Farmers' Adoption of Best Management Practices in Kentucky

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Abstract

This article explores farmers' adoption of the Best Management Practices (BMPs) in Kentucky, and the factors affecting their choices of BMPs through a proposed Water Quality Trading (WQT) program. We introduce a two-step framework to estimate farmers' current and future choices of BMPs using a bivariate probit model. The first step is to investigate the factors influencing farmers' current usage of BMPs, and the second step is to estimate their willingness to implement BMPs given different levels of compensation offered through a survey. The results show that farmers who participate in the conservation programs are more likely to currently be using BMPs. Farmers' previous experience with BMPs is one of the most important contributors affecting farmers' future choices of BMPs. The results also find that increasing compensation will encourage farmers to implement the practices of animal fences and waste storage facilities. Finally, applying the coefficient results, we calculate the probabilities that farmers would likely use BMPs at different levels of compensation, and conclude that the emission credits in WQT markets are able to be supplied in Kentucky.

Key words: best management practices, contingent valuation method, water quality trading, two-step choices

Agriculture run-off is a large source of pollution for water resources. Unlike pollution from point sources, emissions from agricultural nonpoint sources (NPSs) are mostly exempt from federal and state regulation directly (Braden and Boyle 2013; Fowler, Royer and Colburn 2013). Water Quality Trading (WQT) is a promising mechanism for reducing water pollution from agricultural NPSs. WQT programs are market-based programs that establish a mechanism that allows the party with higher abatement costs to purchase emission permits directly or indirectly from the party with lower abatement costs. As a result, those with higher abatement costs will abate less while those with lower costs will abate more, but be compensated by the permit buyers. The overall goal is to maintain or improve the water quality in a watershed where the buyers and sellers of permits coexist. In WQT programs, agricultural NPSs are encouraged to engage in Best Management Practices (BMPs) to abate discharge, and supply emission permits in the trading market.

However, WQT programs are criticized because the trading market does not perform very well, especially in the trading market related to agricultural NPSs. Shortle (2013) points out that most research in WQT programs focus on market mechanism design but fail to understand the factors influencing farmers' engagement in BMPs and participation in WQT programs. Therefore, one research goal in this article is to fill this void by understanding the factors affecting farmers' choices of BMPs through a proposed WQT program.

The purpose of this paper is three-fold. First, this study investigates farmers' adoption of BMPs in Kentucky, and the factors affecting farmers' choices of BMPs in the future. A contingent valuation method (CVM) is used in this study through a survey given to farmers in the Kentucky River Watershed. The survey data were collected from 2011 to 2012. The WQT program did not exist in Kentucky when the data were collected, and still does not exist. Since the WQT program is designed to offer farmers compensation for implementing BMPs, the CVM question is whether the respondent will accept the offer of some compensation for using the BMPs specified by the WQT program. The BMPs featured in this article are riparian buffers, animal fences[1], no till, waste storage facilities, and nutrient management[2]. Using the survey data, we can model farmers' current and future choices of BMPs and obtain a probability function that farmers will implement the BMPs through WQT programs.

Second, we explore farmers' willingness to implement BMPs in order to assess the feasibility of WQT markets in the Kentucky basin. Since the compensation for implementing BMPs can affect farmers' choices of BMPs, we can calculate the probabilities that farmers will implement BMPs at the different levels of compensation, applying the estimation results to the probability function. As a result, we can investigate whether the potential emission permits could be supplied in the trading market given different levels of compensation.

[1] Animal fence is a practice of fencing off animals from direct access to rivers, streams, or lakes.
[2] U.S. Department of Agriculture. Technical Resources-Conservation Practices: Alphabetical Index

Third, previous studies focus on the factors affecting either farmers participation in environmental programs (Lynch and Lovell 2003; Lambert et al. 2006; Nickerson and Hand 2009; Claassen and Duquette 2012) or farmers adoption of environmental practices (Ervin and Ervin 1982; Featherstone and Goodwin 1993; Cooper and Keim 1996; Wu and Babcock 1998; Traoré, Landry, and Amara 1998; Soule, Tegene and Wiebe 2000; Claassen and Duquette 2012; Abdulai and Huffman 2014). None of the studies cited above consider the effect of previous experience with BMPs on farmers' future choices of environmental practices. Cameron and Englin (1997) find that the respondent experience, the number of years in which an individual has been a user of environmental goods, could influence the contingent valuation of those resources. In our research, we consider the current usage of BMPs as the experience with environmental goods, and present a two-step framework to investigate farmers' willingness to participate in WQT programs, which includes farmers' current choices and future choices of BMPs. The results show that farmers currently using some BMP are more likely to expand the scope of this practice in the future through our proposed WQT programs.

The article is organized as follows: survey and data, theoretical model, empirical model, result, and conclusion.

Survey and Data

In order to investigate farmers' current adoption of BMPs and their future willingness to participate in BMPs through WQT programs in Kentucky, a survey was conducted among farmers in the Kentucky River Watershed. The survey data were collected from randomly chosen farmers across 35 counties from 2011 to 2012. The response rate was 23%, and there are 357 valid observations out of 459 responses. The surveys' questions include current usage of BMPs, willingness to participate in BMPs, participations in environmental programs, farm characteristics, and respondents' demographic characteristics.

In the survey, the key questions involved two parts. The first key question is "Are you currently using any of the following water quality management practices on the farm you are operating?" These practices include riparian buffers, animal fences, no till, waste storage facilities and nutrient management. The respondent could answer "Yes" or "No" with respect to each practice. Table 1 presents the numbers and percentages of farmers currently using different types of BMPs in our sample. Of the 357 observations, there are 73.95% of farmers currently using at least one of the BMPs on their farms. Animal fences are the most used practices accounting for the 46.5% of observations, and waste storage facilities are the least used practices accounting for the 6.72% of observations.

The second key question is “Regardless of whether you are currently participating in any government cost share programs, if you knew that by using water quality management practices on your land, a nearby waste/sewage water treatment plant or factory will cover X% of your cost of implementing these practices, would you be interested in using additional water quality management practices (BMPs) in the form of the following activities: riparian buffers, animal fences, no till, waste storage facilities and nutrient management?” The amounts of compensation (X%) are 75%, 80%, 85%, 90%, 95%, 100%, 105%, 110%, 115% and 120%, and are randomly assigned with equal probability to the survey. Each respondent only saw one survey. In order to avoid the sample selection problem, CVM questions are asked regardless of whether a respondent is currently using the BMPs. In addition, the levels of compensation are carefully designed so that the lowest level of compensation, 75% of cost coverage, in our survey is the highest level of compensation in Working-Land Programs (Aillery 2006). This design could avoid sample bias issues, which are that farmers facing higher levels of compensation are more likely to respond to our survey, but farmers facing lower levels of compensation are not. Table 2 presents the response rates at different levels of compensation, and shows that the response rates are similar across the different levels of compensation.

In the second key question, a respondent could answer “Yes”, “No”, or “Not possible for me” with respect to each practice. We provide “Not possible for me” to differentiate the reason why farmers answer “No” to the CV question. When farmers answer “Not possible for me” with respect to a BMP, it indicates that they cannot use this practice. In addition, the “Not possible for me” response captures the possibility that farmers have already maximized their potential to adopt BMPs. If “Not possible for me” were not provided in the survey, the results will be underestimated.

Table 3 reports the frequency of responses for willingness to adopt BMPs with and without the answer "Not possible for me". 65.5% of all respondents answered that they would like to implement at least one of the BMPs through our proposed WQT programs. The highest percentage of "yes" responses is 33.61% for animal fences, and the lowest one is 19.33% for riparian buffers. After excluding the "Not possible for me" responses with respect to each practice, 65.93%, 62.5%, and 62.36% of farmers would like to implement the animal fences, nutrient management and no till on their lands, respectively, but only 46.36% and 46.31% of them would like to use waste storage facilities and riparian buffers, respectively.

Furthermore, the survey was designed with different levels of information explaining the meaning of WQT programs. There are four levels of information in the survey. Basically, the higher the information level, the more information explaining the WQT program was provided. One of the four levels of the information is randomly assigned with equal probability to the survey. This design was implemented to examine whether the informed length of the survey will influence individual responses.

Table 4 defines all of explanatory variables included in this analysis; Table 5 explains discrete levels of some explanatory variables; and Table 6 reports means and standard deviations for the above variables. For the farmers' characteristics, the surveyed farmers have a mean age of 60, a mean farming experience of 32 years, a mean income level of $50000 to $74999, and a mean education level of associate degree. Also, 66.1% of farmers participate in water related activities at least once a year. For the farms characteristics, 42.3% of surveyed farms reported they planted crop or they had farm revenue from crop, and 79.8% of the farms reported they raised livestock or had farming revenue from animals. The average size of farmland is 282 acres, with 86% of farms having surface water on their land or flowing through their land. In addition, the mean percentage of household income from farming is around 16 to 30%, and the mean percentage of household income back to farming is around 16 to 30%.

Besides farms' and farmers' characteristics, the survey also asked farmers to rate their environmental awareness and water quality nearest their farms from one to seven (for awareness, one implies unaware and seven implies very aware; for water quality, one means the lowest quality and seven means the highest quality). The surveyed farmers reported that the mean of farmers' environmental awareness is

4.947, and the mean of water quality nearest their farms is 5.038. Finally, table 6 also reports the statistical summary for each BMP excluding the “Not possible for me” response.

Theoretical model

In this research, farmers’ choices of BMPs are understood through a two-step framework. The first step is farmers’ current choice of BMPs. Let y_i^* represent a latent variable determining farmers’ current choice of BMPs. $y_i^*$is a function of observed variables labeled as vector x_a; β_a is the estimated parameter vectors; ε_a is the $i.i.d.$ random variable with zero mean. The unobserved latent variable could be written as follows:

$$y_i^* = \beta_a x_a + \varepsilon_a$$

where i denotes five different types of BMPs ($i = 1,2,3,4,5$)

The observed decision whether they are currently using the BMPs is determined as follows:

$$y_i = 1 \ \ an\ individual\ is\ currently\ using\ a\ BMP\ \ if\ \ y_i^* > 0$$

$$y_i' = 0 \ \ an\ individual\ is\ not\ currently\ using\ a\ BMP\ ,\ \ if\ otherwise$$

The second step is the future choice of implementing BMPs through our proposed WQT programs. Let $y_i'^*$ represent a latent variable determining farmers’ future choice of BMPs. $y_i'^*$ is a function of observed variables labeled as vector x_b, while β_b is corresponding parameter vectors; ε_b is the $i.i.d.$ random variable with zero mean. The unobserved latent variable could be written as follows:

$$y_i'^* = \gamma y_i + \beta_b x_b + \varepsilon_b$$

where i denotes five different types of BMPs ($i = 1,2,3,4,5$)

The observed decision whether or not to participate in WQT programs to implement a BMP in the future is determined as follows:

$$y_i' = 1 \ \ an\ individual\ answers\ yes\ to\ adopt\ a\ BMP\ through\ WQT\ programs\ \ if\ \ y_i'^* > 0$$

$$y_i' = 0 \ \ an\ individual\ answers\ no\ to\ adopt\ this\ BMP\ ,\ \ if\ otherwise$$

The correlation between the two steps is that we introduce the current choices of BMPs as an explanatory variable for the future choices of BMPs. Cameron and Englin (1997) find that the expected value of WTP increases substantially with any positive amount of experience. The experience in their research is particularly relevant to the issue of use versus non-use. Following their findings, we consider the current choice (y_i) in the first step as an independent variable in the second step to explain the future choice of BMPs (y_i'). In addition, we allow the explanatory variables in the two steps, x_a and x_b, to overlap.

The most commonly used methods to estimate the two-step framework are the sequential estimation and bivariate probit model. The sequential estimation is to estimate the farmers' current choices in the first step, then insert the predicted values, or residuals from the first step into the second step (Rivers and Vuong 1988; Burnett 1997; Traoré, Landry and Amara 1998; Alvarez and Glasgow 1999; Terza, Basu, and Rathouz 2008; Marchetta 2012). The bivariate probit model is to estimate the two steps as a simultaneous equation system (Greene 1998; Waters 1999; Grosjean and Kontoleon 2009; Dalton, lilja, Johnson and Howeler 2009; Konishi and Adachi 2011; Marchetta 2012).

We prefer the bivariate probit model to estimating the two-step choice due to it is a simpler and more straightforward estimator than the sequential estimation. Since the dependent variable in the first equation will enter the second equation as an explanatory variable, the two-step choice could be specified as simultaneou equations. Greene (1998) shows that, for the simultaneous equation model, the endogenous variables on the right-hand side in the second step (in our case) could be ignored in formulating the log-likelihood, so the maximum log-likelihood estimation for simultaneous models could be estimated via standard bivariate probit model.

Hence, we employ the bivariate simultaneous equation model to estimate the two-step framework of current and future choices of BMPs. The two-step choice model in this research is concluded as follows:

$\boldsymbol{Current\ adoption\ of\ BMPs\ function}$: $$y_i^* = \beta_a x_a + \varepsilon_a \quad (1)$$

Where, $y_i = 1\ \ if\ y_i^* > 0, farmers\ are\ currently\ using\ a\ BMP$

$y_i = 0\ , otherwise,$

And

$\boldsymbol{Willingness\ to\ adopt\ BMPs\ in\ the\ future}$: $y_i^{'*} = \gamma y_i + \beta_b x_b + \varepsilon_b$ (2)

Where, $y_i^{'} = 1\ \ if\ y_i{'}^{*} > 0, farmers\ answer\ yes\ to\ CV\ question$

$y_i^{'} = 0\ \ a\ otherwise$

And

$$\varepsilon_a, \varepsilon_b \sim BVN\ [(0,0), 1, 1, \rho]$$

$$Cov(\varepsilon_a, \varepsilon_b | x_a, x_b) = \rho$$

where, BVN denotes the cumulative distribution function of the bivariate normal distribution; ρ is the covariance between ε_a and ε_b.

Empirical Specification

As we discussed above, farmers' choices of BMPs are modeled through a two-step framework using a bivariate probit model. Following the framework, the empirical model is specified into two equations: equation (1) is to investigate the factors influencing farmers' current usage of BMPs, and equation (2) is to estimate farmers' willingness to implement BMPs given different levels of compensation and different levels of information explaining the meaning of WQT given in the survey. In the survey, respondents answer the current usage of BMPs questions and the CV questions with respect to five different types of BMPs: riparian buffers, animal fences, no till, waste storage facilities and nutrient management. Therefore, we estimate equation (1) and (2) simultaneously using bivariate probit models with respect to each practice, which means proceed with five bivariate probit models.

One issue that needs to be considered before the estimation is the response "Not possible for me". In the analysis, farmers who respond "not possible for me" are not included in the analysis of farmers' choices of BMPs, so the answer to the CV questions is still a binary choice with yes/no answers. After removing individuals who answer "Not possible for me" with respect to each practice, there are five subsamples summarized in table 6.

Current choices of BMPs

Equation (1) focuses on understanding farmers' current choices of BMPs. The binary dependent variables (y_i) is whether farmers are currently using each of those BMPs observed from the survey.

The explanatory variables x_a determining the current choices of BMPs include farmers' demographic characteristics (age, education level, and farming experience), farms' types (crop farms and livestock farms), participation in government programs, and environmental characteristics (water quality nearest the surveyed farms, farmers' water recreation activities, and environmental awareness).The same explanatory variables are used to explain the current choices of each practice.

The variable of government payment programs is one of the most important factors leading farmers to adopt BMPs. In our survey, farmers are surveyed asking whether they are currently participating in Conservation Reserve Programs and Working-Land Programs. The Conservation Reserve Program (CRP) is the land retirement program from conservation programs sponsored by the U.S. Department of Agriculture (USDA). Participants in the CRP are compensated annually to retire environmentally sensitive land from agricultural production for 10 to 15 years. The Working-Land Program (WLP) is one of the conservation programs that encourage farmers to adopt BMPs on working-land to achieve environmental benefits (USDA 2014). The WLP in this analysis includes the Conservation Stewardship Program, Environmental Quality Incentives Program, and Wildlife Habitat Incentives Program. From the descriptive summary in table 6, about 11.8% of farms participate in the CRP, and 20.4% of farms participate in the WLP. In the model, participations in the CRP and WLP are examined by binary variables.

Environmental perception is another determinant for farmers' current usage of BMPs. Ervin and Ervin (1982) propose a two-stage decision-making model to model farmers' decision-making processes for implementing BMPs where the two stages are recognition and adoption. Following the decision-making model, several studies introduce the awareness or attitude concerning the environmental issue to explain the environmental behavior, and conclude that the environmental awareness or attitude has a significant effect on environmental behavior (Featherstone and Goodwin, 1993; Wu and Babcock 1998; Traoré et al.

1998). In this analysis, we also consider the variables of water quality nearest the surveyed farms, water recreation activities and environmental awareness as the environmental perception to explain the farmers' current usage of BMPs.

Future choices of BMPs

Equation (2) investigates farmers' future choices of BMPs, the willingness to participate in BMPs through our proposed WQT programs. The dependent variables (y_i') are the binary responses to our CV questions that ask whether they would like to use a BMP if a nearby waste/sewage water treatment plant or factory would cover X% of the cost of implementing these practices.

The decision to participate in BMPs through WQT programs is a function of compensation payment. The expected result is that the probability of adopting BMPs is increasing in the levels of compensation. We also surveyed the farmers with different length of information explaining the meaning of WQT. We expect the more information we provide, the more the farmers are likely to participate in WQT programs.

Besides the compensation and information level, the explanatory variables x_b consist of farms' characteristics (land size, rent percentage, surface water, returns from farms, investment to farms, and farm types) and farmers' demographic characteristics (age, education level, income, race, farming experience, water quality nearest the surveyed farms, and farmers' water recreation activities). We use the same explanatory variables to explain the future choices of each practice.

As we discussed in the theoretical model, the current usage of BMPs (y_i) is included in equation (2) in order to capture the effect of previous experience on farmers' future choices of BMPs. Furthermore, we also include other BMPs in the explanatory variables x_b to examine whether there is any cross-effect that currently using a type of BMPs would encourage farmers to implement other types of BMPs in the future.

Result

In the preliminary estimation, we proceed with the bivariate probit model for each BMP and find that the models fit the data well for all practices. The correlation coefficients ρs are statistically significantly different from zero in the models of no till and nutrient management. For the models of riparian buffers and animal fences, the likelihood ratio test cannot reject the hypothesis that ρ is equal to zero. This means that we can estimate the current and future choice of riparian buffers and animal fences using univariate probit models separately. In our analysis, we still provide the results of the bivariate probit model for those two practices, since results of the bivariate probit model and the univariate probit model will not be different if the correlation coefficient equals to zero. Table 7 and 8 report the results of the bivariate probit model for practice of riparian buffers, animal fences, no till, and nutrient management.

However, the correlation coefficient (ρ) in the model of waste storage facilities has an abnormal result that ρ converges to negative one. The abnormal value negative *one* indicates that the current choice of waste storage facilities perfectly predicts the future choice of this practice. Unfortunately, if the ρ converges to negative one, the result of the bivariate probit model will be questionable. Since there is a (1- ρ^2) in the denominator of the probability density function of the bivariate normal distribution, the numerical computation process for bivariate probit models will be unstable. Consequentially, though the statistic software package could provide a compromising result when ρ converges to negative one, the coefficients of the bivariate probit model will not be reliable.

Instead of presenting a compromising result, we also conduct a two-stage residual inclusion estimator (2SRI) developed by Blundell and Smith (1989) to examine the results of the bivariate probit model for the choices of the waste storage facilities. The 2SRI estimator is that the first-stage residuals are included in the second-stage regression as an additional regressor. In our 2SRI estimator, the first-stage is the current choice of waste storage facilities estimating equation (1) using the probit model, and the second-stage is the future choice of this practice estimating equation (2) using the probit model with the residual generated from the first-stage. Terza, Basu, and Rathouz (2008) prove that the 2SRI estimator has a better performance than the traditional two-stage predictor substitution estimator in addressing the endogeneity in the choice model. Following Marchetta's (2012) work, the residual regressor is the generalized residual introduced by Gourieroux, Monfort, Renault and Trognon (1987) and is represented as follows:

$$Generalized\ Residual = \frac{\varphi(x_a\beta_a)}{\Phi(x_a\beta_a)[1-\Phi(x_a\beta_a)]}[y_i - \Phi(x_a\beta_a)] \qquad (3)$$

We report the result of the 2SRI estimator for the model of waste storage facilities in Tables 6 and 7. The significances and signs of coefficients in the 2SRI estimator are similar to the ones in the bivariate probit model, except the variables *age* and *livestock*. The key variables *Offer* are consistent in these two models. Therefore, we present the results of 2SRI estimator for the practice of waste storage facility, since it is more reliable.

The current choice of BMPs

Table 6 presents the results of farmers' current choice of BMPs. The first four columns are the results of bivariate probit models for practices of riparian buffers, animal fences, no till and nutrient management. The last column is the results of the probit model for the current choices of waste storage facilities.

The results show that participation in the CRP and the WLP is the important contributors to the current usage of BMPs. The coefficients of WLP are positive and statistically significant across four practices, and the coefficient of CRP is positive and significant at the 1% confidence level in current usage of the no till model. These results indicate that farms participating in the WLP prefer to use riparian buffers, animal fences, nutrient management and waste storage facilities on their land, but farmers participating in CRP tend to adopt no till on their farms.

In famers characteristics, farmer's age, education, farming experience and water recreation activities will influence the current usage of BMPs. Holding other factors constant, farmers with higher education prefer to adopt riparian buffers and no till; farmers participating in water related recreation at least once a year would like to implement riparian buffers; older farmers are more likely to build waste storage facilities but not riparian buffers; more farming experience would lead farmers to build riparian buffers along the river or surface water on their land.

Besides, farmers' environmental awareness and farms' types also impact farmers' current choices of BMPs. Different from previous findings, environmental awareness may not be a dominant factor leading farmers to implement BMPs. The coefficients of environmental awareness are only statistically significant in the current choices models of riparian buffers and nutrient management. In addition, farm's type is another significant factor explaining the current usage of BMPs. Holding other factors constant, crop farms are more likely to use nutrient management; livestock farms are more likely to build up the animal fences, since this BMP is designed for livestock farms.

The Future Choices of BMPs

Table 7 presents the results of farmers' future choices of BMPs — their willingness to participate in WQT programs. As mentioned in the previous section, the first four columns are the results of bivariate probit models for practices of riparian buffers, animal fences, no till and nutrient management, and the last column is the results of the 2SRI estimator for the practice of waste storage facilities. In our estimation, the 2SRI estimator is a probit model including a generalized residual as an additional regressor. The generalized residual is generated from the current choice of the waste storage facilities model using equation (3). The coefficient of generalized residual is significant with a negative sign. It implies that the unobserved variables affecting farmers' current choices of waste storage facilities have a negative effect on farmers' future choices of this practice.

Offer (C) is one of the most important factors affecting farmers' future choices of BMPs. The expected results are that the coefficients of offer (C) would be statistically significant with a positive sign. Unfortunately, the regression results show that the increasing levels of compensation do not affect farmers' choices of the practices of riparian buffers, no till, and nutrient management, but only positively affect the probability of implementing the practices of animal fences and waste storage facilities.

In farms characteristics, farm size, rent area, surface water on farmland, investment on farms, returns from farms, and farm types all play a role in farmers' future choices of BMPs through WQT programs. Large-sized farms are less likely to use animal fences; farmers who rent more farmland are less likely to adopt no till through WQT programs. Farms with surface water resources prefer to build waste storage facilities, because this practice is designed to prevent a farm from contaminating water flows. Farmers having more returns from farms are more likely to build animal fences, and famers investing large shares of income to their farms prefer to build riparian buffers and waste storage facilities through WQT programs. Livestock farms have no interest in using animal fences through WQT programs, and are less likely to use no till on their land. The crop farms prefer to implement no till and nutrient management through WQT programs.

In farmer characteristics, the factors affecting farmers' willingness to implement BMPs are age, farming experience, education and water recreation activities. Specifically, older farmers may refuse to use the practices of animal fences, no till, waste storage facilities and nutrient management through WQT programs. Farmers with more farming experience tend to adopt no till through WQT programs; and farmers with higher education are more likely to use animal fences and nutrient management; farmers with water related recreation at least once a year prefer to adopt the practices of riparian buffers, animal fences, no till and nutrient management. The results also confirm that income level and race do not influence farmers' decisions to implement BMPs through WQT programs. Furthermore, poor water quality near the surveyed farms could stimulate farmers to implement the practices of riparian buffers, animal fences, no till and waste storage facilities through WQT programs.

Current experience with BMPs has a significant effect on encouraging farmers to implement BMPs in the future. If farmers are currently using animal fences and waste storage facilities, they are more likely to expand the scope of these practices through WQT programs. In addition, the results find several cross-effects among the different types of BMPs. If farmers currently have riparian buffers on their lands, they will probably refuse the offer to use no till; if farms have animal fences currently, the farms' owners tend to try no till through WQT programs; if farmers are currently using no till on their lands, they also will likely implement nutrient management on their farms; if farmers currently have waste storage facilities in the farm, they may not adopt riparian buffers in the future; if farmers are currently using nutriment management, they are less likely to use no till in the future.

In addition, the results show that the information levels 2 and 3 are the effective forms to introduce the WQT programs. If farmers are informed with a less detailed survey about WQT programs, they are more likely to participate in WQT programs to implement animal fences and nutrient management. If farmers are informed with more detailed survey explaining WQT programs, they are more likely to build waste storage facilities on their land through WQT programs. It implies that a survey with too much or too little information would not help farmers understand the WQT programs.

Finally, applying the coefficients from the estimation, we could calculate the probability of implementing BMPs at different levels of compensation. Since the coefficients of variable *Offer* are only significant in the models of animal fences and waste storage facilities, we only present the results of those two practices.

For calculating the probability of using animal fences, we re-estimate a univariate probit model for farmers' future choices of animal fences instead of using the results of the bivariate probit model. That is because the correlation coefficient in the bivariate probit model of animal fences is not significant and converges to zero, which means there is no difference between the results of the bivariate probit model and the univariate probit model. For the computation convenience, we re-estimate farmers' future choices of animal fences using a univariate probit model. Holding other explanatory variables at median and at mean, we calculate the probability that farmers will implement BMPs at different levels of compensation, applying the coefficients from the univariate probit model into equation (4), and draw the response curves for the practice of animal fences in Figure 1.

$$Prob[y_i' = 1|x_b] = Prob\left[\gamma y_i + \beta_b x_b + \varepsilon_b > 0 \,\middle|\, x\right] = \Phi\left(\gamma y_i + \beta_b x_b\right) \quad (4)$$

where equation (4) is the probability that farmers answer "Yes" to the CV question for animal fences, and Φ is the cumulative distribution function of the standard normal distribution.

To calculate the probability of using waste storage facilities, we apply the coefficients from Table 7 into equation (3). The response curve for the practices of waste storage facilities is also drawn in Figure 2.

From Figures 1 and 2, the trend shows that if the level of compensation rises, the probability that farmers will implement animal fences and build waste storage facilities through WQT programs will increase. At 75%, 100% and 120% of cost compensation, holding other variables at mean, offering information level 1, the probabilities of using animal fences are 54%, 68% and 78%, respectively, and the probabilities of building waste storage facilities are only 22%, 37% and 50%, respectively. Furthermore, Figures 1 and 2 show that the length of information in the survey has a significant effect to increase the probability of farmers being willing to participate in WQT programs.

Conclusion

This article explores farmers' adoption of the Best Management Practices (BMPs) in Kentucky, and the factors affecting farmers' choices of BMPs in the future. We propose a two-step framework to estimate farmers' current and future choices of BMPs using a bivariate simultaneous probit model. The first step is to investigate the factors influencing farmers' current usage of BMPs and the second step is to estimate farmers' willingness to implement BMPs given different levels of compensation and different levels of information explaining the meaning of WQT offered through the survey. The correlation between the two steps is to consider the current choices of BMPs as an explanatory variable in the future choices of BMPs.

For the farmers' current usage of BMPs, the most significant result is that farmers already participating in conservation programs are more likely to be using BMPs currently. Besides, farm's types affect farmers' current usage of BMPs. For the farmers' future choices of BMPs through a proposed WQT program, the most important finding is that increasing the compensations for installing or maintaining BMPs could encourage farmers to build up animal fences and waste storage facilities. Another interesting finding is that if farmers are currently using animal fences and waste storage facilities, they are more likely to expand the scope of those practices. In addition, the results also show that if farmers are informed in modest length of information about WQT programs, they are more likely to participate in WQT programs. This will help policy makers introduce and facilitate the trading market in Kentucky.

Using the coefficient results from the estimations, we could obtain the probabilities that farmers would likely implement BMPs through WQT programs at different levels of compensation. Based on the results, we could infer that the trading credit related to the practices of animal fences and waste storage facilities, such as nitrogen and phosphorus, could be supplied by farmers in Kentucky at certain levels of cost coverage compensation, so the water quality trading for the nitrogen and phosphorus is potentially feasible in the Kentucky basin.

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Table 1 Numbers and Percentages of Farmers Currently Using BMPs (N=357)

	number	**percent**
Riparian buffers	131	36.69%
fence	166	46.50%
No till	111	31.09%
Waste storage facility	24	6.72%
Nutrient management	86	24.09%
At least currently using one of BMPs	264	73.95%

Table 2 Response Rates at Different Levels of Compensation

Offer	**Frequency**	**Percentage**
75%	41	11.48%
80%	37	10.36%
85%	46	12.89%
90%	32	8.96%
95%	30	8.4%
100%	28	7.84%
105%	34	9.52%
110%	35	9.8%
115%	30	8.4%
120%	44	12.32%

Table 3. Frequency of Responses for Willingness to Adopt BMPs (N=357)

BMPs	Frequency of responses			Frequency of responses without "Not possible for me"	
	Yes (=1)	No (=0)	Not possible for me	Yes	No
Riparian buffers (y_1')	19.33%	22.41%	58.26%	46.31%	53.69%
Fencing off animals (y_2')	33.61 %	17.37%	49.02 %	65.93%	34.07%
No till (y_3')	31.09%	18.77%	50.14 %	62.36%	37.64%
Waste storage facility (y_4')	19.61%	22.69%	57.70 %	46.36%	53.64%
Nutrient management (y_5')	30.81%	18.49%	50.70%	62.50%	37.50%
At least implement one of the BMPs	65.5%	8.12%	34.45%	87.61%	12.39%

Note: "At least implement one of BMPs" means farmers at least answer "yes" to one of five different types of BMPs.

Table 4. The Definition of All Variables

Variable	Definition of Variables
Current BMPs Adoption:	
Riparian buffers (y_1)	Currently using riparian buffers (=1); otherwise (=0)
Fence (y_2)	Currently using fencing off animals (=1); otherwise (=0)
No till (y_3)	Currently using no till (=1) ; otherwise (=0)
Waste storage facility (y_4)	Currently using waste storage facility (=1) ; otherwise (=0)
Nutrient management (y_5)	Currently using nutrient management (=1) ; otherwise (=0)
Cost Coverage Compensation:	
Offer	The percentage of treatment plant or factory will cover the cost of implementing the BMPs if the farmer uses the additional BMPs, there are ten different levels of coverage (75%, 80%, 85%, 90%, 95%, 100%, 105%, 110%, 115% and 120%).
Farms' Characteristics	
Land size	Land size for operating includes renting size for operating and owning size for operating. (unit: 1000 acre)
Rent percent	Rent size for operating / Land size for operating
Surface water	Surface water on farmland (=1) ; otherwise (=0)
Returns from farms	Share of pre-tax household income from farming (see table 2)
Investment to farms	Share of pre-tax household income back to farming (see table 2)
Crop farms	Farmers have revenue from crop or plant crop in their land (=1) ; otherwise (=0)
Livestock farms	Farmers have revenue from livestock or raise livestock (=1) ; otherwise (=0)
Farmers' Characteristics	
Age	Farmer's age
Education	The highest level of education farmers have completed (see table 2)
Non-white	Operator's race is not white (=1) ; otherwise (=0)
Income level	The household annual pre-tax income level (see table 2)
Farming experience	The years farmers have been farming
Water recreation	Participating in water related recreation at least once a year (=1) ; otherwise (=0)
Environmental Characteristics	
Water quality	The water quality nearest to farmers' property rated by respondents
Environmental awareness	The respondents' awareness of issues concerning the environment rated by themselves with seven levels. Level seven is very aware, and level one is unaware.
CRP	Currently participating in Conservation Reserve Program (CRP) (=1) ; otherwise (=0)
WLP	Currently participating in Working-land Program (WLP) (=1); otherwise (=0). WLP includes Conservation Stewardship Program (CSP), Environmental Quality Incentives Program (EQIP), Wildlife Habitat Incentives Program (WHIP)
Information: The survey was designed with 4 levels of information explaining the meaning of WQT programs	
Level 1	The least detailed information level (=1); otherwise (=0)
Level 2	The less detailed information level(=1); otherwise (=0)
Level 3	The more detailed information level(=1); otherwise (=0)
Level 4	The most detailed information level(=1); otherwise (=0)

Note: the discrete levels in table are interpreted in table 2.

Table 5. The Explanation for Discrete Variables

Level	Returns from farms	Investment to farms	Education	Income level ($)	Water Quality
1	0-15%	0-15%	Not a high school graduate	0 to 14999	Lowest quality
2	16-30%	16-30%	High school graduate	15000 to 24999	Lower quality
3	31-45%	31-45%	Some college, no degree	25000 to 49999	Low quality
4	46-60%	46-60%	Associate degree	50000 to 74999	Fair quality
5	61-75%	61-75%	Bachelor degree	75000 to 99999	High quality
6	75-90%	75-90%	Master degree	100000 to 149999	Higher quality
7	above 90%	above 90%	Professional degree	above 150000	Highest quality
8	-	-	Doctorate	no response	-

Table 6. Statistical summary

	All sample		Riparian buffers		Fence		No till		Waste storage facility		Nutrient management	
	N=357		N=149		N=182		N=178		N=151		N=176	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
Offer	0.970	0.150	0.964	0.147	0.964	0.151	0.961	0.147	0.959	0.144	0.959	0.150
Land size	0.282	0.537	0.340	0.709	0.319	0.651	0.366	0.703	0.381	0.737	0.343	0.689
Rent percentage	0.142	0.275	0.147	0.275	0.158	0.292	0.171	0.300	0.182	0.301	0.166	0.293
Surface water	0.860	0.348	0.872	0.335	0.890	0.314	0.882	0.323	0.881	0.325	0.852	0.356
Returns from farms	2.417	1.815	2.450	1.880	2.478	1.847	2.517	1.848	2.550	1.886	2.500	1.833
Investment to farms	2.529	1.542	2.517	1.536	2.610	1.515	2.607	1.560	2.755	1.649	2.682	1.535
Crop farms	0.423	0.495	0.403	0.492	0.434	0.497	0.517	0.501	0.470	0.501	0.483	0.501
Livestock farms	0.798	0.402	0.832	0.375	0.868	0.339	0.831	0.375	0.861	0.347	0.852	0.356
Age	60.154	11.908	61.792	11.142	59.786	11.946	60.202	12.060	60.278	12.025	59.915	11.521
Education	4.078	1.920	4.268	1.958	4.170	1.946	4.180	1.881	4.139	1.953	4.409	1.907
Income level	4.359	1.499	4.577	1.607	4.484	1.530	4.522	1.574	4.530	1.608	4.670	1.612
Non-white	0.045	0.207	0.027	0.162	0.033	0.179	0.039	0.195	0.020	0.140	0.028	0.167
Water recreation	0.661	0.474	0.638	0.482	0.654	0.477	0.669	0.472	0.636	0.483	0.676	0.469

(Continued)

Table 6 Continued

	All sample		Riparian buffers		Fence		No till		Waste storage facility		Nutrient management	
	N=357		N=149		N=182		N=178		N=151		N=176	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
Farming experience	32.220	15.307	33.453	14.941	33.266	14.651	33.396	14.690	33.315	14.669	32.264	15.412
Water quality	5.038	1.365	5.050	1.344	5.148	1.284	5.183	1.321	5.195	1.310	5.094	1.325
Environmental awareness	4.947	1.556	5.141	1.656	5.011	1.573	5.000	1.548	4.967	1.538	5.159	1.503
CRP	0.118	0.323	0.141	0.349	0.1211	0.327	0.146	0.354	0.179	0.384	0.136	0.344
WLP	0.204	0.404	0.262	0.441	0.247	0.433	0.253	0.436	0.305	0.462	0.244	0.431
Riparian buffer	0.367	0.483	0.456	0.500	0.396	0.490	0.410	0.493	0.384	0.488	0.438	0.497
Fence	0.465	0.499	0.503	0.502	0.577	0.495	0.478	0.501	0.490	0.502	0.523	0.501
No till	0.311	0.464	0.356	0.480	0.319	0.467	0.444	0.498	0.351	0.479	0.375	0.486
Waste storage facility	0.067	0.251	0.081	0.273	0.060	0.239	0.096	0.295	0.113	0.317	0.091	0.288
Nutrient management	0.241	0.428	0.329	0.471	0.264	0.442	0.303	0.461	0.291	0.456	0.358	0.481
Information level 1	0.235	0.425	0.275	0.448	0.253	0.436	0.264	0.442	0.219	0.415	0.233	0.424
Information level 2	0.261	0.440	0.228	0.421	0.258	0.439	0.247	0.433	0.272	0.446	0.250	0.434
Information level 3	0.210	0.408	0.201	0.402	0.181	0.386	0.202	0.403	0.212	0.410	0.222	0.417
Information level 4	0.294	0.456	0.295	0.458	0.308	0.463	0.287	0.453	0.298	0.459	0.295	0.458

Table 7. First Part: Current Usage of BMPs

	Bivariate probit				2SRI model
	Riparian Buffers	Animal fences	No till	Nutrient management	Waste storage facilities
Crop farms	0.351	0.230	0.326	0.392*	0.066
	(0.245)	(0.210)	(0.213)	(0.217)	(0.307)
Livestock farms	-0.077	1.609***	-0.032	0.233	0.606
	(0.323)	(0.382)	(0.284)	(0.309)	(0.584)
Age	-0.022*	0.006	<0.000	-0.017	0.037*
	(0.013)	(0.011)	(0.011)	(0.012)	(0.019)
Education	0.141**	0.036	0.136**	0.044	0.004
	(0.065)	(0.056)	(0.061)	(0.061)	(0.083)
Farming experience	0.021**	-0.004	0.007	0.004	<0.000
	(0.010)	(0.009)	(0.009)	(0.009)	(0.013)
Water recreation	0.537**	0.325	0.366	0.099	0.261
	(0.258)	(0.222)	(0.230)	(0.245)	(0.353)
CRP	0.549	0.507	1.527***	0.197	0.358
	(0.339)	(0.347)	(0.340)	(0.322)	(0.351)
WLP	0.608**	0.600**	0.214	0.435*	0.560*
	(0.270)	(0.251)	(0.203)	(0.235)	(0.324)
Water quality	-0.147	0.030	-0.071	-0.092	0.149
	(0.091)	(0.082)	(0.079)	(0.083)	(0.123)
Environmental awareness	0.247***	0.0454	0.088	0.223***	-0.015
	(0.085)	(0.071)	(0.068)	(0.080)	(0.104)
Constant	-1.255	-2.476***	-1.648**	-1.011	-5.321***
	(0.947)	(0.879)	(0.811)	(0.912)	(1.595)
N	149	182	178	176	151
pseudo R^2	-	-	-	-	0.140

Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8. Second Part: Willingness to Participate in BMPs in the Future

	Bivariate probit model				**2SRI model**
	Riparian Buffers	Animal fences	No till	Nutrient management	Waste storage facilities
Cost coverage compensation:					
Offer	1.184	1.464*	0.526	0.744	1.734*
	(0.890)	(0.889)	(0.724)	(0.688)	(0.943)
Farms' Characteristics:					
Land size	-0.618	-0.990*	0.135	-0.047	-0.066
	(0.525)	(0.515)	(0.290)	(0.142)	(0.237)
Rent percent	0.652	0.375	-0.850**	0.064	-0.659
	(0.617)	(0.501)	(0.415)	(0.389)	(0.522)
Surface water	0.262	-0.194	0.123	-0.126	0.877**
	(0.435)	(0.385)	(0.357)	(0.329)	(0.438)
Returns from farms	-0.078	0.201*	0.0379	0.040	-0.092
	(0.099)	(0.118)	(0.084)	(0.078)	(0.088)
Investment to farms	0.361***	0.128	0.0313	0.119	0.289***
	(0.116)	(0.130)	(0.085)	(0.095)	(0.107)
Crop farms	0.001	-0.025	0.625**	0.571**	-0.059
	(0.281)	(0.286)	(0.243)	(0.227)	(0.261)
Livestock farms	-0.230	-0.427	-0.915**	-0.137	-0.342
	(0.360)	(0.604)	(0.389)	(0.375)	(0.401)
Farmers' Characteristics:					
Age	-0.005	-0.033**	-0.041***	-0.029**	-0.033**
	(0.016)	(0.016)	(0.015)	(0.013)	(0.016)
Education	0.095	0.189**	0.099	0.117*	-0.015
	(0.086)	(0.082)	(0.0713)	(0.069)	(0.072)
Income	-0.031	0.034	0.0631	-0.023	-0.115
	(0.102)	(0.095)	(0.0758)	(0.080)	(0.093)
Non-white	0.437	1.398	1.144	0.853	1.361
	(0.875)	(1.727)	(0.942)	(1.000)	(0.955)
Water recreation	0.958***	0.592**	0.595**	0.440*	-0.106
	(0.298)	(0.301)	(0.262)	(0.240)	(0.280)
Farming experience	-0.021	0.009	0.0252**	0.002	-0.015
	(0.014)	(0.012)	(0.011)	(0.010)	(0.011)
Water quality	-0.211**	-0.433***	-0.226**	-0.022	-0.263**
	(0.099)	(0.116)	(0.091)	(0.089)	(0.104)

Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

(Continued)

Table 8. Continued

	Bivariate probit model				2SRI model
	Riparian Buffers	Animal fences	No till	Nutrient management	Waste storage facilities
Current Experience of BMPs:					
Riparian buffers	0.245	0.094	-0.533**	0.024	0.041
	(0.763)	(0.284)	(0.238)	(0.214)	(0.265)
Fence	0.353	1.759*	0.464**	0.247	0.298
	(0.267)	(0.930)	(0.214)	(0.215)	(0.258)
No till	0.445	0.141	0.078	0.655**	0.313
	(0.322)	(0.360)	(0.481)	(0.318)	(0.316)
Waste storage facility	-1.620**	0.948	0.273	-0.567	3.606**
	(0.642)	(0.667)	(0.438)	(0.395)	(1.554)
Nutrient management	-0.336	-0.590*	-0.071	-0.461	-0.064
	(0.326)	(0.331)	(0.264)	(0.749)	(0.300)
Information level:					
Level 2	0.267	1.056***	0.362	0.719**	0.473
	(0.364)	(0.399)	(0.277)	(0.327)	(0.333)
Level 3	0.073	0.174	0.371	0.371	0.669*
	(0.385)	(0.396)	(0.308)	(0.347)	(0.371)
Level 4	0.092	-0.071	-0.173	0.443	0.239
	(0.346)	(0.324)	(0.263)	(0.285)	(0.351)
Generalized Residual	-	-	-	-	-1.878**
	-	-	-	-	(0.860)
Constant	-1.072	0.505	1.691	-0.315	0.883
	(1.606)	(1.612)	(1.329)	(1.281)	(1.742)
	Correlation: Rho				
athrho	0.355	-0.111	1.291*	1.222	-
	(0.498)	(0.600)	(0.634)	(1.060)	-
rho	0.341	-0.110	0.859***	0.840***	-
	(0.441)	(0.592)	(0.166)	(0.311)	-
Likelihood-ratio test of rho=0					
chi2(2)	0.525	0.034	7.701***	2.843*	-
Prob > chi2	0.469	0.853	0.006	0.092	-
N	149	182	178	176	151
pseudo R^2					0.217

Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

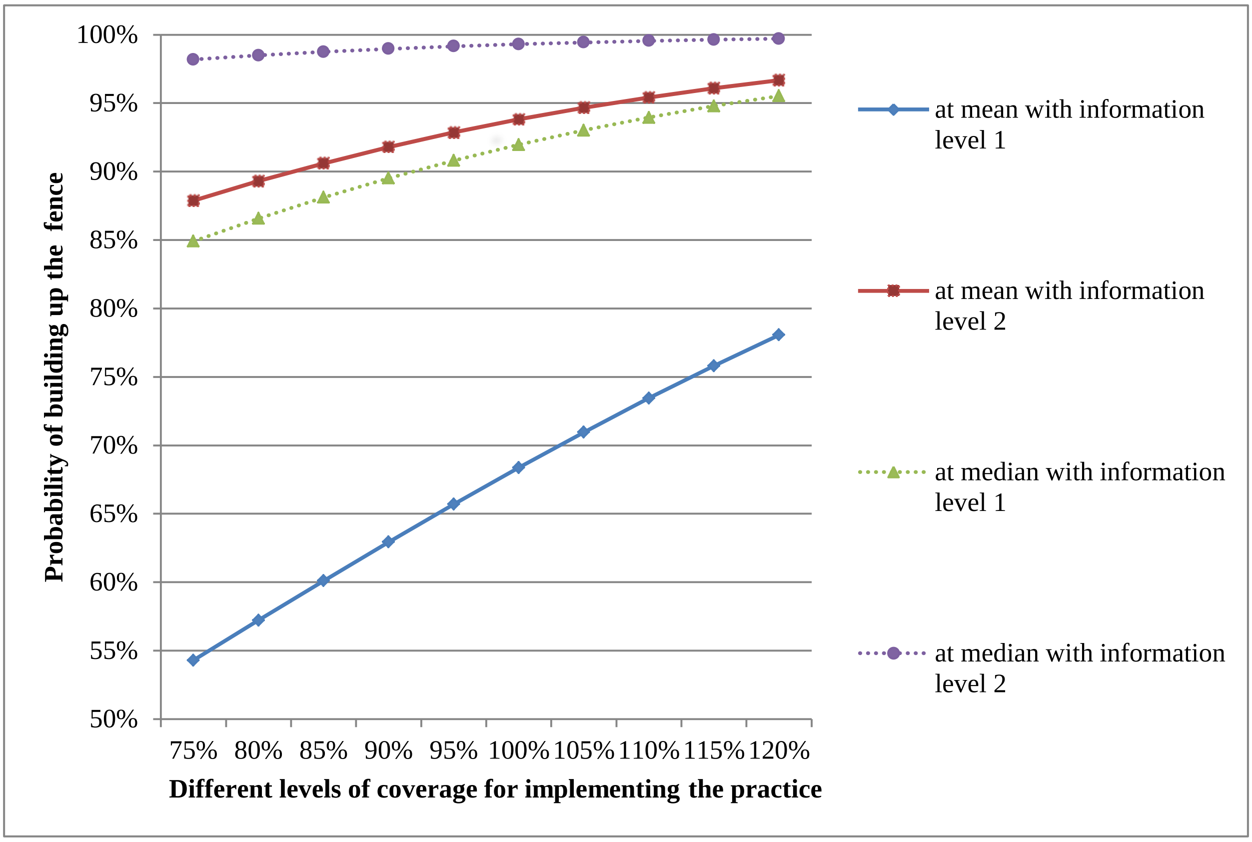

Figure 1. Response curves for the practice of animal fences (fencing off animals from direct access to rivers, streams, or lakes)

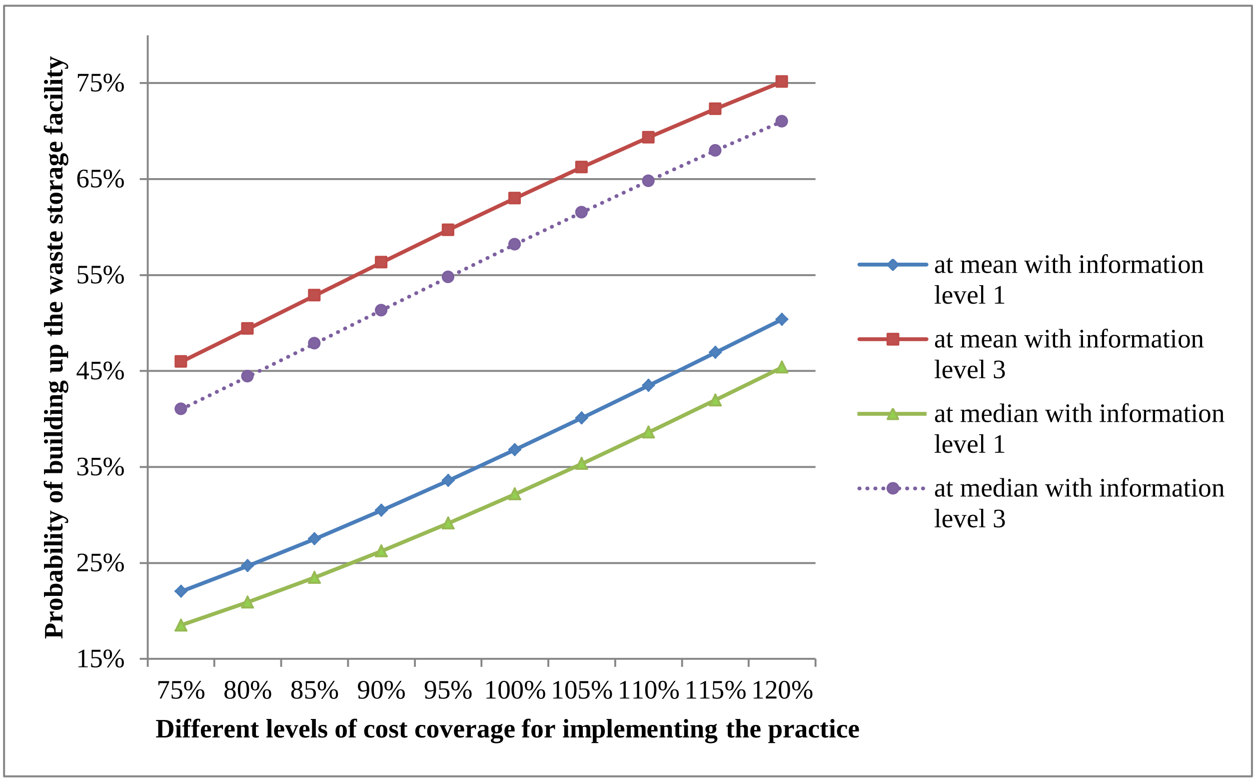

Figure 2. Response curves for the practices of waste storage facility