it is necessary to find the probability of an individual to adopt a technology. The dependent variable (Y) is qualitative binary, that is, it assumes only two values (0 = non-adoption of technologies; 1 = adoption). The explanatory variables (X) are represented by a vector x which explains the decision between adopting and not adopting a technology. These models provide adoption probabilities for individuals. The proposed econometric model can be described by the following general form (GUAJARATI, 2011):

$$L_i = \ln (P_i/(1-P_i)) = \beta_1+\beta_2 X_i+u_i$$

The descriptive statistics, the statistical hypothesis testing, as well as the econometric analysis were conducted using SPSS 20.0 software.

4. Results

Table 3 presents the results obtained with the descriptive statistics and the statistical test of hypotheses. It can be observed that for the continuous variables the t-test for comparison of means was statistically significant (at a 5% significance level) for citrus varieties grown (VARIET) as well as for income (INCOCITR), and was statistically significant (at a 10% significance level) for the education level (EDUC). The average of the number of citrus varieties grown in the properties, the percentage of income derived from the citrus activities, and the number of years of formal education are greater for the producers who use irrigation systems.

For the dummy variables, the Chi-square for comparison of frequencies was statistically significant (at a 10% significance level) only for technical assistance (TECHASSIST). Among the producers who are not adopters of irrigation systems, 57.14% do not pay for technical assistance while 42.85% pay for it; among the adopters of irrigation, 63.63% pay for technical assistance while 36.36% do not pay for it.

Table 3. Descriptive statistics and statistical hypotheses of the variables analyzed for the two groups of citrus producers.

Variables (continuous)	**Group 1:** adopt irrigation systems 34 citrus producers		**Group 2:** do not adopt irrigation systems 64 citrus producers		**Decision H_0**	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**p value**	**Hypothesis**
VARIET	3.56	1.28	2.81	1.50	0.016	Reject*
INCOCITR	60.62	34.12	44.03	33.48	0.023	Reject*
EDUC	13.88	5.30	11.81	4.90	0.056	Reject**
CITRAREA	62.30	33.36	61.16	28.25	0.858	Accept
PRICE	9.53	3.27	9.59	5.20	0.952	Accept
Variables (nominal)	**Freq. (n) (1)**	**Freq. (n) (0)**	**Freq. (n) (1)**	**Freq. (n) (0)**	**p value**	**Hypothesis**
CREDRUR	24	10	25	38	0,315	Accept
TECHASSIST	21	12	27	36	0,053	Reject**
PARTIORG	29	5	56	8	0,759	Accept
COMMERCHAN	17	17	35	29	0,658	Accept

Note: Asterisks * indicate that the p-value is statistically signficant at the 5% level;** indicate that the p-value is statistically signficant at the 10% level. For the variable TECHASSIST it was considered 63 non-adopters and 33 adopters of irrigation systems; for the variables CREDRUR it was considered 63 non-adopters and 34 adopters of irrigation systems.

Table 4 presents the results obtained with the logit model. It can be inferred that the coefficients of four of the nine explanatory variables used in the model were statistically significant, namely: citrus varieties grown (VARIET), income (INCOCITR), technical assistance (TECHASSIST), and education level (EDUC). Low correlation between the explanatory variables controls for multicollinearity. The predicted overall percentage was 72.1%. Thus, the model has a good prediction. .

Table 4. Coefficient estimates of the logit model for analysis of the determinants of adoption of feedlot systems by the beef cattle farmers interviewed.

Variable	Coefficient	Wald Statistic	P-value
Constant **	-2,466	3,222	0,073
VARIET **	0,311	3,060	0,080
INCOCITR*	0,024	7,584	0,006
TECHASSIST **	0,877	2,892	0,089
EDUC **	0,088	2,778	0,096
CITRAREA	-0,014	2,221	0,136
PRICE	-0,079	1,705	0,192
PARTIORG	-0,481	0,461	0,497
CREDRUR	0,647	1,326	0,249
COMMERCHAN	-0,825	2,292	0,130
Predicted Overall Percentage: 72,1 %			
Nagelkerke R^2: 0,281			
LR Statistic (8gl): 101,02			

Source: the authors (2015). Note: Asterisks * indicate that the coefficient is statistically significant at 5% level; ** indicate that the coefficients are statistically signficant at 10% level.

5. Discussion

In this section, the four determinants of adoption found in the previous section will be discussed. The results showed that the level of education (EDUC) has a positive impact on the adoption of irrigation, that is, the greater the level of education of the producer, the greater the chance of adoption of an irrigation system, such as hypothesized and observed in other empirical studies. Producers with more years of schooling probably have more information concerning the use of irrigation systems and more capacity to process information related to new technologies. In the same direction, the most schooled producers perhaps have more management skills, which can lead to better resource allocation.

The technical assistance (TECHASSIST) also showed a positive effect in the adoption of irrigation, as hypothesized. The probability of the producers of adopting an irrigation system increases with technical assistance from specialists, since this can be a source of information on new technologies. In this study, this variable takes into account the producers that pay for this service, which can indicate a gap in rural public policies as well as a greater capacity of these producers to contracting specialized rural assistance. In the state of São Paulo there are agriculture consulting group/firms specialized in citrus production and irrigation.

Another variable that presented positive effect on the adoption of irrigation was income (INCOCITR), which corroborates with the hypothesis initially raised. It was observed that the producer whose income comes mainly from citrus production has more probability of adopting irrigation. Since these producers are more dependent on this activity, they probably need to be more efficient by adopting new technologies.

Finally, the variable varieties grown (VARIET) also presented a positive impact on the adoption, as expected. The greater the number of citrus varieties grown in the farm, the greater the probability of the producer adopting an irrigation system. Farmers with more varieties of citrus are able to sell not only to juice processors but also to the fresh fruit market where better prices are obtained.

The variables price received (PRICE) and commercialization channels (COMMERCHAN) did not show statistically significant parameters. However, as can be seen in Table 3, a larger number of the producers who do not adopt irrigation sell 50% or more of their production to juice processor. This does not happen in the group of adopters, as they sell relatively more to the fresh fruit market, retail, and institutional markets. Since the average price received by the two groups is almost the same, diversifying the citrus production and the commercialization channels can also be a mechanism of reducing risks associated with whether conditions and default in payments.

One factor to be considered in the adoption of irrigation systems is the fixed cost, which can be an expensive investment to some producers. According to the farmers, the cost associated with the installation of an irrigation system can range from $ 1.200/ha to $ 1.600/ha depending on the type of irrigation: sprinkler or drip, respectively.

6. Conclusions

Technological intensification of citrus production has become very important to ensure the economic viability of the activity. The objective of this paper was to identify and analyze the determinants of the adoption of irrigation technologies by Brazilian citrus growers. As seen, the greater the number of varieties of citrus grown, the education level, the receipt of technical assistance from specialists and the income obtained from citrus activities, the greater is the likelihood of adoption of irrigation by the producers.

Other factors such as the percentage of the citrus area in the total area of the farm, the price received per box of orange, the participation in farming organizations, the receipt of rural credit and the type of commercialization channels did not show to be significant factors in the adoption decision process.

This empirical investigation brought results that are not found in the literature regarding the citrus sector, which represents an innovative aspect of the study. In this sense, it would be important to formulate public policies that could provide, especially, technical assistance to producers. The information provided by these services could enhance the efficiency in the use of the production factors, improving the investments and allowing farmers to adopt irrigation in the orchards. In the same direction, the design of rural credit policies for farmers who want to adopt irrigation in their orchards could speed up the diffusion of this technology.

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