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Application of Logit Model in Innovation Adoption: A Study of Biotechnology Companies in Malaysia

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Abstract: Malaysia is moving towards industrialization and throughout this movement; agro-biotechnology has been given a great role due to the country's specific needs and social, geographical and industrial context. Nevertheless, the level of adoption of agricultural biotechnology in Malaysia is low. This paper seeks to find the nature of technology adoption in Malaysia with formulating and optimizing the level of adoption to determine the best solution to the problem of accelerating the level of technology adoption, which is essential in Malaysia. Several parameters have been identified as influencing the adoption behavior including level of knowledge, fund, acceptance and receptiveness, cooperation and transfer of technology. Among the variables mentioned above only amount of fund does strongly influence the level of adoption of biotechnology innovation in Malaysian agro-biotechnology companies and the others are ignored by these companies. To accelerate the adoption of new biotechnology innovations it is suggested that policy makers place greater emphasis on providing funds, because this is the single most effective strategy to be implemented in phase one (2005-2010) of the biotechnology plan, according to biotechnology companies.

Key words: Innovation · Adoption · Logit Model · Biotechnology Companies · Policy Makers

INTRODUCTION

The level of adoption of agriculture biotechnology in Malaysia is low when compared with other countries in Asia and in the world based on the report published by Runge and Ryan [1]. According to this report and supported by AGBIOS [2], FAO [3], ISB [4], WISARD [5], there are four major categories of crops, namely field crops, vegetables, fruits and other crops involved in the biotechnology activities. Malaysia ranks 30 among 34 countries in terms of adoption of agriculture technology for field crops, 23 among 29 countries for vegetables, 14 among 20 countries for fruits and 14 among 19 countries for other crops. Under the Ninth Malaysian Plan, the target was to at least increase the number of biotech and biotech-related companies to 400 by 2010 to enhance application of biotechnology to various sectors of the economy.

A list provided by Ministry of Science, Technology and Innovation (MOSTI) shows that as at 2nd September 2009, the number of the biotechnology companies' total 114 in all biotechnology sectors, which is 28.5% of the 2010 target. So the level of biotechnology activities in Malaysia is low compared to both to global standards and the countries milestones. Malaysia's agri-food sector faces several challenges in the process of innovation application, among which includes adoption of technology [6].

According to International Development Research Center of Canada [7], a major problem relating to the development of the agriculture sector is the low technology adoption level. The case in Malaysia is not differing significantly about technology adoption in agricultural sector. Thus, the main aim of this work seeks to illuminate the nature of technology adoption in Malaysia with a view to formulating and optimizing the level of adoption to find the best solution to the problem

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of accelerating the level of technology adoption, which is essential in Malaysia.

MATERIALS AND METHODS

The MOSTI supported agriculture biotechnology companies that were investigated in this study are limited to 51 organizations. Since the target population was limited to 51 agriculture biotechnology companies the characteristics of the target population complies with Creswell's [8] justifications for collecting data from the whole target population, the target population and the sample are considered the same in this research.

The data collection was done by means of a self-administered questionnaire which was devised by the researcher. The questions and their content were developed based on the literature review and the local and social situation to ensure validity. The adopted questions were modified to match the research context. The validity of the questionnaire was ascertained by a panel of experts and through a pilot test. A pilot test was carried out to determine the validity and reliability of the questionnaire. The pilot test was conducted in ten Malaysian biotechnology companies.

The reliability was measured by using the Cronbach's alpha internal consistency [9]. The calculated reliability coefficients for managing director and R&D managers' questionnaire in the biotechnology companies were 0.807, 0.798, 0.752, 0.810, 0.800 and 0.913 for the different sections of the questionnaire namely: level of knowledge, amount of found, level of acceptance, level of cooperation, level of transfer of technology and rate of adoption, respectively. The reliability coefficient for this questionnaire as a whole was equal to 0.902.

The validated and reliable questionnaire was distributed to the 51 existing agro-biotechnology companies. The response rate was 90.19% (N=46). The obtained data was used to conduct the logistic regression.

Logit Model: The logit model is a random variable, which predicts the probability of adoption biotechnology innovations. The goal of logistic regression is to find the best fitting model to describe the relationship between the dichotomous characteristic of interest (dependent variable = response or outcome variable) and a set of independent (predictor or explanatory) variables. Logistic regression generates the coefficient estimates and its standard errors with significance levels of a formula to predict a logit transformation of the probability of presence of interest:

$$logit(p_i) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + ,......+\beta_n X_{ni} \quad (1)$$

Where p_i is the probability of presence of the characteristic of interest and characterized by the logistic function.

$$p_i = \frac{\exp(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + ,......+\beta_n X_{ni})}{1+\exp(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + ,......+\beta_n X_{ni})} \quad (2)$$

The logit transformation is defined as the logged odds:

$$odds = \frac{p_i}{1-p_i} \quad (3)$$

and therefore the logits (natural logs of the odds), of the unknown binomial probabilities are modelled as a linear function of the X_i generally known as link function as:

$$\log it(p_i) = Ln\left(\frac{p_i}{1-p_i}\right) = \beta_o + \sum_{j=1}^{n} \beta_i X_{j,i}, \quad (4)$$

The logit model assumes that underlying stimulus index *logit* (p_i) is a random variable, which predicts the probability of biotechnology innovation adoption:

$$chance\ of\ adoption = p_i = \left(\frac{1}{1+e^{-Logit(p_i)}}\right) = \frac{e^{Logit(p_i)}}{1+e^{Logit(p_i)}} \quad (5)$$

The above formulas have been used to calculate the probability of adoption of biotechnology innovations that is to predict the possibility and chances for the innovations to be adopted. The maximum likelihood estimates are obtained by computer intensive iterative reweighted least square algorithm.

Empirical Model Specification: The population of this study can be defined as all the people and organizations that use the transferred biotechnology innovations in Malaysia. This is in line with the definitions given by experts in the field of research methodology such as Creswell [8], Ary *et al.* [9], Gay and Airasian, [10], who believe that a population is the group to which the researcher would like the findings of the study to be generalized or the total group of subjects to whom the researcher wants to apply the conclusion from the findings. Based on the definitions from the same sources, the target population is a group of individuals (or a group of organizations) with some common defining characteristics that the researcher can identify and study.

In a survey research it is also possible to study the entire population if it is small and can be easily identified. This type of survey sometimes called a census study, permits conclusions to be drawn about the entire population. Therefore, random sampling will not be necessary [8]. Taking cognizance of the above, the target population in this research was defined as all the agriculture bio-technology companies supported by MOSTI, being the practical users of the bio-technology innovations. The scope of this research was to determine the level of adoption of agricultural biotechnology innovations by agro biotechnology companies. The target population was defined considering these criteria.

The MOSTI supported agriculture bio-technology companies are limited to 51 organizations. Since the target population was limited to 51 agriculture bio-technology companies and the characteristics of the target population complies with Creswell's [8] justifications for collecting data from the whole target population, the target population and the sample are considered the same in this research (i.e all the managers of the agricultural biotechnology companies supported by MOSTI). The definition and measurement of variables as well as sample characteristics are presented in Table 1.

Table 1: Specific Variables: Definition of Independent Variables

Variable Categories	Variable	Definition	Nature of Variable
Level of Knowledge	Knowledge, Information and Awareness (X1)	Knowledgeable=1; Level of Knowledge=0	Dichotomous
	Skilled Personnel (X2)	% of Technical experienced employees	Continues
	Research and Development (X3)	R and D performance by the companies. R and D conduction =1; Otherwise= 0	Dichotomous
	Training (X4)	Training program=1; Otherwise=0	Dichotomous
	Experience (X5)	Year	Continues
Amount of Fund	Resources (X6)	Self finance, Government fund,…	Dichotomous
	MOSTI financial support (X7)	Yes=1; No=0	Dichotomous
	Innovation Cost (X8)	Low=1; High=0	Dichotomous
Level of Acceptances and Receptiveness	Risk Acceptance (X9)	Acceptance=1; Lack of Acceptance=0	Dichotomous
	Public Acceptance (X10)	Acceptance=1; Lack of Acceptance=0	Dichotomous
	Responsiveness of the Company to Innovation (X11)	Responsiveness=1; Non Responsiveness=0	Dichotomous
Level of Cooperation	Cooperation with other Companies (X12)	Low and High Cooperation With Other Companies. High Cooperation=1 Low Cooperation=0	Dichotomous
	Cooperation With Academic Centers (X13)	Low and High Cooperation With Other Academics. High Cooperation=1 Low Cooperation=0	Dichotomous
	Cooperation With Extension (X14)	Low and High Cooperation With Other Extension. High Cooperation=1 Low Cooperation=0	Dichotomous
	Cooperation with other personnel (X15)	Low and High Cooperation With Other Personnel. High Cooperation=1 Low Cooperation=0	Dichotomous
	Cooperation with MOSTI (X16)	Low and High Cooperation With MOSTI. High Cooperation=1 Low Cooperation=0	Dichotomous
Personal Characteristics	Age (X17)	Years	Continues
	Educational Level (X18)	Highest Formal Schooling (Years)	Continues
	Gender (X19)	Male=1; Female=0	Dichotomous
	Personal Attitude towards Science and Technology (Technology Optimism) (X20)	Positive=1; Negative=0	Dichotomous
	Working Age (X21)	Years spent Working	Continues
Level of Transfer of Technology	Rate of Transfer (X22)	Fast=1; slow=0	Dichotomous
	National or International (X23)	National=1; International=0	Dichotomous
	Technology Capacity (X24)	Build up capacity=1; Otherwise=0	Dichotomous
	Government Assistance (X25)	Getting Assistance=1; Otherwise=0	Dichotomous

Empirical Results: The participants from biotechnology companies were 28.3% female and 71.7% male. The average of data from companies shows that the adoptions of biotechnology innovations for the male population equals 1.19 while the female 1.63, during the period 2005-2008. This significant difference shows that Malaysian female managers, involved in the field of biotechnology, are more willing to accept and adopt biotechnology innovations.

Age, education and work experience were the three factors among the biotechnology companies' that affect the level of adoption of innovations. Sorting the companies' data by age of participants revealed that the most innovative group is in the age range of more than 50 years. The lowest level of adoption was in the age group 41 to 50 years, with the rate as low as 1.16. The younger managers in the age range of 30 to 40 years show higher level of adoption of innovation at 1.36 compared to those in the 41 to 50 years group. The difference however is not substantial. Therefore, it can be concluded that the age of the manager affects decision making with regard to adoption of innovations in Malaysian biotechnology companies. The older and younger managers are more receptive to adopting new ideas compared to those in the middle age group.

The data reveals similar results by showing that those with work experience of between 11 to 15 years are most willing to adopt, at a rate of 1.55, just as the group with the least years of experience (between 1 to 5 years) at a rate of 1.4. However the intermediate group with work experience of 6 to 10 years was the least willing to accept biotechnology innovation. These results are compatible with the age factor outcomes.

The other personal factor included in the demography section was the level of the education of the company managers. The participants were classified into 3 groups, those with a Bachelor, Masters' or Ph.D. degrees. Based on the information presented in the literature and the findings of this study, it was not surprising to find out that companies whose managers had higher educational qualifications were more receptive to adoption of innovations. The companies with managers who had a Ph.D. degree showed an adoption rate of 1.48 while withe Masters Degree reported an adoption rate of 1.32. Those with Bachelor's degree holders had the lowest rate of 0.12. This is a significant factor. Improving the companies' level of adoption can be achieved by increasing the flow of the knowledge and cooperation from the universities. MOSTI can provide the company managers with additional courses and programs via extension experts to enhance their links with the universities.

The data shows that the average of level of adoption in international biotechnology companies is higher than other types of companies (1.88). The private companies are next with a rate of 1.36. The Government-linked companies the lowest adoption rate among biotechnology companies. Considering the fact that Government-linked companies receive substantial share of the assistance provided by MOSTI, their low adoption rate is a cause of concern and requires further study. Although the source of expertise of employees doesn't show a significant difference with regard to adoption of technology, it is evident that companies with employees, who have gained skills from their job experience, are more open towards adopting innovations than those which have university educated or company trained personnel.

The last piece of information gathered was on the mode of assistance from MOSTI that is being used by the Malaysian biotechnology companies. As mentioned, MOSTI provides biotechnology companies with a range of supportive programs and facilities, including loans and grants, R&D support, commercialization support and information. The findings reveal that the companies are more interested in utilizing the loans and grants. Only 13% of the biotechnology companies used the R&D and commercialization facilities support.

The biotechnology information facilities and programs provided by MOSTI were used by 19.6% of the companies while 67.4% have benefited from loan and grants. Since knowledge and information, R&D and commercialization are major factors affecting the process of adoption of biotechnology innovations, it will be very advantageous if MOSTI can encourage the companies to utilize such facilities.

Extension experts can undoubtedly play a major role in introducing the programs and encouraging the companies to use them to improve their level of adoption of technology and make profits at the same time as well. MOSTI can bind the use of loans and grants to the use of other programs and services, to ensure that the companies participate in those programs. Evidences of the present scenario of adoption of biotechnology innovation in Malaysia are presented here. These conclusions are drawn based on descriptive analysis of the data collected via the questionnaires.

Company managers use the printed media, the extension services and MOSTI educational activities as a source of information. Another source of knowledge on biotechnology innovations is the MTDC (Malaysian Technology Development Corporation), which provides biotechnology-related information. Unfortunately its services are not used fully. For example, only 30% of the company managers use the services provided by the MTDC. Perhaps there is a need for more promotion of the services provided. There is also a weak link between the universities and companies, with regard to collaboration in terms of providing and receiving information on basic and applied research findings.

Rate of Adoption: The rate of adoption is the relative speed with which members of a social system adopt an innovation. It is measured as the number of individual who adopt a new technology within a specific period [11]. We used MATLAB and SPSS software to derive estimates for rate of biotechnology innovation adoption.

The chi-square goodness-of-fit test tests the null hypothesis and determines the justification of the step. In this calculation, the step is defined from the constant-only model to the all-independents model. When the step was to add a variable or variables, the inclusion is justified if the significance of the step is less than 0.05. Had the step been to drop variables from the equation, then the exclusion would have been justified if the significance of the change was large (ex. over 0.10).Therefore the ratio chi-square of 50.459 with a p-value of 0.000 in Table 2 shows that the presented model as a whole fits significantly.

The Cox-Snell R^2 and Nagelkerke R^2 in Table 3 are attempts to provide a logistic R^2. The Nagelkerke measure adapts the Cox-Snell measure so that it varies from 0 to 1. Since R^2 and $\overline{R}^2$ exceeds 0.3, it is evidence that the model performance is good for prediction.

Table 4 is classification a 2 x 2 table which tallies correct and incorrect estimates for the full model with the independents and the constant. The columns are the two predicted values of the dependent, while the rows are the two observed (actual) values of the dependent. In a perfect model, all cases will be on the diagonal and the overall percent correct will be 100%. If the logistic model has homoscedasticity (not a logistic regression assumption) the percent correct will be approximately the same for both rows. Here it is, with the model predicting all cases. Meanwhile the overall percent correctly predicted seems good at 95.7%. Since the observed correct classification rate was 60.9 (Block 0: Beginning Block) and the fitted correct classification rate is 95.7, which is much larger than the base line of the cut point 0.5, it may concluded that the model performance is acceptable.

Logit regression analysis using MATLAB shows the most coefficient are not consistent with hypothesis relationships and their test of significance help to indicate their importance in explaining adoption decisions of

Table 2: Omnibus Tests of Model Coefficients

		Chi-square	Df	Sig.
Step 1	Step	50.459	5	0
	Block	50.459	5	0
	Model	50.459	5	0

Table 3: Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	11.119[a]	0.666	0.903

a. Estimation terminated at iteration number 8 because parameter estimates changed by less than .001.

Table 4: Classification Table[a]

			Predicted		
			High Level of Adoption		
	Observed		Disagree	Agree	Percentage Correct
Step 1	High Level of Adoption	Disagree	17	1	94.4
		Agree	1	27	96.4
	Overall Percentage			95.7	

a. The cut value is .500

Table 5: Analysis of Maximum Likelihood Estimates

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1[a]	Level of knowledge (Avr.B)	-1.096	4.842	.051	1	.821	.334
	Amount of Fund (Avr.C)	4.667	2.256	4.279	1	.039	106.335
	Level of Acceptance (Avr.D)	3.279	3.473	.892	1	.345	26.559
	Level of Cooperation (Avr.E)	3.933	5.701	.476	1	.490	51.069
	Level of Transfer of Technology (Avr.F)	4.412	2.492	3.133	1	.077	82.428
	Constant	-48.218	27.397	3.098	1	.078	.000

a. Variable(s) entered on step 1: Avr.B, Avr.C, Avr.D, Avr.E, Avr.F.

biotechnology innovations. The parameter estimates for the model was evaluated at 5% level of significance. Logit estimates for Biotechnology Company (Table 5) revealed that level of knowledge, level of acceptance and receptiveness, level of cooperation and level of transfer of technology are not statistically significant in explaining rate of adoption; amount of fund is statistically significant at 5% level.

The positive sign and significance of fund variable imply that fund is the most important and unique factor promoting the adoption of innovations by biotechnology companies in the study area. The findings further confirmed that increase in funding may lead to a higher level of adoption of biotechnology innovations. This is compatible with the findings of other researches, such as Annor and Kusi [12], who have stressed that accessibility to capital is critical to high growth firms and the provision of funding and initial capital influence decisions on adoption of technology.

Several parameters have been identified as influencing the adoption behavior such as knowledge, acceptance, group influence or cooperation and transfer of technology [13]. Bhattacharyya *et al.* [14] also found that the accumulation of knowledge and information regarding alternative technologies that come through experience is another key element in the adoption process. However, the findings of this study do not support the earlier research. The results from the perspective of managing directors or R&D managers illustrate that level of knowledge, level of acceptance, level of cooperation and level of transfer of technology do not have a significant impact on the technology adoption decisions of their companies.

This may be attributed to the fact that the biotechnology activities are a new trend in Malaysia. Therefore, companies at this stage are more concerned about profits and neglect the importance of other independent variables [15]. Moreover the 15 year plan (2005-2020) for biotechnology development is still at its first phase the capacity building phase (2005-2010).

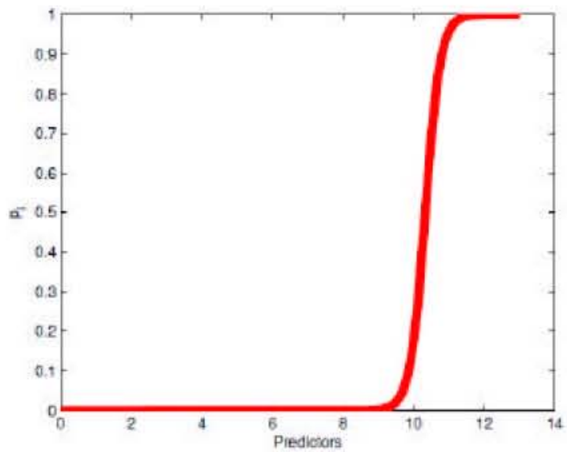

Fig. 1: Chance of Adoption Biotechnology Innovation by Using Biotechnology Company Managers'

This situation will most probably be similar to the global models in the later phase.

The estimated model is used to predict adoption probability of biotechnology innovation created by Malaysian Universities for biotechnology companies:

$$\text{logit}(p_i) = Ln\left(\frac{p_i}{1-p_i}\right) = -48.218 + 4.667\ AvrC \quad (6)$$

The probability that a company will adopt a biotechnology innovation for any units allocated to the predictors is given by:

$$\text{Chance of adoption} = p_i = \left(\frac{1}{1+e^{-Logit(p_i)}}\right) \quad (7)$$

The empirical model can be used to draw economic justifications for strategies to improve biotechnology innovations in Malaysia. To show clearly the percentage change in chances of biotechnology adoption by companies when any unit is allocated to predictors, a probability of adoption's graph is drawn.

The X axis shows the value of unit for predictor and Y axis demonstrates the chance of adoption, other factors being equal. As illustrated in Figure 1, the graph does not have a monotone slope. It means that the slope is not the same in all intervals and the chance of adoption is not increased in a monotone way.

DISCUSSION AND CONCLUSION

The empirical evidence revealed that new biotechnology innovations have the potential to increase the level of adoption. However, increase in level of adoption will not be achieved if biotechnology companies are not liked appropriately and complementarily. Among the variables, level of knowledge, level of acceptance and receptiveness, level of cooperation and level of transfer of technology does not strongly influence the level of adoption of biotechnology innovation in Malaysian agro-biotechnology companies.

On the other hand, according to the data the level of adoption is affected largely by the fund variable. To accelerate the adoption of new biotechnology innovations it is suggested that policy makers place greater emphasis on providing funds. This is the single most effective strategy to be implemented in phase one (2005-2010) of the biotechnology plan, according to biotechnology companies. Through this the trust of companies to adopt new innovations will be gained.

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