

2009

Three essays on environmental issues associated with broiler production in Louisiana

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**THREE ESSAYS ON
ENVIRONMENTAL ISSUES ASSOCIATED WITH BROILER PRODUCTION IN
LOUISIANA**

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Agricultural Economics & Agribusiness

by
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May 2009

To the almighty of lord for the Love and Merci...

To my parents for giving me the strength to continue...

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my major professor Dr. Krishna P. Paudel for his valuable guidance and advice throughout my dissertation. My appreciation is also extended to the committee members Dr. R. Carter Hill, Dr. Rex H. Caffey, Dr. Richard R. Kazmierczak Jr., and Dr. Hector O. Zapata. I am indebted to all my committee members for their incredible help and guidelines in the dissertation research, analysis and writing.

I would like to thank Dr. Gail Cramer, the department head of the Agricultural Economics and Agribusiness for generously providing me an assistantship to pursue this degree. My sincere thank also goes to Dr. J. Matthew Fanning for providing me a financial assistance when I needed it the most.

I have enjoyed the friendship with my friends and fellow graduate students in and outside the department. I thank their help and friendship to make my life at Louisiana State University a peaceful and fruitful journey.

My deepest gratitude goes to my husband Mohan Adhikari and my brother-in-law Murali Adhikari for their role in my career development. My husband has shown great strength and support for this achievement. Without his love and devotion, my study could not have been accomplished. Thank you my kids, Ashna, Ashish and Anuja for letting me to be a Ph D student instead of your mother.

Thank you my parents for your endless love and support throughout my study and especially during the time I was sick and could not take care of myself. I sincerely appreciate the help from my parent-in-laws, without their support I could not have achieved the goal of my life.

Last but not least, I like to thank my extended family including my brother and sister their families and in-laws.

TABLE OF CONTENTS

DEDICATION	ii
ACKNOWLEDGEMENTS	iii
LIST OF TABLES	vii
LIST OF FIGURES	viii
ABSTRACT.....	ix
CHAPTER ONE: INTRODUCTION	1
I. Louisiana Broiler Production	3
II. Rationale of the Study.....	5
III. Current Programs Mitigating Agricultural Pollution.....	8
IV. Research Questions	10
V. Research Objectives.....	10
VI. Outline of The Dissertation.....	11
VII. References	12
CHAPTER TWO: SURVEY METHODOLOGY	14
I. Survey Instrument.....	14
II. Data Description	16
III. References	26
CHAPTER THREE: ADOPTION OF BEST MANAGEMENT PRACTICES (BMPs) TO MITIGATE NUTRIENT POLLUTION: A DURATION ANALYSIS.....	27
I. Introduction	27
II. Literature Review	30
III. Model	33
IV. Data.....	41
V. Result and Discussion	47
VI. Conclusion.....	55
VII. References	56
CHAPTER FOUR: IS PRODUCTION TERMINATION A GOOD POLLUTION CONTROL ALTERNATIVE? AN ASSESSMENT OF WILLINGNESS TO ACCEPT VALUES BY BROILER PRODUCERS.....	60
I. Introduction	60
II. Literature Review	62
II. Model	66
IV. Data.....	70
V. Result and Discussion	76
VI. Conclusion.....	85
VII. References	87

CHAPTER FIVE: BROILER PRODUCERS' WILLINGNESS TO PAY TO REDUCE WATER POLLUTION.....	90
I. Introduction	90
II. Literature Review	91
III. Model	95
IV. Data	100
V. Result and Discussion	103
VI. Conclusion.....	111
VII. References	113
CHAPTER SIX: CONCLUSION	117
I. References	122
APPENDIX A: TREND IN MEAT CONSUMPTION	123
APPEINDIX B: PROPORTIONAL HAZARD RESIDUAL PLOTS AND TESTS	124
APPENDIX C: HECKMANS SAMPLE SELECTION MODEL USIGN TWO-STEP PROCEDURE AND RESULT	131
APPENDIX D: DISTRIBUTION OF VARIABLES USED	136
APPENDIX E: STATA PPROGRAM.....	138
APPENDIX E1: CODES USED IN CHAPTER THREE	138
APPENDIX E2: CODES USED IN CHAPTER FOUR	142
APPENDIX E3: CODES USED IN CHAPTER FIVE	146
VITA.....	150

LIST OF TABLES

2.1	Characteristics Of Respondents	15
2.2	Description Of Manure Management By Louisiana Broiler Growers	21
2. 3	Manure Handling By Louisiana Broiler Growers.....	21
2.4	Crop Area, Crop-Nutrient Demand And The Nutrient Supply From Broiler Production .	24
3.1	Alternative Models, Their Abilities to Handle Heterogeneity and Event Correlation, Their Pitfalls and Advantage	40
3.2	Summary Statistics of Variables Used	46
3.3	Variance Corrected Models for BMP Adoption (Cox Regression Model)	47
3.4	Variance Correction Models for BMP Adoption (WLW Model)	49
3.5	Individual Heterogeneity Model for BMP Adoption (Shared Frailty Model)	51
3.6	Event Dependence and Heterogeneity Models for BMP Adoption (Conditional Frailty Model).....	54
4.1	Summary Statistics of Explanatory Variables.....	73
4.2	The Determinants of Willingness to Participate: Binary Variable B_i	80
4.3	The Determinants of WTA: Sample Selection and No-Selection Models for W_i	82
5.1	Summary Statistics for the Variables Used	104
5.2	Parameter Estimates Using Ordered Response Models on Stated WTP Range	105
5.3	Marginal Effects of Ordered Probit Models on Stated WTP Ranges.....	107
5.4	Coefficient Estimates Using Generalized Ordered Probit Model	109
5.5	Marginal Effects Estimated From the Generalized Ordered Probit Model	110

LIST OF FIGURES

2.1	Broiler Producing Parishes in Louisiana.	14
2.2	Farm Size Measured by Number of Broiler.....	16
2.3	Broiler Houses Built by Years.	17
2.4	Broiler Houses Retrofitted to Include New Technology.	18
2.5	Duration of Litter Remains in Piles.....	19
2.6	Stated Reasons for Not Selling Broiler Litter.	20
2.7	Land Use Pattern in Study Area.....	22
2.8	Land Use Classification of Louisiana.....	23
3.1	Total Number of BMP Adoptions over the Years.....	42
3.2	Percentage of Broiler Producers Adopting Best Management Practices.....	43
A1	Trend in Meat Consumption over Ninety Five Years	123
B1	Residuals Plots to Check the Whether the Proportional Hazard Assumption Hold for Each Variable Used in the Model.	125
B2	Nelson Aalen Cumulative Hazard Function for BMP Adoption Differentiated by Type of Available BMPs	126
B3	Nelson Aalen Cumulative Hazard Function for First BMP Adoption for an Individual.	127
B4	Nelson Aalen Cumulative Hazard Function for Second BMP Adoption for Individual...	128

ABSTRACT

The increasing trends of integrated and concentrated broiler production results in a serious threat to environment through excessive litter production and lack of its proper disposal. Production concentration in limited area is a major source of surface as well as ground water pollution. Nonpoint source pollution from broiler litter applied on land remains a major concern in Louisiana and elsewhere in Southeastern USA. This study examines alternative approaches to reduce pollution originating from broiler production. First, I evaluate why some producers adopt BMP faster than others and what kind of factors affect the time to adoption decision. The duration model is employed to allow the censored observation while evaluating the impact of farm and individual specific characteristics on time to adoption decision. The information and awareness about the BMPs and the negative effects of broiler production on water-bodies are found to be the main factors to encourage the adoptions. Larger farmers are also the early adopters of BMPs.

The existing literature finds voluntary BMP implementation serves only as complementary-instrument to economic-incentive-based approaches. Therefore, the option of economic-incentive based approach to mitigate water pollution becomes crucial. I evaluate the factors associated with the incentive level that motivates broiler producers to either terminate the production practices or pay pollution abatement costs so as to reduce pollutant entering water resources. I attempt to answer the question of “what is the minimum amount that a broiler producer is willing to accept to forgo the production practice so as to reduce pollution generation”. It is found that broiler producers are willing to terminate production only if the government payment is very high as compared to the profit from the production. However, the

producer's willingness to pay pollution abatement tax is comparatively small, if they were to pay to mitigate the water pollution at their current production technology.

CHAPTER ONE

INTRODUCTION

Rapid growth on broiler production and its spatial concentration have been a serious issue due to the negative environmental consequences originating from excessive litter production (Glover, 1996; Wastenberger and Dedson, 1995). The concentration of broiler production exacerbates the level of litter¹ application in the broiler production areas (Glover, 1996). Broiler litter, when applied on land improperly and in excessive amounts², causes higher nutrients concentration in soil which eventually results in leaching and surface runoff into the water-bodies (Kingery *et al.*, 1994). In addition, the lack of perfectly operating litter markets results in a repetitive application exacerbating the nutrient buildup, runoff, and leaching (Sharpley *et al.*, 2004) – causing externalities to other inhabitants in the region.

Excess nitrogen may leach into ground water causing risk to human health, or runoff to the coastal waters causing hypoxia, whereas the phosphorus (the main nutrient pollutant from broiler litter) runs off along with the sediments from crops and pasture lands, adding on to the water contamination and eutrophication. These adverse environmental effects are largely attributed to the litter application in excess of the nutrient requirement of crops and pastures, and/or trying to dispose the byproduct of chicken production (Glover, 1996).

These externalities prevent a socially optimal use of the water resources among users posing negative effects on human health as well as to the ecosystem. The governmental and public concern over the potential health effects has forced the United States Environmental Protection Agency (US EPA) and state agencies to intensify the regulatory approaches to reduce

¹ Broiler litter represents the mixture of broiler excreta, bedding material and waste feed removed from the production units during the cleaning process.

² Excessive litter application is defined as an application that provides nutrients (Nitrogen and Phosphorous) greater than the crop requirement.

nutrient pollution. In fact, the broiler industry is under the threat of environmental regulation because of the increased level of nutrient buildup and run off which originates from excessive and repetitive litter application (MacDonald, 2008).

Conceptually, the externality problem can be solved by using price mechanisms, control instruments or the pollution standards and restricting the use of pollution-generating inputs in the production process. The problem can also be solved by implementing management practices which reduces the nutrients amount from reaching the water-bodies. In addition, the concept of production termination has been an alternative strategy to reduce agriculture related pollution, in recent years (Lambert, *et al.*, 2007; Reichelderfer and Boggess, 1988).

Governmental incentive payments are provided in order to motivate producers to voluntarily modify their production practices to meet pollution-reduction goals. Further, the section 319 of the Clean Water Act focused on voluntary adoption of best management practices (BMPs) to reduce agriculture related non-point source pollution. The implementation of BMPs requires farmers' investment although the farmers fail to experience full benefits out of their investments. Such fact affects the BMPs adoptions negatively, resulting in slow rate of BMPs adoption among farmers (Gillespie *et al.* 2008). The first section of this dissertation evaluates the underlying factors hindering the voluntary implementation of BMPs.

The failure to encourage producers from implementing BMPs generates a concern that the voluntary effort may fail to meet the desired water pollution reduction goal. The fear of failure to mitigate existing agricultural water pollution through voluntary BMP adoptions is also fueled by the current environmental conservation programs being economically inefficient (Babcock, 1995). In addition, the existing literature argues that the voluntary effort fails to

generate desired level of pollution reduction if not combined with other complementary governmental regulation (Lyon and Maxwell, 2002).

Then, the option of terminating (partially/fully) the production program to reduce water pollution emerges as a potential alternative to control agricultural water pollution. However, the question remains on whether the farmers are willing to terminate the production process to comply with water pollution regulation. On the other hand, if the producers are not regulated/not charged for the pollution they generate, the non-regulated operations continue contributing significantly to the water contamination. Hence, the second section seeks to explore the notion of incorporating polluters on pollution reduction processes.

Thus in this dissertation, three measures of mitigating nutrient pollution originating from broiler industries are explored. It covers the concept of bringing the polluters on pollution reduction process either through voluntary implementation of BMPs or through providing economic incentives and disincentives to the producers. Farmer's willingness to maintain water quality through the manipulation of broiler numbers is evaluated by assessing the level of incentive level that the farmer desires to receive, if producer were to cooperate with pollution reduction program. In addition, the concept of charging pollution abatement cost to force the producers to pay for pollution control measures is also examined in this dissertation. Thus the key concept of this dissertation lies on the fact that the implementation of corrective mechanisms for nutrient pollution depends on the producers' response behavior toward mitigating generation of the nutrient pollutant.

I. LOUISIANA BROILER PRODUCTION

According to Louisiana Agricultural Summary, there were 468 broiler producers in Louisiana in 2006 (Louisiana Agricultural summary, 2006). The number of producers has

decreased from 579 in 2002, but the production has not decreased (Louisiana Agricultural summary, 2003). The numbers suggest the concentration of broiler litter production or the concentration of nutrient production has increased in years between 2002 and 2006. The absence of a well functioning litter market and cost-efficient transportation system has forced broiler producers to dispose excess litter on nearby crops and pasture lands.

Broiler production in Louisiana is clustered in relatively small, localized areas generating a higher concentration of broiler litter in a few counties of northern Louisiana. Essentially, all broiler production in Louisiana is vertically integrated and thus operated under contract. In fact, production through contractual arrangements provides benefits to the producers such as reduced market risk, production reduction responsibilities, lower operating capital requirements, and relatively reliable and predictable incomes (Vest and Lacy, 1996). Contract based production processes also result in rapid technology adoption, improved production efficiency, as well as easy access to capital (Vukina, 2001). However, contract-based production leaves narrow margin for profit and full responsibility of litter management to broiler producers.

The vertical integration of broiler production includes integration from hatcheries through feed mills and processing plants. However, broiler production operations require substantial investments on litter management which becomes the responsibility of the broiler producers. Thus, the producers, not the contractors, face the responsibility of complying with the governmental regulations and restrictions regarding environmental issues associated with broiler production.

More specifically, the producers bear the burden of complying to government regulations associated with the impact of litter on water quality – increasing their cost of production. Furthermore, the producers are awarded or punished based on their production performances. For

example, the producers producing more pounds on lower costs and/or having a lower mortality rate are paid higher as compared to other growers (Vukina, 2001; Vest and Lacy, 1999), which leaves limited or negative economic incentive to broiler producers for litter management.

Hence, the producers not only have to invest in management practices that lower the nutrient production but also are punished by the integrators for increased production costs. Therefore, the pressure for the broiler producers comes from both sectors -- the government and the contractors, forcing the producers to seek for a low cost litter management option so that they can stay in the business.

II. RATIONALE OF THE STUDY

The Environmental Protection Agency's National Water Quality Inventory of year 2000 reported that more than 41% of Louisiana's water-bodies either partially or fully fail to support the designated use (EPA, 2000)³. In particular, out of 9,455 miles of streams and rivers surveyed, only 52% of surveyed miles support the designated water quality goal. More than 11% of rivers and streams do not support the designated use and 37% only partially support water quality standards (EPA, 2000).

Similarly, out of 664,124 acres of surveyed lakes in Louisiana, only 57% fully support their designated water quality standard. More than 5% of the lakes surveyed fail to support their designated use and 15% of the lakes partially support their required characteristics. Moreover, only 10% of surveyed wetlands fully meet the criteria for its designated use (EPA, 2000).

In Louisiana, water-bodies within the western parts of the Ouachita River Basin and the eastern parts of the Red River Basin partially meet their designated use or are largely threatened

³ Environmental Protection Agency. Louisiana waters
<http://www.cleanwaternetnetwork.org/docs/publications/factsheets/states/la.pdf>

by the nutrients flow produced by broiler operations and pastureland runoff⁴. Large scale broiler productions concentrated in the northern parishes of Louisiana are responsible for contributing the significant amounts of phosphorus and nitrogen in nearby water-bodies⁵.

In addition, the lack of a fully functioning litter market has caused an excessive amount of litter application on crops and pasture lands. The excessive nutrient application thus accelerates both the accumulation and surface flow of nutrients in the watersheds surrounding the broiler production region in northern Louisiana. It is well recognized that the improper and excessive litter application results in increased nutrient leaching and surface runoff causing water contamination (Kingery *et al.* 1994). However, due to the market driven nature of broiler industry and contract based production, the problem of excess litter has been in the shadows among the producers.

EPA noted that the nutrient runoff from land application of livestock manure or poultry litter is a major source of pollution that is discharged into the surface waters (EPA, 2000). The USDA Natural Resource Conservation Service in consort with the US EPA has recommended a voluntary implementation of the BMPs. These practices if implemented decrease the generation and transportation of nutrient pollution into the water-bodies⁶. However, those changes on farming operations – to meet nutrient standards – tend to increase production costs through investments in nutrient management operations. Thus, changing the farming practices to comply with stringent pollution standards is likely to decrease producers' profits through increased production costs (Dupraz *et al.*, 2003). These added production costs and associated profit loss have been blamed for a slow rate of BMPs adoptions (Houston and Sun, 2000). Since a reduction

⁴ <http://nonpoint.deq.louisiana.gov/wqa/poultry.htm>

⁵ <http://nonpoint.deq.louisiana.gov/wqa/poultry.htm>

⁶ Environmental Issues Facing the Louisiana Poultry Industry: Magazine: Poultry Waste Management accessed from <http://www.lsuagcenter.com/MCMS/RelatedFiles/{95071472-8B1F-40D9-8162-404692A70A48}/PoultryEnvironmentalConcerns.pdf>

in producers' profits has been recognized as a major factor in hindering the adoption of environmentally friendly practices (such as BMP), there is a need to identify alternative measures of pollution reductions.

In addition, after a thorough literature survey of voluntary practices in the United States and Europe, Lyon and Maxwell (2002) emphasized that voluntary implementation of environmentally friendly production practices are complementary to the environmental regulation and/or standard, not the substitute. Therefore, only the voluntary BMPs adoptions may not suffice to achieve pollution reduction as desired. The notion of a production termination and pollution tax along with voluntary BMPs seems to be a potential combination to reduce nutrient build up and runoff.

Production termination, either partially or fully, is not in the producers' own interest but it is inspired by the threat of environmental regulation. Therefore, the producers require sufficient incentives to recover losses associated with the termination of their production process. Assigning the level of incentive payment revolves around the notion of farmers' willingness to participate in pollution reduction programs or proposed policies for nutrient pollution reduction. Therefore, it is also imperative to understand how much the individuals expect to receive if they were to comply with the proposed policies of pollution reduction. Such values in this study are measured using contingent valuation approaches. The willingness to accept and willingness to pay, are the two different measures to elicit farmers' desire to participate in a pollution-reduction program either through terminating production practices to reduce pollution generation or by paying pollution abatement cost.

I employ willingness to pay and accept measures to evaluate broiler growers' interest to mitigate water pollution problem. This study assumes that the producers are aware of their

contribution toward water pollution and the water pollution is negatively associated with human health as well as with the ecosystem.

III. CURRENT PROGRAMS MITIGATING AGRICULTURAL POLLUTION

The EPA and the states regulated point source pollution through the National Pollutant Discharge Elimination System (NPDES) permit program under the Federal Water Pollution Control Act (Clean Water Act)⁷. The program focused on water pollution mitigation through regulatory actions over point sources. A considerable progress was made in restoring and maintaining pollution flow. However, the achievement could not solve the nation's water quality problems. Thus, by 1987, the importance of acting over nonpoint source pollution was well recognized.

The amended Clean Water Act, "1987 Water Quality Act" established a national level of Nonpoint Source Management Programs to address nonpoint source pollution. The Nonpoint Source Management Programs established by section 319 of the amended CWA started to provide the EPA the authorities to offer grants, guidance and technical help for the state programs to encourage implementation of nonpoint source management programs. Section 320 of amended CWA authorizes EPA to provide grants and technical guidance to state and local governments for implementing comprehensive management plans to maintain estuaries.

The Rural Clean Water Program (RCWP) was started in 1980 to address agricultural NPS pollution in watersheds until 1990 as an experimental effort. The program focused on minimizing pollutant production and improving water quality while producing agricultural commodities in the rural areas. The experimental projects included implementation of BMPs to

⁷ *National Management Measures to Control Nonpoint Source Pollution from Agriculture*, EPA 841-B-03-004, July 2003. <http://www.epa.gov/owow/nps/agmm/chap1.pdf> retrieved on Dec 1st 2008

mitigate agriculture related nonpoint water pollution and monitoring to examine the effects of the BMPs.

The conservation provisions of the Farm Bill (1996) provides landowners the technical and financial assistance to conserve, improve, and sustain the soil, water, air, and related natural resources on their land. Environmental Quality Incentives Program (EQIP) was established by the Federal Agriculture Improvement and Reform Act (1996 Farm Act) and jointly administered by Natural Resource Conservation Service (NRCS) and Farm Service Agency (FSA) for the purpose of providing incentives to the farmers and ranchers posing threats to soil and water resources. The EQIP provides financial incentives, technical guidance and education to comply with Federal, State, Tribal, and local environmental regulations as well as to encourage the implementation of conservation practices that manage agricultural pollution.

The EQIP supplies cost-share (generally about 60% but up to 90% for limited resource farmers) for an implementation of conservation practices to the grass lands, forest and crops that reduces nutrient loading to the nearby water-bodies. Incentive payments are also extended to the eligible farmers and ranchers implementing nutrient and manure management from their livestock as well as crops and pasture lands. Incentive payments may be extended to three years to encourage the implementation of the practices otherwise the farmers will not. The maximum of ninety percent cost-share is permitted for the small and limited-resource-farmers. However, it may not exceed \$450,000 for all EQIP contracts entered during the term of the Farm Bill.

The 2008 Farm Bill increased cost incentive payments up to 90% for socially disadvantaged farmers or ranchers in addition to limited resource producers as of 2002 Farm Bill. Farm Bill 2008 further allowed farmers to receive advance payment up to 30% of the amount needed to purchase materials to install and/or implement pollution reduction

mechanisms. The funding for EQIP was \$200 million in fiscal year 2002 which increased to \$1.1 billion in year 2007. The amount for fiscal year 2008 is authorized to be \$1.2 billion which will again increases gradually to \$1.75 billion in 2012⁸.

IV. RESEARCH QUESTIONS

The return from increased level of incentive payments for the implementation of voluntary practices has been unconvincing. The unsatisfactory improvement in BMP adoptions needs an examination of the factors associated with the rate of adoption over time. The first topic of this dissertation explores the duration to implement BMPs as a tool to mitigate nutrient generation and runoffs. More specifically, the chapter seeks to answer the question of “what are the underlying factors associated with the slow dissemination of BMPs?”

The next issue incorporated in this dissertation examines the level of government incentive to encourage broiler producers to implement environmentally friendly production decisions. The dissertation answers what is the minimum amount that the broiler producers are willing to accept to forgo their production practices in order to reduce pollution generation.

Then, the third issues addressed here is the amount that a producer is willing to pay as pollution abatement cost. In this regard, this dissertation seeks to evaluate the maximum amount that a broiler producer would like to pay as pollution abatement cost and keep on continuing their existing level of production. This serves as the third alternative to mitigate the water pollution control issue.

V. RESEARCH OBJECTIVES

Due to intensive market oriented broiler production and lack of economic incentive, the broiler producers fail to accommodate pollution control efforts on their production function.

⁸*At a glance: Environmental Quality Incentives Program*. May 2008 retrieved from http://www.nrcs.usda.gov/programs/farmbill/2008/pdfs/EQIP_At_A_Glance_062608final.pdf on Dec 2nd, 2008

Therefore, the primary concentration of this study remains on exploring the mechanisms to accommodate polluters on pollution reduction efforts. In addition, the possibility of litter transportation will also be examined. The specific objectives are to;

- a) Examine time to adopt BMP. The focus remains on the factors affecting the time to BMP adoption.
- b) Evaluate broiler producer's willingness to accept value to participate on the environmentally benign production practices. The value is assumed to represent an amount of incentive payment that the farmers desire to receive in order to internalize pollution reduction efforts on their production function.
- c) Examine the producer's willingness to pay value which is assumed to represent an amount that an individual can afford (willing to spend) to improve water quality.

VI. OUTLINE OF THE DISSERTATION

This dissertation examines the four viable alternatives to involve farmers on pollution reduction programs. The core content of the research is presented on three "journal article style" chapters. The second chapter presents the data collection approach, details on descriptive characteristics of respondents, and simple analysis of manure surplus/deficit in broiler producing parishes in Louisiana.

Chapter three, the first essay, evaluates the broiler producers BMP adoption decision using a Cox proportional hazard model. The event dependence and heterogeneity among individual farmers are accounted for using frailty and conditional frailty models.

Chapter four estimates the WTA of an individual to reduce pollution generation through reduction in broiler production. WTA assumes to represent incentive required by an individual if environmental regulation requires them to cut production size to reduce pollution generation.

Similarly, chapter five examines the farmers WTP value in the form of additional tax if they were to continue their production practice at current size. Chapter six concludes with policy implications of this research.

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CHAPTER TWO

SURVEY METHODOLOGY

I. SURVEY INSTRUMENT

The data used in this dissertation came from a survey where the population included all the broiler producers in Louisiana. The questionnaire design, sampling process and the data collection are not a part of this dissertation. Rather I used secondary data collected through survey to understand broiler production related issues in Louisiana⁹. The data covers the broiler producers in the major broiler producing parishes of Louisiana including Bienville, Claiborne, Jackson, Lincoln, Natchitoches, Ouachita, Sabine, Union, Vernon, Webster, and Winn parishes. Figure 2.1 shows the locations of major broiler-producing parishes in Louisiana and table 2.1 shows the characteristics of respondents.

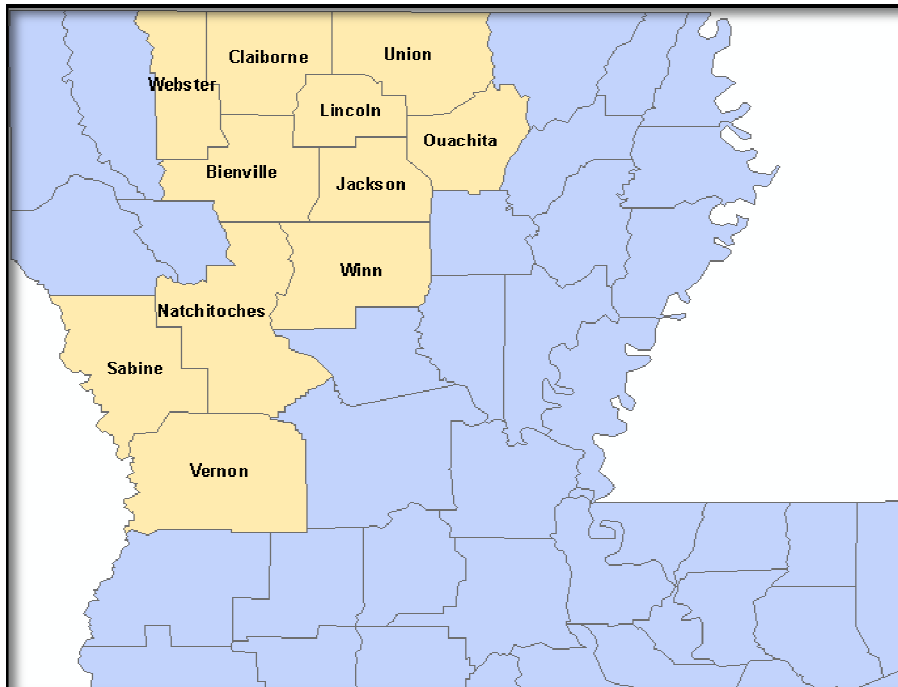


Figure 2.1 Broiler producing parishes in Louisiana.

⁹ Survey design and data collection were done by Paudel (2005). Ref: Paudel, K.P. "Survey of Broiler Farmers in Louisiana." Department of Agricultural Economics and Agribusiness, Louisiana State University Agricultural Center, Baton Rouge, Louisiana. 2005.

Table 2.1: Characteristics of respondents

Age of the respondents (years)	*US Census (%)	Sample (%)
15 to 19 years	8.2	0
20 to 24 years	7.3	8.11
25 to 34 years	13.5	14.86
35 to 44 years	15.5	32.43
45 to 54 years	13.1	13.51
55 to 59 years	4.7	13.51
60 to 64 years	3.8	16.22
65 to 74 years	6.3	1.35
Educational attainment		
Less than high school graduate	25.20	12.16
High school graduate (includes equivalency)	32.40	56.76
Some college, no degree	20.20	14.86
Bachelor's degree	12.20	9.46
Graduate or professional degree	6.50	6.76
Associate degree	3.50	0.00
Marital status		
Never married	28.60	16.22
Married	53.80	79.73
Widowed	7.40	4.05
Divorced	10.20	0.00
Asset to liability ratio		
No debt		18.92
Up to 20% of asset		22.97
21% to 40% of asset		22.97
41% to 60% of asset		21.62
Greater than 60% of asset		13.51
Ownership of broiler farm		
Individual ownership		71.62
Family Ownership		20.27
Others		8.11
Percentage of household income from broiler industry		
0 to 20 percent		20.27
21 to 40 percent		9.46
41 to 60 percent		20.27
61 to 80 percent		22.97
81 to 100 percent		27.03

On an average an individual broiler grower: Raises 470,556 broiler birds; Owns 86 percent of production land; Applies litter on 46 percent of crop land;

*Source: US census bureau at <http://factfinder.census.gov>

The data contains the information on three alternative approaches to mitigate nutrient pollution generated by broiler producers in Louisiana. The data contains general information for BMP adoptions, broiler producers' willingness to participate in the production termination programs, and the amount they need to terminate the production process partially or fully. The data also provides information on willingness to pay values as pollution abatement cost. The willingness to pay values represent broiler producer's desired amount to pay for pollution abatement in the form of tax. In addition, a separate section adds the information on manure application and storage approaches employed by broiler producers. The detailed description of data and variables used in this dissertation are presented on the "DATA AND METHOD" sections of the associated essays.

II. DATA DESCRIPTION

The first section provides the information on farm size and manure application approaches employed by the growers. Farm size is represented by numbers of broiler birds raised per year (Figure 2.2).

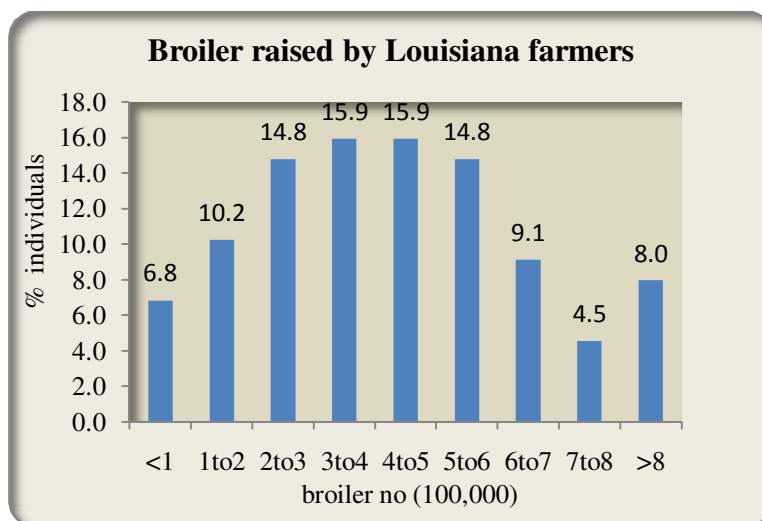


Figure 2.2: Farm size measured by number of broiler

More than thirty one percent of farmers raise 300-500 thousand broilers per year. Nearly seven percent farmers are small broiler growers with less than one hundred thousand broiler birds in a year. In general, one house accommodates twenty five thousand broiler birds. Most of the houses are built in between 1985 to 1994 (Figure 2.3) when the demand for chicken increased rapidly and demand for red meat dropped down (See Figure A1 in Appendix).

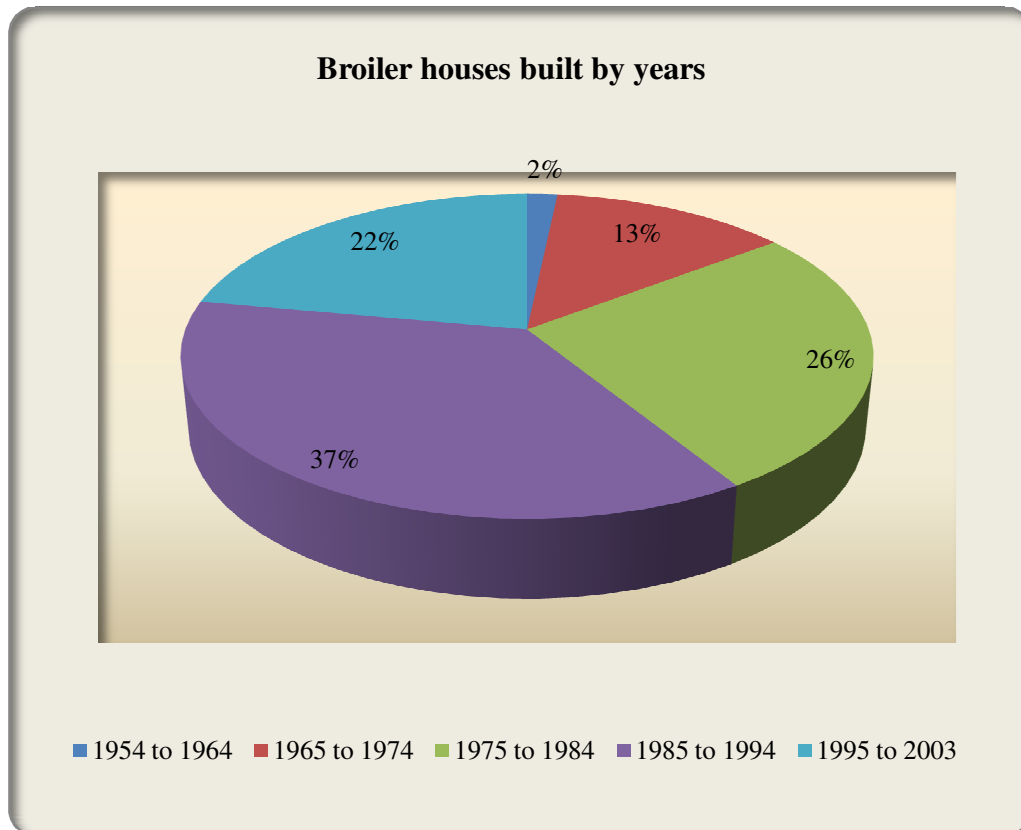


Figure 2.3: Broiler houses built by years.

Thirty seven percent of broiler housings are built in the years from 1985 to 1994. Macdonald (2008) also listed more than sixty five percent of the broiler houses nationwide which were built in between the years of 1986 and 2000. Only two percent of the houses built in between 1954 and 1964 are still in operation (Figure 2.3). Most of those houses are retrofitted to fit with the new technology for competitive production. Figure 2.4 shows the number of houses retrofitted by years.

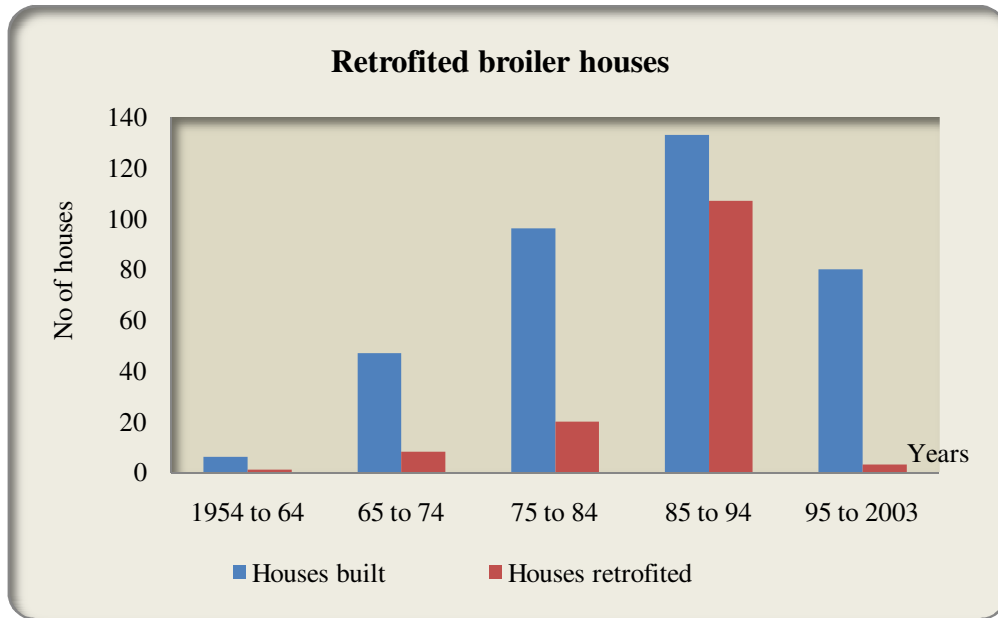


Figure 2.4: Broiler houses retrofitted to include new technology.

The second section presents background information on broiler production in Louisiana and its impact on water sources. The data contains information on three alternatives measures to mitigate water pollution including BMPs adoptions, terminating production process, and paying pollution abatement cost in the form of tax.

The average number of birds produced by Louisiana broiler farmers is 480,000 producing approximately 600 tons of broiler litter. Existing litter disposal and management by broiler growers often fail to account for nutrient contents of the litter, nutrient required by the plant and nutrient content of the soil. On average, Louisiana broiler growers cake out the litter five times in one year (Table 2.2). Cake out is a process of removing litter near watering and evaporating cooling system normally after each flock of birds are removed for marketing . The remaining loose litter is then reused for the new flock until it is ready to be replaced.

The litter taken out during the cake out process or the cleaning process is piled in the storage facilities until the time for land spreading. In general, the data shows more than fifty percent of producers keep the litter on pile for only six months (figure 2.5).

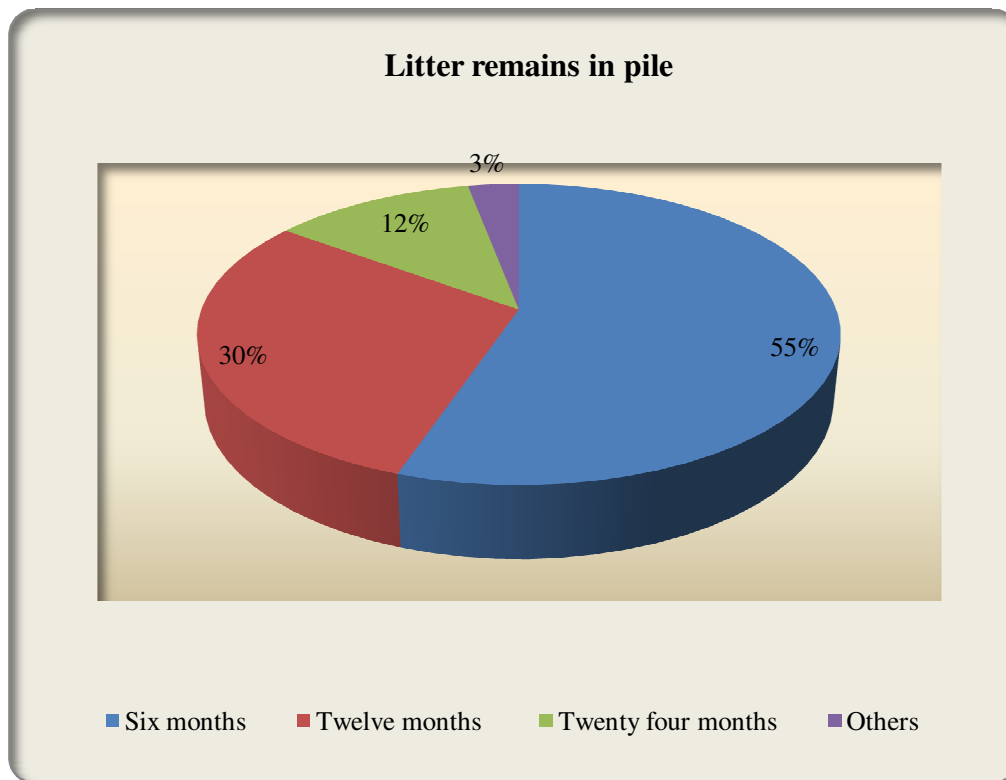


Figure 2.5: Duration of litter remains in piles.

Additionally, an individual farmer has been spreading litter on production land for seven years on average. Pasture land receives broiler litter up to six times a year (Figure 2.6). The result indicates that more than twenty five percent of respondents apply litter on their pasture land at least five/six times a year. Whereas, the application on crop land is almost zero. Only about 1.3 percent of respondents apply litter on crop land about one to two times a year.

Therefore, it can be said that the litter is applied on pasture land irrespective of nutrient content of soil and nutrient need of pasture land, whereas, only one or two application of fertilizer (nitrogen, phosphorous and potassium) are needed based on climatic condition and variety of grass grown by the farmers (Barnhart, 1997). These applications of broiler litter, a common practice by Louisiana broiler farmers imply an over-application of litter on available crop and pasture land. This indicates that the land application of litter is treated as litter disposal without any concern over crop nutrient need or the environmental quality.

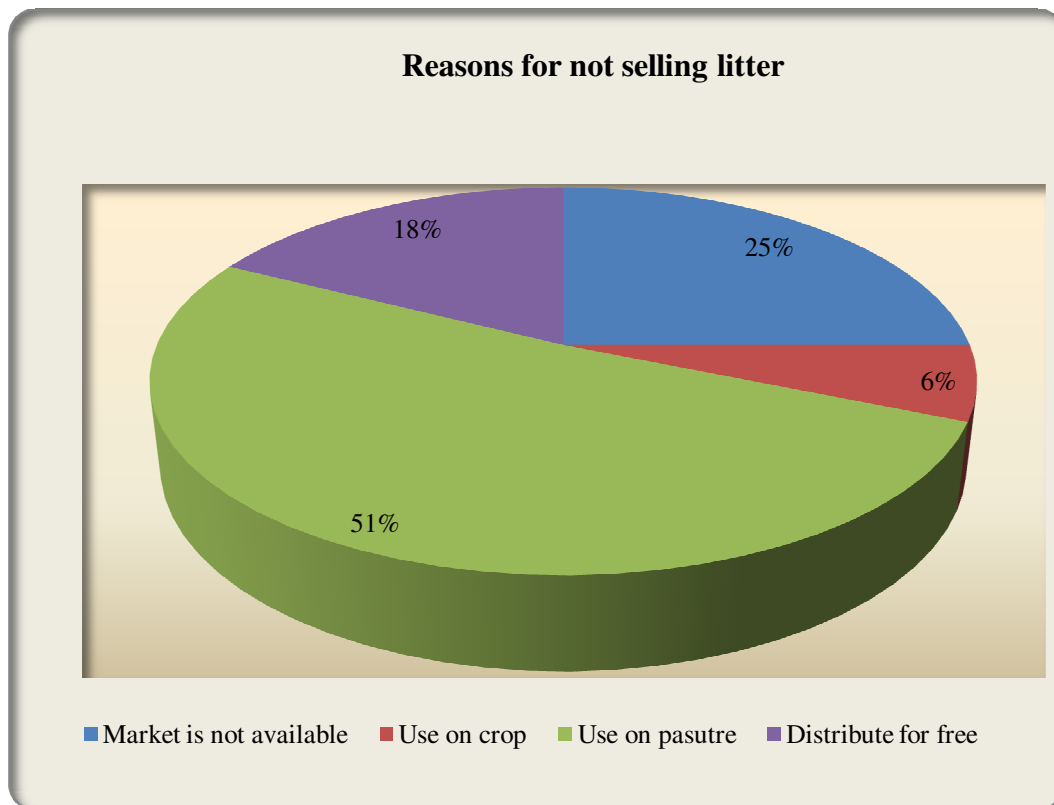


Figure 2.6: Stated reasons for not selling broiler litter.

The excessive litter application in pasture land mainly results from absence of a well functioning litter market and imperfect information about the benefits of broiler litter on crop and pasture land. More than twenty five percent of broiler growers in Louisiana stated the absence of a litter market as their main reasons for not selling the byproduct (Figure 2.7). In addition eighteen percent of the broiler producers distribute litter to their neighbors and other receivers for free, where the underlying reason is absence of a broiler trading market (Figure 2.7).

It is well recognized that the litter applications replace commercial fertilizer; however, it poses a serious concern over the economic gain relative to the conventional commercial fertilizer. The cost of litter loading transportation, litter spreading, and the relative cost of commercial fertilizers are among the main economic variables affecting substitutability of litter to replace commercial fertilizer.

Table 2.2: Description of manure management by Louisiana broiler growers

Variables	Mean	Std. Dev	Min	Max
Litter loading cost (\$/ton)	1.77	4.61	0	25
Litter spreading cost (\$/acre)	5.40	12.16	0	60
No of times an individual cakes out the litter	4.44	2.23	0	8

Broiler litter, the byproduct of meat production, is generally used on pastures and hay lands after the removal from broiler houses in Louisiana. Nitrogen, phosphorous and potassium are the major elements that the plants require in relatively larger proportion. On average, one dry ton of broiler litter provides 57.5 lbs nitrogen, 51.4 lbs of phosphorus and 39.8 lbs of potassium¹⁰ where the nutrient content of litter found to vary from 34.0 to 89 lbs/ton of nitrogen, 32.0 to 67.2 lbs/ton of phosphorus and 16.0 to 48.2 lbs/ton of potassium. The nutrient content of litter depends on the weather condition, material used for bedding, feed etc.

Table 2. 3: Manure handling by Louisiana broiler growers.

Variables	Mean	Std. Dev	Min	Max
No of times an individual cakes out the litter a year	4.44	2.23	0	8
No of years that individuals have been applying litter on crop and pasture land	6.98	10.81	0	37
Sell litter = 1	0.53	2.67	0	25
Store litter = 1	0.58	0.62	0	4

The nutrient rich broiler litter is generally transported from production sites to the application sites. The existing research shows the litter transportation posed a great concern over the economic gain as compared to the conventional commercial fertilizer (Kellog, *et al.*, 2000;

¹⁰ Source: Nutrient content of broiler litter. Texas cooperative Extension, the Texas A & M University System. <http://gallus.tamu.edu/extension%20publications/waste/nutrientcontent.pdf>

Fleming *et al.* 1998). The cost of litter loading, transportation, litter spreading, and the relative cost of commercial fertilizers are among the main economic variables affecting substitutability of litter to replace commercial fertilizer.

Louisiana broiler producers transfer litter for about 4.5 miles whereas, the cost of litter transportation is not cost prohibitive up to one hundred miles from production site (Pellitier, *et al.* 2001). About 53% of respondents stated that they sell the byproduct too but the price they receive is very low, which is only about \$6.99, whereas Paudel *et al.* (2002-2003) stated litter should command as much as \$35.60 per ton based on nutrient content of broiler litter.

Potential Use of Broiler Litter in Louisiana

The main agricultural production area in Louisiana occurs in the north-eastern part, where the broiler production is also a major agricultural component. Figure 2.7 and 2.8 show the land use classification based on crop grown in study area and in Louisiana. The crop-based production system is also found in south-western and south-central Louisiana.

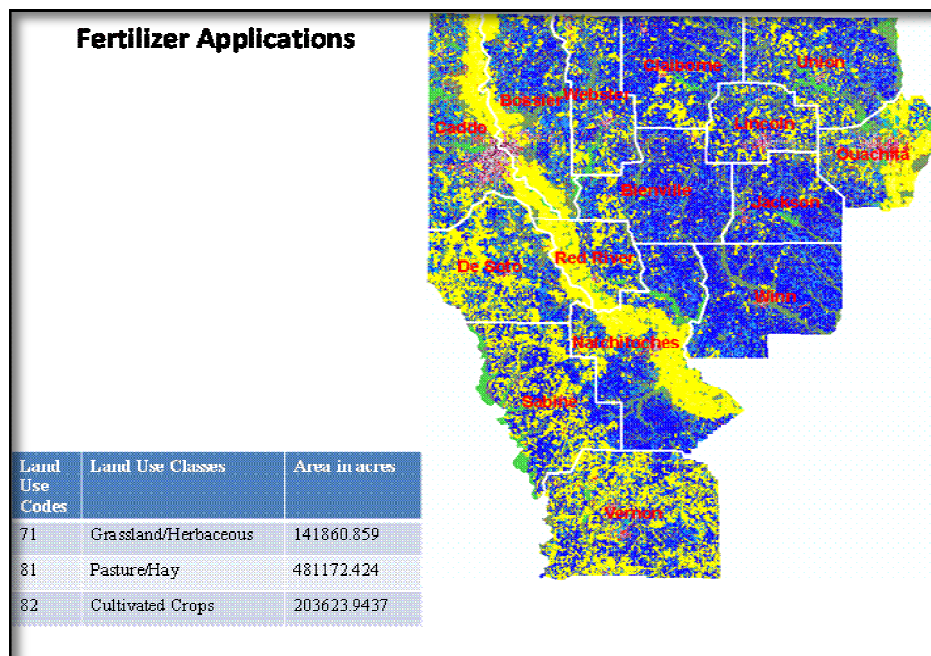


Figure 2.7: Land use pattern in study area

The main crops grown in Louisiana are sugarcane, soybeans, corn, rice and cotton. Based on the nutrient requirement of the major crops grown in Louisiana soybean is the only crop where poultry litter may not be the good source of nutrient since it needs no additional nitrogen for the production. The nutrient components are not separable in broiler litter and therefore, the litter may not be a potential nutrient source for legumes. Other crops can absorb the litter production without affecting the environment adversely and within Louisiana, if managed properly.

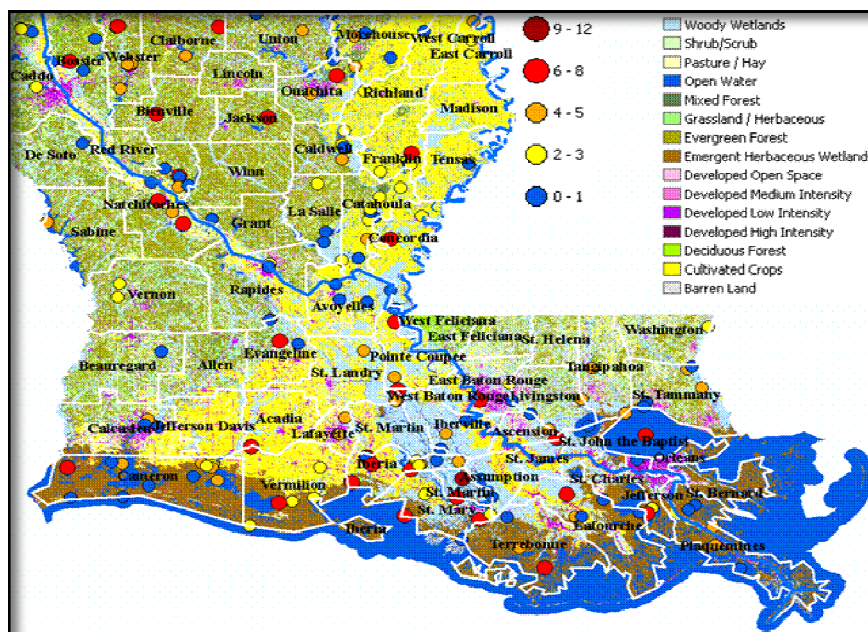


Figure 2.8: Land use classification of Louisiana.

Table 2.4 details the litter production from the broiler producing parishes in Louisiana. Estimated tonnage of litter production and associated nutrient contents are also presented for the study region in the table 2.4. The table determines whether the county produces more broiler litter than the crop production in the parish can absorb. This determination of a parishes being excess/deficit depends on the acreage of crop production, recommended nutrient levels, total quantity of litter production, and nutrient content of litter at the time of application.

Table 2.4: Crop area, crop-nutrient demand and the nutrient supply from broiler production

Parishes	Production broiler/major crops	Total Production (lbs)/acre	No of broiler birds	Litter produced (tons/yr)	N (ton)	P (ton)	K(ton)	Litter based classification (surplus/deficit)
Bienville	Broilers (Total)	24,174,220	4,395,313	5,494				
	Corn	679			51	20	20	
	Hay	5,000			33	33	33	Excess
	Total crop nutrient requirement				83	53	53	
	Nutrients equivalent supplied by parish's broiler production				159	140	110	
Claiborne	Broilers (Total)	125,100,900	22,745,618	28,432				
	Corn	223			17	7	7	
	Hay	27,000			176	176	176	Excess
	Total crop nutrient requirement				192	182	182	
	Nutrients equivalent supplied by parish's broiler production				825	725	569	
Jackson	Broilers (Total)	92,702,725	16,855,041	21,069				
	Hay	10,500			68	68	68	
	Total crop nutrient requirement				68	68	68	Deficit
	Nutrients equivalent supplied by parish's broiler production				611	537	421	
Lincoln	Major crops are vegetables where broiler litter application is not an appropriate option							
	Nutrients equivalent supplied by parish's broiler production				1,143	1,005	788	Excess
Natchitoches	Broilers (Total)	97,100,000	17,654,545	22,068				
	Corn	17,010			1,276	510	510	
	Soybean	9,890			0	247	148	
	Sorghum	4,626			278	81	81	Deficit
	Hay	19,000			124	124	124	
	Total crop nutrient requirement				1,677	962	863	
	Nutrients equivalent supplied by parish's broiler production				640	563	441	
Ouachita	Broilers (Total)	23,939,000	4,352,545	5,441				
	Corn	14,949			1,121	448	448	
	Sorghum	4,082			245	71	71	
	Hay	1,800			12	12	12	Deficit
	Total crop nutrient requirement				1,378	531	532	
	Nutrients equivalent supplied by parish's broiler production				158	139	109	

Table 2.4 Contd.

Sabine	Broilers (Total)	165,175,000	30,031,818	37,540			
	Hay	2,200			14	14	14
	Total crop nutrient requirement				14	14	14 Excess
	Nutrients equivalent supplied by parish's broiler production			1,089	957	751	
Union	Broilers (Total)	342,269,282	62,230,779	77,788			
	Hay	3,500			23	23	23
	Total crop nutrient requirement				23	23	23 Excess
	Nutrients equivalent supplied by parish's broiler production			2,256	1,984	1,556	
Vernon	Major crops are vegetables where broiler litter application is not an appropriate option						
	Broilers (Total)	1,450,000	263,636	330			Excess
	Nutrients equivalent supplied by parish's broiler production				10	8	7
Webster	Broilers (Total)	7,200,000	1,309,091	1,636			
	Corn	265			20	8	8
	Total crop nutrient requirement				20	8	8 Excess
	Nutrients equivalent supplied by parish's broiler production				47	42	33
Winn	Broilers (Total)	7,400,000	1,345,455	1,682			
	Hay	2,900			19	19	19
	Total crop nutrient requirement				19	19	19 Excess
	Nutrients equivalent supplied by parish's broiler production				49	43	34
Total nutrient supplied by broiler production in major broiler growing parishes of Louisiana				5,843	5,138	4,030	

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CHAPTER THREE

ADOPTION OF BEST MANAGEMENT PRACTICES (BMPs) TO MITIGATE NUTRIENT POLLUTION: A DURATION ANALYSIS

I. INTRODUCTION

Best management practices (BMPs)¹¹ are structures or management practices adopted by farmers to reduce the diffused source of pollution in agricultural practices. Accelerating BMPs adoption has been one of the urgent objectives of reducing nutrient pollution associated with agricultural production practices. The non-point source management program established by section 319 of the Clean Water Act centered its goal on reducing non-point source pollution through voluntary adoption and implementation of BMP. Currently, cost-share up to ninety percent and fixed payments, are provided to encourage farmers to adopt these environment friendly practices. Despite these incentive payments and cost-share mechanism, there has been a concern that the diffusion of BMP remains very slow generating a serious concern over achieving the desired level of pollution reduction.

The BMP adoptions require investment to reduce pollution externality where investors fail to experience a full benefit of their investments. The need of private investment to produce public goods becomes the main hindrance for BMP adoption. Other likely reasons for slow rate of BMP adoptions are the uncertainty of outcome, yield and cost, larger amount of initial and recurring investments, and less feasible options when planning horizon is limited (Valentin *et al.*, 2004; Gillespie *et al.*, 2007).

These characteristic of BMP force the broiler producers to delay or avoid investment on BMP adoption. Potential adopters thus tend to wait until the utility from incentive payment for

¹¹ The Best Management practices under this study are; Filter strips; Field borders; Grassed waterways; Wildlife corridors; Critical area planting; and Compost facility.

adoption equals the disutility associated with the cost of adoption, or until the time when benefits from adoption outweigh the cost (punishment caused by stringent regulation) associated with pollution generation.

The duration of time that a farmer decides to wait, until he/she adopts a practice, depends on individual as well as other farm level characteristics. Although, farmers are generally exposed to these practices over time, they decide to adopt the practice only after a certain time. Some individual tend to be more interested on adopting than others and some farm characteristic favor some BMP adoption better than others. Thus, the individual and farm specific characteristics contribute differently on BMP adoption decision resulting into individual specific heterogeneity among BMP adoptions.

Furthermore, some individual or the farm level characteristics favor multiple BMP adoptions while others hinder the adoption of second/third practices. The occurrence of multiple adoptions by the same individual generates correlation among the practices by a particular individual. The dependence among adoptions originates from the fact that the events of BMP adoptions share some characteristics that are unobserved or unmeasured at the time of survey. For example, adoption of one BMP practice may make another adoption more/less likely.

Studies have acknowledged the occurrence of multiple BMP adoptions (Gillespie *et al.*, 2007; Cooper, 2003; Dorfman, 1996). Gillespie *et al.* (2007) examines adoption decision of sixteen best management practices while Cooper (2003) and Dorfman (1996) examine five and two BMPs. These studies failed to accommodate the interdependence on adoption decision of different management practices caused by individual specific heterogeneity or event (adoption) dependence in their analysis.

Thus, the most appealing issues that have been remained unaddressed in the BMP literature are dealing with correlation among adoptions caused by individual specific heterogeneity as well as event dependence. Studies failing to accommodate such correlation provide bias and inefficiency in the parameter estimates. Therefore, the validity of the research done without allowing the correlation among adoption decisions remains questionable.

Therefore, the main objective of this section is to develop farm level model of BMP adoption allowing the individual specific heterogeneity as well as the event dependence among multiple BMP adoptions. I employ the duration model to understand what variables influence farmers to wait and eventually decide to adopt the BMPs. The focus remains on the covariates affecting the time to adopt BMP. While evaluating the important factors affecting the time to adopt, this study accommodates the individual specific heterogeneity as well as event dependence assumed to exist in the data set.

I employ the Cox proportional hazard model to evaluate the factors affecting the diffusion of BMP. The analysis provides better estimates of the factors affecting the slow rate of BMP adoption after correcting for the event dependence and heterogeneity. More specifically

- a) I employ variance corrected models which simply corrects the covariance matrix leading to more reliable hypothesis testing.
- b) I employ shared frailty model to allow for the individual specific characteristic (random effects).
- c) Finally, I employ conditional frailty model to allow for the individual heterogeneity as well as event dependence that occurs on multiple adoptions.

II. LITERATURE REVIEW

BMP Adoptions

Most of the empirical work on the field of technology adoption and technology diffusion are focused on the field of technologies that enhance the profitability of a firm (Abdulai and Huffman, 2005). Adoption of new technologies designed to reduce the adverse effect of agricultural practices on natural resources has also been a focus of recent studies.

A few examples include evaluating factors affecting BMP adoption decision (Kim *et al.* 2005); effect of BMP adoption on farm profitability (Valentin *et al.* 2004); incentive level to enhance adoption of conservation practices (Cooper and Keim, 1996; Devuyst and Ipe, 1999). Some attempts have been made to examine the reasons for the slow rate of BMP adoption (Gillespie *et al.* 2007) from the perspective of evaluating the factors hindering the adoption decision of a producer.

These studies conclude the farmers are less likely to implement in conservation practices due to uncertain results, larger amount of investments, and less feasible options when a planning horizon is limited (Valentin, *et al.*, 2004). The age of farmers, scale of production and productivity levels of farmers are also considered to be main contributing factors of farmers' decisions to adopt and implement the best management practices (Rahelizatovo and Gillespie, 2004). In addition, uncertainty about soil conditions, production levels, associated profits and risk taking behaviors of producers are also responsible for the slow adoption rates of newer technologies of farming practices (Isik and Khanna, 2003).

Most of the studies in the area of technology adoption associated with farming practices often tend to use binomial or multinomial logit and probit models (Dorfman, 1996: Neill and

Lee, 2001; Cooper, 2003; Kim *et al.* 2005). These studies base their analysis on the individual's adoption behavior at a particular point in time.

In general, BMP adoption should reveal a slow increasing trend in the initial stages – eventually increasing, once the farmers become more familiar with the new practices.

Technology diffusion theory suggest that the adoption rate improves at an increasing rate once the individuals become better informed about the potential benefits – eventually slowing down after a certain point, thus producing an S-shaped adoption curve.

The existing studies neglect the dynamic aspects of BMP adoption and fail to accommodate the effects of regressors on the time path of an adoption which is an important element while studying the slow process of BMP adoption. Even though the models explain why some producers adopt/do not adopt at a given time, the models lack the examination of reasons why some individuals adopt sooner or later than others.

Duration Analysis, Heterogeneity and Event Dependence

The duration or the failure time model examines the patterns of BMP adoption and diffusion along with evaluating the effects of individual's characteristics on the timing of BMP adoption. Duration analysis is originally employed in biomedical research (Hougaard, 1995, Duchateau *et al.*, 2002). Recent use of this approach accommodates the studies in technology adoption (Karshena and Stoneman, 1993; Bapista 2000), labor economics (Han and Hausman, 1990; Addison and Pedro 2004; An *et al.* 2004), marketing research (Gonul and Srinivasan, 1993) and agricultural economics (Burton, *et al.* 2003, Fuglie ad Kascak, 2003).

The duration model, in the context of farming technology adoption, evaluates the impact of covariates on the time to adoption since the technology became available to farmers (Dadi, 2004). Dadi (2004) estimates adoption behavior of Ethiopian farmers using the duration model.

The estimates suggest timing of adoption is influenced by the incentive payment received by farmers. The probability that a farm exits from the state of non-adoption to adoption (represented by a hazard rate) is influenced by the economic incentive observed by farmers (Dadi, 2004). In fact, the rate measures the proportion of adopters during a particular time t compared to those who have not adopted until time $t - 1$.

Similarly, the duration model used to evaluate the diffusion of conservational practices supports a very slow rate of adoption (Fuglie and Kascak, 2003). Diffusion patterns suggest some factors have comparatively stronger effect at the early stages of adoption process (Baptista, 2000) as compared to later stage. The pattern of adoption over time is explained by the farm as well as individual producer's characteristics (Baptista, 2000).

Further, the timing of adoption is correlated within a geographical area supporting the notion that the surrounding farming operations also affect the process of technology adoption (Abdulai and Huffman, 2005). Also, the individuals bear different individual or firm specific characteristics that may generate a higher or lower adoption rate for some cases than others. For example, a producer having varied level of soil characteristics or building structures may influence the likelihood that they will adopt the BMP.

Some producers bearing similar characteristics tend to behave similarly on adoption decision than others. Such behavior introduces heterogeneity across individuals and correlation within groups having similar characteristics. Sometimes, an individual may adopt more than one BMP simultaneously. In such case, the adoptions are correlated within subject and are heterogeneous among subjects.

Wei, Lin and Weissfeld (1989) illustrate an example that includes recurrence of tumors on cancer patients. Their model assumes the patients are at risk of developing multiple tumors

from the beginning. The same concept is borrowed in the context of BMP adoption where the broiler producers are likely to adopt from the onset of BMP. The core concept is that the adoption of one BMP may affect the happening of another adoption either positively or negatively given the fact that these adoptions come from the same individual. Thus, the event occurrences share some unobserved characteristics of the individuals.

Current studies employing the hazard model allows those correlations within a group and heterogeneity among individuals through corrected variances (Box-Steffensmeier and Zorn, 2002; Jensen and Ahlburg, 2004). These models correct the variance covariance matrix to provide valid hypothesis testing. There are other sets of studies which believe that the heterogeneity and event dependence generate biased parameter and therefore need suitable models to work for the issues. Shared frailty models have been suggested for allowing individual heterogeneity (Hougaard, 1995; Duchateau *et al.*, 2002) and conditional frailty model for allowing repeated event process (Box-Steffensmeier *et al.*, 2007).

Recently, the conditional frailty approach has been used in order to accommodate individual heterogeneity as well as the multiple event dependence. The model is suggested to provide asymptotically unbiased and efficient estimates in presence of heterogeneity as well as event dependence (Box-Steffensmeier and De Boef, 2006). As per my knowledge the model is employed in Medical (Box-Steffensmeier and De Boef, 2006) and political research (Box-Steffensmeier *et al.* 2007) and this study will be the first application in the field of economics.

III. MODEL

Basic Model

The duration model has been used in agricultural technology adoption and diffusion literature by several authors (Dadi, 2004; Fuglie and Kascak 2003; Baptista, 2000; Abdulai and

Huffman 2005). It evaluates the impact of covariates on the time to adopt the BMP from the time that it became available to farmers. Consider a set of farmers ($i = 1, 2, \dots, n$) are examined from a time when the first BMP became available (time zero t_0), to a failure time (T_i), when a farmer adopts a BMP; or to a censoring time (survey time, C_i). The observed time for an individual is a random variable denoted by $T_i^o = \min(T_i, C_i)$ with an indicator δ_i . The δ_i takes a value of one, if failure time T_i is observed (adoption occurred before the survey) and zero otherwise (censored). The main interest of time-to-adoption data are (a) The survivor function, defined as the probability that the adoption has not occurred at time t , that is adoption has not occurred until time $t - 1$.

$$S(t) = P(T \geq t) = 1 - F(t)$$

(b) The hazard functions of T_i , which is defined as the probability that the spell is completed at time t given that it is not completed by anytime before t .

$$\lambda(t) = \lim_{dt \rightarrow 0} \frac{Pr(t \leq T < t + dt | T \geq t)}{dt}$$

(c) The cumulative density function of T_i which is expressed as;

$$F(t) = \int_0^t \lambda(u) du$$

The duration models and the analysis of duration, in general, are formulated in terms of hazard of failure or the distribution of duration of a spell denoted by t_i .

It is assumed that the variation in the distribution of the duration is characterized by a vector of p explanatory variables $\{x_i = x_{i1}, x_{i2}, \dots, x_{ip}\}$. In case of the proportional hazard model, the hazard is expressed as a product of baseline hazard and some function that explains how the risk of adoption is associated with the different values of covariates. The hazard function of an i^{th} individual at time t is thus expressed as;

$$\lambda(t|\mathbf{x}_i) = \lambda_0(t)\varphi(\mathbf{x}_i)$$

where, $\lambda_0(t)$ is the baseline hazard function which provides the shape to the hazard function.

The $\lambda_0(t)$ is assumed to be an unspecified baseline hazard corresponding to an individual whose covariates takes values of zero. In absence of any effect of covariates on the hazard function, the baseline hazard shows the value of risk common to all individuals. The baseline hazard explains the duration dependence such as whether the hazard rate of an individual adopting a BMP depends on the time that an individual has already spent in the spell.

The $\varphi(\mathbf{x}_i)$ represents a non-negative functions of \mathbf{x}_i . The widely used functional form for the hazard model as proposed by Cox (1972) is $\varphi(\mathbf{x}_i) = \exp(\mathbf{x}_i \boldsymbol{\beta})$. The model that uses exponential functional form of explanatory variable along with the baseline hazard is widely known as the Cox proportional hazard model. Under the Cox proportional hazard model, the hazard function is expressed as;

$$\lambda_i(t|\mathbf{x}_i) = \lambda_0(t)\exp[\mathbf{x}_i\boldsymbol{\beta}] \quad (3.1)$$

The vector $\boldsymbol{\beta}$ represents unknown regression parameters explaining the dependence of hazard on the explanatory variables. The corresponding survival function can be expressed as;

$$S_i(t|\mathbf{x}_i) = S_0(t)\exp[\mathbf{x}_i\boldsymbol{\beta}]$$

where, $S_0(t) = \exp\left(-\int_0^t \lambda_0(u)du\right)$ represents the survival function of an individual whose all covariates are equal to zeros. Assuming no ties among the event times, the parameters can be estimated by maximizing the partial likelihood function as suggested by Cox (1972)

$$L(\boldsymbol{\beta}) = \prod_{i=1}^n \left[\frac{\exp(\mathbf{x}_i\boldsymbol{\beta})}{\sum_{j=1}^n Y_j \exp(\mathbf{x}_j\boldsymbol{\beta})} \right]^{\delta_i} \quad (3.2)$$

Y_j is observed duration. Computationally, maximizing the log of the likelihood function is more convenient to obtain the maximum likelihood estimates. Further, the variance is obtained by using second derivative of the likelihood function evaluated at estimated coefficient.

$$Var(\hat{\beta}) = - \left[\frac{d^2 \log L(\beta)}{d\beta^2} \right]^{-1}_{\hat{\beta}}$$

Correlated Time-to-event Data

Correlated event times may occur due to recurrent event processes such as multiple BMP adoptions by an individual. In case of repeated occurrences, correlation among the event times can arise from the following two sources;

a) Individual Heterogeneity

Individual broiler producers bear different individual or firm specific characteristics, some of which may be unknown, unmeasured or un-measurable to the researchers. Those unobserved characteristics generate higher or lower rate of adoptions for some BMPs than others. For example, producers have diverse level of soil characteristics and building structures which may influences the likelihood that they will adopt the BMP but either can't be measured or are unknown to the researcher at the time of data collection. As a result, some producers tend to adopt faster than others introducing heterogeneity across individuals. Furthermore, a producer who adopts one BMP may be more inclined or resistant to another BMP adoption. This fact generates correlation among recurrent BMP adoptions or the timing of those BMPs adoptions.

b) Event Dependence

In some time-to-event models, an occurrence of one BMP adoption may make successive events more or less probable. For example, adoption of one BMP may provide producers incentive/disincentive to adopt another set based on how they perceive the benefit/cost of

adopting previous BMP. In any case, the likelihood of adoption is a function of previous occurrence inducing within individual level correlation among the observations.

Thus, the correlation among events can either be produced by individual heterogeneity or by event dependence or by both. In the presence of individual level heterogeneity or recurrence of events, it is realistic to assume lack of independence among individual events (Collet, 2003). The correlation among event times violates the assumption of independence assumed by the Cox proportional hazard model. Failing to account for the correlation among events and analyzing correlated events produce biased and inefficient estimates (Kelly and Lim, 2000). Doing so overstates the level of information that each observation provides, leading to incorrect standard errors. In addition, the analysis restricts the impacts of covariates to be the same across the multiple events, while there may be different effects from one event to another.

The variance corrected models estimate the standard Cox proportional model and adjusts the covariance matrix in order to allow for the correlation due to repeated events and/or individual heterogeneity. The Cox model provides consistent estimates to the population parameters even in the presence of correlation. However, the covariance matrix is inappropriate for hypothesis testing (Lin and Wei 1989). One of the most widely used variance corrected models is a model developed by Wei et al. (1989). The model allows multiple events to have different baseline hazards so that the hazard function can differ from the first BMP adoption to the second BMP adoption and so on.

Each individual farmer is considered to be at risk for all the consequent events from the beginning. More specifically, individual farmers are at risk set of adopting all available BMPs at all the time prior to the occurrence of that particular event. The observations are then stratified based on the number of adoptions occurred. A separate baseline hazard is constructed for the first

adoption then the second and so on. However, the effects of covariates are assumed to be constant over the different events.

The Cox proportional hazard model changes into the following expression while allowing for stratification based on event occurrence. The individual farmers are stratified into k ($k = 1, 2, \dots, 6$ available set of BMPs) categories based on the number of BMPs adopted.

$$L(\boldsymbol{\beta}) = \prod_{i=1}^n \prod_{k=1}^K \left[\frac{\exp(x_{ik} \boldsymbol{\beta})}{\sum_{j=1}^n \sum_{k=1}^K Y_{jk} \exp(x_{ik} \boldsymbol{\beta})} \right]^{\delta_{ik}} \quad (3.3)$$

The variance corrected model takes account of the inefficiency contributed by the heterogeneity through correcting the standard errors. However, the approach fails to incorporate the heterogeneity effect on the estimates and therefore the estimates remain inconsistent (Kelley and Lim 2000).

The frailty model incorporates the heterogeneity into the model estimators by treating the frailty term as random draws from a known parametric distribution. Experiencing an event is assumed to be independent of the chosen distribution. The frailties are unobserved random effect across individuals and are assumed to be constant over time for a particular individual. The model also treats the correlation due to repeated events as a special case of more general heterogeneity induced by the individual specific characteristics (Box- Steffensmeier , 2007; Vaupel, 1979).

With the inclusion of random effects in the proportional hazard model, the hazard rate equation changes as follows;

$$\lambda_{ik}(t|\mathbf{x}_{ik}) = \lambda_0(t) \exp[x_{ik} \boldsymbol{\beta} + \omega_i] \quad (3.4)$$

where, ω_i is the vector of random effects or frailty for i^{th} individual and k is the number of possible events for each individual.

The frailty models have been criticized because of lacking sufficient theoretical support on choosing a particular parametric distribution. Additionally, the estimates are generally sensitive to the selected error distribution (Kosorok *et al.* 2004). The random effects model can be presented in the following form so as to make easier illustration of functional form of the random effects;

$$\lambda_i(t|\mathbf{x}_{ik}) = \lambda_0(t)\exp[\mathbf{x}_{ik}\boldsymbol{\beta}] \exp(\omega_i) = \lambda_0(t)u_i\exp[\mathbf{x}_{ik}\boldsymbol{\beta}]$$

The random effects are assumed to have gamma distribution for which the probability density

function is expressed as; $f_U(u) = \frac{u^{\frac{1}{\gamma}-1} \exp\left[-\frac{u}{\gamma}\right]}{\gamma^{\frac{1}{\gamma}} \Gamma\left(\frac{1}{\gamma}\right)}$. The interest here is on the variance of the random

effects, $Var(\omega_i)$, which is used to explain heterogeneity. For gamma distribution variance is assumed to be $Var(u) = \gamma$.

Now, the likelihood function for the model, conditional on the random effects becomes;

$$L(\boldsymbol{\beta}) = \prod_{i=1}^n \left[\frac{\exp(\mathbf{x}_{ik}\boldsymbol{\beta} + \omega_i)}{\sum_{j=1}^n Y_{jk} \exp(\mathbf{x}_{jk}\boldsymbol{\beta} + \omega_i)} \right]^{\delta_i} \quad (3.5)$$

In fact, both the variance-corrected proportional hazard model as well as random effects model has been used in order to account for the correlated events (Jensen and Ahlburg, 2004; Box-Steffensmeier and Zorn, 2002). Table 3.1 shows the ability of different models to handle the heterogeneity and event dependence.

To allow within subject correlation through event dependence as well as the individual heterogeneity, there is a need to develop a new model. In this model, event dependence is controlled through “event based stratification” and the unobserved heterogeneity through inclusion of a random factor in the model (Box-Steffensmeier *et al.* 2007). This new model is called the conditional frailty model which originates using gap time where the parameters are interpreted in terms being at the risk of k^{th} event after the occurrence of previous one.

The hazard of observing k^{th} event for i^{th} individual is then expressed as (Box-Steffensmeier *et al.* 2007);

$$\lambda_{ik}(t|\mathbf{x}_i) = \lambda_{0k}(t - t_{k-1})\exp[\mathbf{x}_{ik}\boldsymbol{\beta} + \omega_i] \quad (3.6)$$

where, k represents the number of events (BMP adoptions) that an individual producers experience. λ_{0k} is the baseline hazard rate that varies with the number of events that an individual experiences. $(t - t_{k-1})$ represents a gap time from $(k - 1)^{\text{th}}$ event occurrence to k^{th} event occurrence. The ω represents an unknown vector of random effects contributed by individuals and each individual contain a random effect that is shared within recurrent events. Then the partial likelihood of the event occurrence becomes;

$$L(\boldsymbol{\beta}) = \prod_{i=1}^n \prod_{k=1}^K \left[\frac{\exp(\mathbf{x}_{ik}\boldsymbol{\beta} + \omega_i)}{\sum_{j=1}^n \sum_{k=1}^K Y_{ik} \exp(\mathbf{x}_{ik}\boldsymbol{\beta} + \omega_i)} \right]^{\delta_{ik}} \quad (3.7)$$

Table 3.1: Alternative models, their abilities to handle heterogeneity and event correlation, their pitfalls and advantage

Models	Does it handle		Pitfall of the model	Advantage of the model
	Heterogeneity	Event correlation		
Cox-proportional Hazard model	No	No	Assumption not met	Easy to estimate
Variance Corrected model 1	No	Yes	Inconsistent	Comparatively Efficient Estimates
Variance Corrected model 2	No	Yes	Inconsistent	Comparatively Efficient Estimates
Frailty Model	Yes	No	Large standard errors.	Reduced bias
Conditional Frailty Model	Yes	Yes	Large standard errors	Asymptotically consistent and efficient estimates

Note: Variance corrected model 1 corrects variance using cluster corrected robust standard errors. Variance corrected model 2 is developed by Wei *et al.* (1989) which creates a separate baseline hazard for each event occurrence.

IV. DATA

The state of interest in this chapter is non-adoption which is defined as the state at which an individual is at the risk of adoption. And the event of interest is the exit from non-adoption to the adoption of the practice. The duration of adoption starts from the first recorded adoption of a practice (Karshenas and Stoneman, 1993) and ends when an individual either adopts a practice from a set of BMPs or is censored. The spells that were not completed before the survey (summer 2004) were considered to be censored. The non adopters are censored at the calendar year of 2004 when the survey was conducted.

The time starting from the year 1954 to the time of adoption or time of censor is considered to be the dependent variables for the models except for the conditional frailty model (Karshenas and Stoneman, 1993; Fuglie and Kascak, 2003). The time that a farmer waits before adopting a BMP is measured by the number of years elapsed since the introduction of BMP (assuming first BMP was introduced in 1954).

The conditional frailty model requires data organized in a different format than the other models require. The setting of the data for the conditional frailty model is listed in the Appendix B. The repeated adoptions of BMP are assumed to be recurrence of events. Under the case of BMP adoption, a recurrence of event is defined as “the event occurrence where an individual adopts BMP/s more than once in his farming period or under the study period”.

The data used in this section comprise 88 broiler producers with 57 events of interest (adoptions). Farmers are assumed to be exposed to six available BMPs once they became available or the producer entered the firm. The producers who entered the business later than 1954 entered the risk set as soon as they entered the business (Dadi *et al.*, 2004). For late entrants the duration variable counted from the year they started in the broiler industry to the year they

adopted the BMP/censored at the time of survey. This is because the BMP practices were already available when the individual entered the business and they started to be at risk as soon as they entered the business.

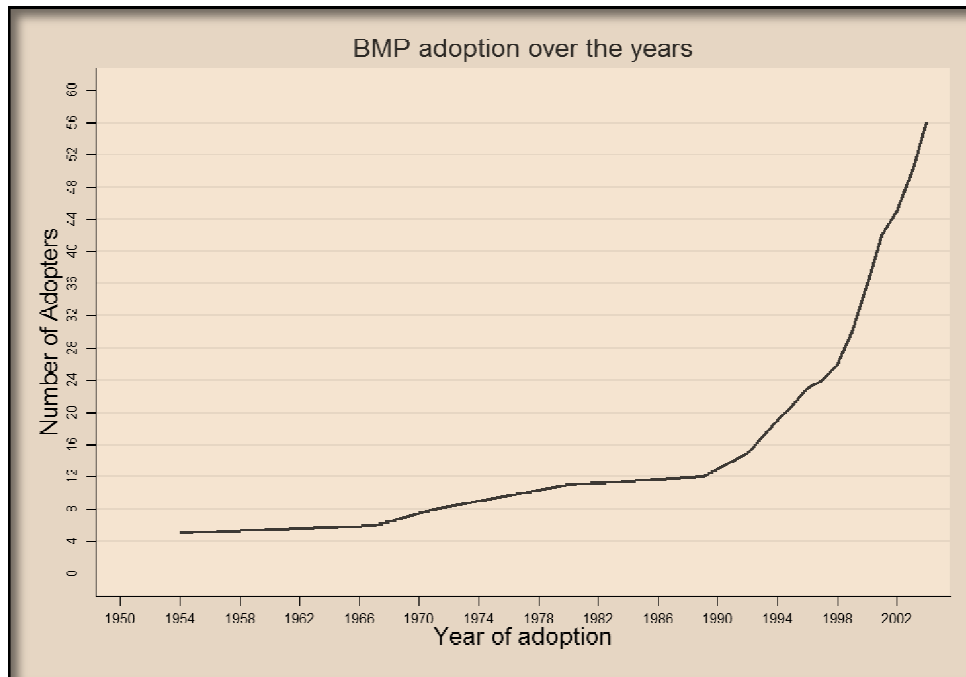


Figure 3.1: Total number of BMP adoptions over the years

There were six best management practices available or suggested to the producers. The best management practices available or suggested to the producers are included in the survey and are listed as follows;

Filter strips: Filter strips are designed for removing or blocking the sediments and other nutrient pollutants from runoff. The strips are the area of vegetation adjacent to the stream if there is one near or on the farm. The vegetative strips also increase the nutrient intake reducing the leaching of excessive nutrients from the field to the water sources. The cost of adopting this practice is 210 dollars per acre (2003)

Field borders: Field borders are the strips of perennial vegetation planted on the edge of the fields. The borders are designed to control sediment runoff which carries excessive phosphorus from the field to the water-bodies. Adoption cost per ft is about 0.10 dollars (2003).

Grassed waterways: The grassed waterways are natural or constructed vegetative channel designed to stabilize the surface runoff. The grassed waterways help to prevent the nutrient flow through sediment erosion. The estimated cost of adoption is 2400 dollars per acre.

Wildlife Corridors: These are designed to creating restoring and enhancing wildlife habitat. The estimated cost of adoption is 25 dollars per acre.

Critical area planting: Critical area planting represents the plantations that are designed for reducing erosion from highly erodible fields and the fields with greater slope (find better words).

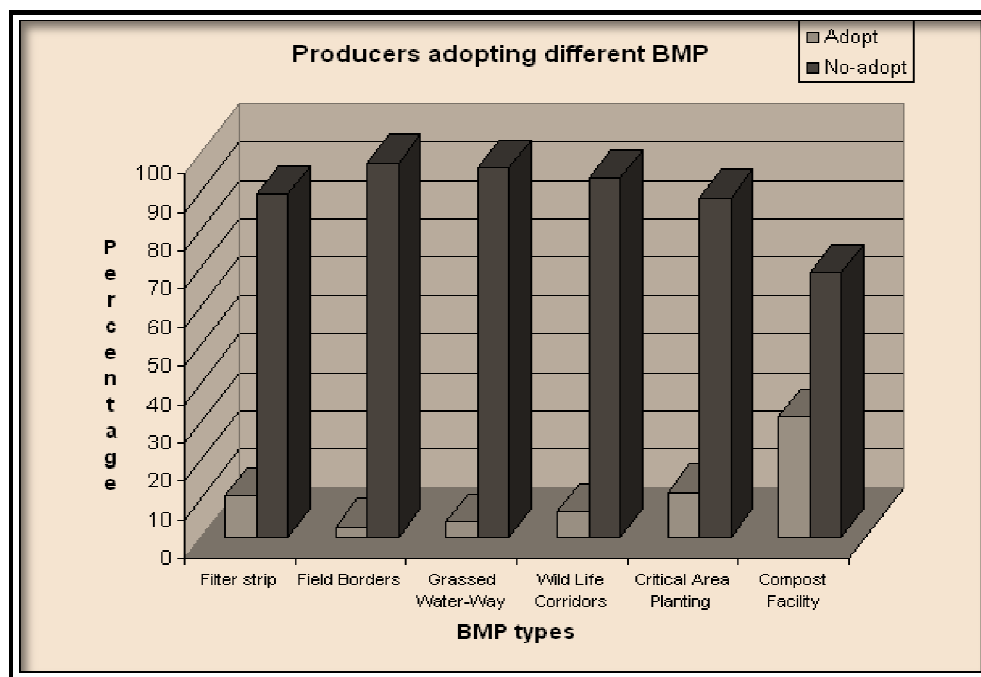


Figure 3.2: Percentage of Broiler Producers Adopting Best Management Practices

Compost facilities: The facilities convert organic matter, such as dry poultry litter, dead chickens or other poultry wastes into more uniform and less odored substance. The estimated cost of building 6-bin composting facility is 18,000. Figure 3.2 shows the percentage of broiler producers implementing different BMPs.

Explanatory Variables

a) Farm Characteristics

Number of broilers represents the total number of broiler birds raised by an individual producer in 2003. The numbers are divided by 1000 for easier computational purpose. The larger the number of birds implies a larger production level. The production size is found to be positively related to the technology adoption (Karshenas and Stoneman, 1993) including BMP adoption (Rahelizatovo and Gillespie, 2004).

Farm income is defined as the income associated with broiler production. Producers with higher farm income are more likely to adopt BMP (Gillespie *et al.*, 2007). In this study, farm income is defined as a dummy variable to indicate whether a farm is earning a positive or a negative profit. Positive profit provides a financial flexibility to the producers to be willing to adopt BMP.

b) Information Dissemination

The producers who have better information regarding BMP either through education or exposition to the extension services are more likely to adopt BMP (Koundouri *et al.*, 2006). Level of education and contact with extension agents are employed to capture the effect of information accessibility on BMP adoption. Education is a dummy variable indicating whether an individual holds at least a college degree.

Contact with extension agents was constructed using the information obtained indicating whether an individual has visited the extension agents in the last year. The variable is then used as a proxy for his/her general contact with the extension service providers. The variable represents whether an individual has visited extension agents or have been visited by the agents in the previous year. Individual producers who are exposed to the extension service are aware about BMPs. Both the education (Gillespie *et al.*, 2007) and contact with extension agents are assumed to be positively affecting the BMP adoption (Koundouri *et al.*, 2006).

c) Demographic Variables

Farmer's own characteristics play a major role in the choice of technology adoption. The variable, Age, provides mixed result. Age is positively associated with the likelihood of BMP adoption (Gillespie *et al.*, 2007), while it is negatively related with irrigation technology adoption (Koundouri *et al.*, 2006). Younger farmers are found to be more knowledgeable and more risk taking due to longer planning horizons, and therefore, are more likely to adopt BMP (Adesina and Zinnah, 1993).

Years of being in farming is considered to be an important factor on adoption decision (Gillespie *et al.*, 2007). Studies consider number of years in the business as experience of an individual producer. However, in absence of successor we assume the coefficient associated with this variable may have a negative sign. This is because the longer the time in the business, it is more likely that the producers retire from the business. The existing literatures, however, show a positive relationship of experience with the likelihood of adoption (Adesina and Zinnah, 1993). Therefore, the coefficient associated with this variable may show either a positive or negative sign.

Business ownership is a dummy variable indicating whether the firm is individually or family owned. Individually owned businesses are more likely to adopt erosion and sediment control BMPs. Having family members to take over the business, once the producer is retired, extends the planning horizon. Thus having descendants to continue the business is hypothesized to be positively related to the BMP adoption (Gillespie *et al.*, 2007).

d) Policy Variable:

Policy variable is created as a dummy representing whether the adoption was before the initiation of the cost-share program in 1996. Economic incentives associated with the adoption increases the likelihood of technology adoption (Karshenas and Stoneman, 1993).

Table 3.2: Summary statistics of variables used

Variables	Obs.	Mean	Std. dev.	Min	Max
Number of broilers/1000	528	455.38	288.56	18	1900
Age of farmer at the time of survey	522	52.95	12.58	23	79
At least collage education =1	528	0.80	0.272	0	1
Individual ownership=0 otherwise=1	492	1.012	0.109	0	1
Number of years in the business	528	19.53	12.51	0	57
Income from broiler production positive income=1	510	0.894	0.307	0	1
Descendants to continue farming after retire	456	0.171	0.367	0	1
Adoption after 1996=1 otherwise=0	500	0.954	0.209	0	1
Contact with extension agent =1 otherwise=0	522	.586	.493	0	1
Calendar year of adoption	500			1954	2004
Duration from base year to adoption year or censor	500	19.35	12.19	0	50

Note: There were 88 observation points obtained from the survey. With the individuals being at risk of adopting six different practices within a set of BMP, the total number of observation becomes 528.

V. RESULT AND DISCUSSION

The duration models presented above are estimated to examine the time taken by broiler producers to adopt BMP given its availability. The time to adoption is considered to be a function of individual producer specific as well as farm specific characteristics. The model estimates the probability of a producer adopting a BMP at a particular time t given that the producer hasn't adopted until time $t - 1$.

Table 3.3: Variance corrected models for BMP adoption (Cox regression model)

Variables	Coefficients	Hazard ratio
Broiler numbers	0.002*** (0.0007)	1.002
Experience	-0.020 (0.025)	0.980
Education	0.464 (0.631)	1.591
Age	0.002* (.0008)	1.001
Farm income	0.114 (0.375)	1.011
Contd. after retirement	0.557 (0.589)	1.745
Ownership	-1.049 (0.818)	.0350
Policy	-3.500*** (0.414)	0.301
Contact with extension agent	1.297*** (0.497)	3.659
Wald test	113.99***	
Log likelihood	-147.952	

Note: *, **, and *** represents the significance level at 0.10, 0.05 and 0.01 respectively.
The numbers in parenthesis are robust standard errors.

Results from two variance corrected models are presented on table 3.3 and 3.4. The results for two frailty models are presented on table 3.5 and 3.6. The tables present coefficient estimates and their standard errors with hazard ratios. The first table (Table 3.3) presents the result for the Cox proportion hazard model with cluster corrected robust standard errors. The cluster corrected variance matrix is robust to any kind of intra cluster correlation and arbitrary heterogeneity, given that the number of observations is relatively larger than the number of groups (Wooldridge, 2002: page: 300). The second column presents the hazard ratio.

Table 3.4 contains results for the marginal model of Wei, Lin and Weissfeld (1989). The Wei, Lin and Weissfeld (WLW) model allows separate baseline hazards for each event occurrence. In addition, it allows all the individuals to be “at risk” of adopting any of the available BMPs from the beginning of the observation period. Individual heterogeneity is taken into account by using cluster corrected variance and the observations are stratified to allow for different baseline hazards for each BMP adopted.

In presence of individual level heterogeneity, variance correction models may not suffice to provide reliable parameter estimates since the model only corrects the variance-covariance matrix and provides better hypothesis testing. Box-Steffensmeier *et al.* (2007) suggested using a random effect model in order to estimate consistent parameters. Their study claims a significant improvement on model performance while using the frailty model. I therefore estimate frailty models which are presented on table 3.5 and table 3.6. The frailty models account for the individual level heterogeneity assumed to exist among individual producers and event dependence within an individual’s recurrent adoptions.

Table 3.4: Variance correction models for BMP adoption (WLW model)

Variables	Coefficients	Hazard ratio
Broiler numbers	0.002*** (0.001)	1.002
Experience	-0.032 (0.028)	0.968
Education	0.093 (0.391)	1.593
Age	.0021** (.001)	1.002
Farm income	0.093 (0.391)	1.097
Contd. after retirement	0.340 (0.637)	1.406
Ownership	-0.852 (0.789)	0.426
Policy	-1.755*** (0.574)	0.173
Contact with extension agent	1.403* (0.501)	4.066
Wald test	61.05***	
Log likelihood	-96.026	

Note: *, ** and *** stands for the variable is significant at 0.10, 0.05 and 0.01 percent level of significance respectively.

The first column in table 3.5 contains estimates for the shared frailty model and the second column provides the hazard ratio associated with the models. The model incorporates variations across individuals, which are unaccounted for the inclusion of observed variables. These unobserved variations affect an individual's susceptibility to adopt BMP. The heterogeneity originates from the fact that some individuals are more susceptible to hazard of adoption than others; however, the measured variables fail to account for those characteristics

causing the variations on adoption. Some producers are frailer to the adoption due to such unmeasured/unknown factors. The random effect parameter included in the model absorbs the unknown factor causing heterogeneity in the BMP adoption. Thus the presence of unmeasured variation can be determined by the inclusion of the random effects in the model. Since there are multiple adoptions by one individual there, effects of unobserved characteristics are shared by different adoptions.

A Likelihood ratio test is carried out to examine the presence of heterogeneity. The test statistics measures whether the variance of the random effect (let's denote it by θ) term is greater than zero. The result from likelihood test for θ shows variance of the random effect is greater than zero at 0.05 percent level of significance. The result indicates the presence of the random effect. This result suggests that the unobserved heterogeneity is affecting the models where the random effect might have originated from the individual heterogeneity or by event dependence.

Furthermore, event dependence is suspected as the data comes from the same individual who may become more susceptible or resistant to adoption after adopting one BMP. In addition, no theory or the analysis guides about the source of greater variance estimate of the random effect parameter. The random effect can either be from individual heterogeneity or from event dependence.

A conditional frailty model is employed to allow for the event dependence. The model estimates different baseline hazards for each successive event. In addition, the model accounts for the heterogeneity by allowing the estimation of random effect parameter into the model. The conditional frailty model reduces bias in estimated parameters and/or reduces the size of variance of random effect (θ), as compared to variance corrected and shared frailty models (Box-Steffensmeier *et al.*, 2007).

Table 3.5: Individual heterogeneity model for BMP adoption (Shared frailty model)

Variables	Coefficients (Robust Std. Err)	Hazard. Ratio
Broiler numbers	0.002* (.001)	1.002
Experience	-0.090*** (0.036)	0.914
Education	0.383 (0.872)	1.466
Age	0.002* (0.001)	1.002
Farm income	0.304 (0.351)	1.356
Contd. after retirement	0.486 (0.699)	1.625
Ownership	-2.685 (2.192)	0.068
Policy	-4.669*** (0.627)	.009
Contact with extension agent	1.287** (0.605)	3.625
Theta	1.141	
Wald test	60.64***	
Log likelihood	-146.576	

Shared frailty model: LR test of theta=0: $\chi^2_1 = 2.75$ Prob>= χ^2_1 chibar2 = 0.049

Note: *, ** and *** stands for the variable is significant at 0.10, 0.05 and 0.01 percent level of significance respectively.

Table 3.6 presents the result obtained from the conditional frailty model as suggested by (Box-Steffensmeier and De Boef, 2006). The conditional frailty model is estimated using the R software, as STATA and SAS lack the built-in function to perform a conditional frailty analysis.

Once the observations are stratified based on events, using the conditional frailty model, the estimated variance of the random effect reduces to zero. Such result indicates the heterogeneity in the model is contributed by event dependence. The large variance of random factors appeared in the shared frailty model disappeared with conditional frailty model. The result thus supports the fact that the main source of within subject correlation was contributed by event dependence.

Hence, the result from conditional frailty model is used to interpret the results. Once heterogeneity as well as the event dependence is accounted for, the estimated beta coefficients are interpreted as “estimated change in logarithm of hazard ratio due to one unit change in a covariate” (Collett 2003; page 90). So, the hazard ratio of exiting from the state of non-adoption is $r \cdot \exp[\hat{\beta}]$ when x changes by r units. The hazard ratios are used to test the hypothesis of no impact of the covariates on hazard of adoption. The hazard ratio, greater (smaller) than one, is equivalent to the positive (negative) sign of the coefficients.

The size of farming is probably the most prominent variable on technology adoption literatures (Abdulai and Huffman, 2005; Dadi *et al.* 2004; Dorfman, 1996, Adesina and Zinnah, 1993). The variable is positively related to the adoption decision (Adesina and Zinnah, 1993; Abdulai and Huffman, 2005). In this study, number of birds represents the size of farming. The farm size shows a positive effect on hazard of adoption. One unit in broiler number in the analysis represent 1000 birds so, one unit increase in broiler number increases the conditional probability of adoption by 0.1 %. The result indicates that duration of adoption decreases with increase in the size of production. Thus the result implies that the larger firms are early adopters.

The *experience* in the business represents the years that an individual spent on broiler production. The variable is negative and significant at a ten percent level of significance. One year increase in year that an individual spent on farming decreases the hazard of adoption by four

percent ($1 - .959 = 0.041$). The significant negative impact of years spent on farming implies that an individual who is involved in farming for many years tends to wait longer to adopt a best management practice to reduce water pollution. The result implies that these individuals spent long enough in the broiler business and are ready to retire from farming. Therefore, these individuals are less likely to adopt the technology. Adesina and Zinnah, (1993) also finds the effect of *number of years in the farming* to be insignificant on adoption of rice variety.

The significant positive effect of *contact with extension agent* on the likelihood of BMP adoption (hazard greater than one) indicates that the broiler producers who meet extension agents are more likely to adopt BMP as compared to those who do not. The producers exposed to information through extension agents have conditional probability of adoption which is 1.32 times greater than those not exposed to extension agents (Abdulai and Huffman, 2005; Baptista, 2000).

Age of an individual producer is found to be significantly affecting the adoption of other technology (Dadi *et al.* 2004) as well as BMP (Gillespie *et al.*, 2007). The age variable on technology adoption has been providing mixed effect on literatures. The younger individuals are more likely to adopt new irrigation technology (Koundouri *et. al*, 2006). However, older individuals are more likely to adopt BMP to reduce nutrient pollution (Gillespie *et al.*, 2007). The age variable in this study shows significant (at 0.10 level) with a positive sign indicating older broiler producer are earlier adopters.

Ownership of farming practices has been found to influence the adoption decision of technology (Rahelizatovo, 2002; Gillespie *et al.*, 2007). If the production is an individual operation, the conditional probability of adopting a technology is higher as compared to the others. Gillespie *et al.* (2007) also finds positive effect on adoption if a family owns the farm.

Table 3.6: Event dependence and heterogeneity models for BMP adoption (Conditional frailty model)

Variable	Coefficients (Robust Std. Err)	Haz. Ratio
Broiler numbers	0.0013** (.0007)	1.001
Experience	-0.032* (0.018)	0.959
Education	0.087 (0.632)	1.092
Age	0.031* (0.018)	1.031
Farm income	0.558 (0.376)	1.748
Contd. after retirement	0.311 (0.479)	1.365
Ownership	1.310* (0.801)	3.709
Policy	-1.091* (0.577)	0.336
Contact with extension agent	0.843** (0.307)	2.323
Theta	0.00	
Wald test	21.7***	
Log likelihood	-117.5	
R square	0.186	

Note: *, ** and *** stands for the variable is significant at 0.10, 0.05 and 0.01 percent level of significance respectively.

Policy dummy to measure the effect of changes in incentive payment as a cost-share is found to be highly negative. The unexpected result of this kind to some extent was contributed by the within-subject correlation. This is because the magnitude of negative effect reduced to

1.09 from 4.669. I therefore, presume that there might be other unobserved factors that affected this factor to be negative (Dadi *et al.* 2004).

While comparing estimates from the shared frailty model with the conditional frailty model the only significant change is found in ownership of the business. The variable changes the sign going from shared frailty to the conditional frailty model. In addition, the magnitude of negative policy effect becomes smaller on conditional frailty model.

VI. CONCLUSION

A slow rate of BMP adoption has been a serious concern among policy makers. Even more, the increasingly stringent government regulation has been a fear factor for the producers to adopt BMPs. The existing literature on BMP adoption discusses the factors affecting the adoption decision of agricultural producers. However, it fails to accommodate the factors related to the diffusion process of BMPs over time. I examined why some producers adopt BMP faster than others and what kind of factors affect the time to adoption decision. I employed a duration model which accounts for the censored observation. In addition, the model also permits an evaluation of the impact of farm and individual characteristics on the duration of adoption from the time when the BMP became available.

The most appealing issue appeared, was the occurrence of multiple adoptions by some broiler producers. The correlation among BMP adoptions may arise from individual level heterogeneity and/or from event dependence in the presence of multiple adoptions. In order to accommodate the correlation, I employed the variance correction approach which corrected the variance covariance matrix to provide better hypothesis testing.

I allowed individual level heterogeneity to enter the model as a random factor. The result showed a presence of heterogeneity by providing the larger variance of the random factor which

entered in the third model (result of which is on table 3.5). The significantly greater variance for the random factor suggested the estimates may not be correct since they are affected by the presence of heterogeneity and/or event dependence.

The larger variance only suggests the presence of random effect but fails to indicate where the random effect comes from. The random effect may either be from individual heterogeneity or from event dependence. I therefore, ran a conditional frailty model, as suggested by Box-Steffensmeier (2006), which is assumed to correct both the heterogeneity and event dependence allowing different baseline hazards for different rank of adoption.

The result showed that the longer the farmers spend on broiler production the less likely they are to adopt BMPs which are the investment on the programs that are designed for long term goals. Larger and more informative farmers, through contact with extension agents and education, are early adopters of the new management practices. Even though the result did not show significant difference on parameter estimates from all four models, the parameter estimates from conditional frailty models are assumed to be more reliable than the estimates from other models.

The study found that the estimates suffered from random effect (frailty) which should be taken into consideration while evaluating the factors associated with slow rate of BMP adoption. The scope of this approach can be extended to other kinds of technology adoptions in the areas of agriculture, for example, adoption of cost minimizing irrigation technology.

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CHAPTER FOUR

IS PRODUCTION TERMINATION A GOOD POLLUTION CONTROL ALTERNATIVE? AN ASSESSMENT OF WILLINGNESS TO ACCEPT VALUES BY BROILER PRODUCERS

I. INTRODUCTION

Incentive payments have been a popular policy instrument to motivate agricultural producers toward employing environmentally friendly production practices. Wetlands Reserve Program (WRP), Conservation Reserve Program (CRP), and Environmental Quality Incentive Program (EQIP) are the major examples of the incentive payments to support producers to employ environmentally friendly agricultural practices.

The EQIP is established to provide technical and financial support to the farmers who agree to adopt environmentally friendly production practices (Classen and Horan, 2000). The CRP encouraged the farmers to terminate the commodity production (either by switching to tree or perennial grass planting or by idling the land) through incentive payments primarily to reduce soil erosion and other negative impacts on ecosystem.

Other programs such as payment for restricted water use on agricultural production, as implemented by the state of Georgia and the Dairy Termination Program (DTP) are additional examples where farmers are paid to reduce production amount or cultivated acres. The Draught Protection Act of Georgia pays farmers who voluntarily withdraw irrigation permit in lieu of compensation to increase water flow in a river. On the other hand, the DTP of 1986-1987 offered incentive payments to milk producers who were willing to reduce milk production either temporarily (at least for five years) or permanently.

All of these programs provided incentive payments to the farmers participating voluntarily in production termination programs or environmentally friendly agricultural practices. Although, the goal of these programs could be one thing (reducing erosion in CRP,

reducing water use in agriculture in Georgia's ground water use incentive program, reducing dairy cows numbers in DTP), but these programs resulted other benefits too (increasing commodity prices in CRP, water conservation and reduction in crop output in Georgia).

A similar concept of incentive payments for production termination can be borrowed to mitigate water pollution problems associated with broiler production in Louisiana. Thus, the main focus of this chapter remains on the production control program with a direct consequence of reducing pollution in a given watershed. Incentive payment is a viable option to motivate Louisiana broiler producers to terminate (permanently or temporarily) the broiler production and help reduce the water pollution in environmentally sensitive areas. Additionally, the incentive payments help farmers to balance farm income while meeting the environmental goal.

The question remains on how to estimate the dollar amount that represents producers' desired level of incentive that encourages them to participate in a production termination program in order to mitigate water pollution in a watershed. In fact, it is difficult to obtain a dollar value that a producer desires to receive to terminate the production practices. The dollar amount that encourages producers can't be obtained through market transactions. Contingent valuation studies are designed to assess the amount that reflects a minimum monetary amount required by the producers to relinquish one unit of broiler production from their current operation level. The value is assumed to represent an amount of incentive payment that the farmers require if they were to incorporate pollution reduction efforts on their production process. The payment level is evaluated based on farmer's household income, their perception about the governmental role on pollution control, and other farm characteristics.

In order to examine the farmer's desired level of incentive requirement, a clear understanding of their utility function is required. It is because a producer should be paid the

amount that leaves him/her at least indifferent to either continue (remain on same level of utility) or to terminate the production practices (move to a new utility level with additional income in the form of incentive). I examine producers' willing to accept (WTA) amount which suffices the producers to terminate their production practices and move to a new utility level.

It is assumed that by terminating the broiler production, the problem of nutrient pollution can be mitigated through reduced level of broiler litter. Reducing¹² litter production could be one of the viable alternatives to save Louisiana watersheds adjacent to and encompassing broiler production parishes from nutrient pollution. This chapter highlights the WTA value elicitation and examination under the hypothetical but potential governmental policy of production termination for pollution reduction.

This chapter is based on the assumption that the establishment of an appropriate baseline incentive payment is important in order to avoid negative consequences of incentive payments on either production process or in environmental services. For the purpose, it becomes imperative to understand the underlying factors that impact the amount of incentive payments that the broiler producers require. I, therefore, estimate a WTA function based on the survey data collected from Louisiana broiler producers.

II. LITERATURE REVIEW

Generally speaking, farmers fail to implement environmentally sound production practices because of the perception that pollution reduction efforts provide low personal benefit-cost ratio. In addition, if negative externalities from farming operations are not properly penalized; farmers are less likely to incorporate this externality in the production function as they are not liable for the pollution abatement cost. Under such circumstances, one of the approaches

¹² Phytase can be added in the broiler diet which reduces phosphorus content in litter (Bosch et al. 1997 JAAE), however, this may not be sufficient to reduce nutrient pollution in a given watershed.

to mitigate the water pollution problem is through providing government incentive payments to encourage farmers' production practices with minimum environmental effect (Cooper, 1997; Batie, 1999; Classen and Horan, 2000). If the incentive payment is substantial, the likelihood of farmers' participation as well as the acreage enrolled on environmentally friendly production practices (Cooper, 1997) becomes significant.

Broiler farmers are willing to participate in the programs only if the size of the incentive payment covers the full cost of participation (Classen and Horan, 2000). Wossink and Swinton (2007) examined the cost of producing environmental services. The study showed how complementary or substitutive relationships change the cost of producing environmental services. Producing environmental service as complementary to market good costs less to the producers as compared to the ones produced as substitutes which are produced outside of agricultural practices (Wossink and Swinton, 2007). Thus, their study supports the idea of bringing the farmer on pollution control programs with substantial amount of incentive payment.

However, recognizing an appropriate amount of incentive payment becomes difficult. Establishing the incentive payment based on individuals' production function becomes inappropriate because of the varied nature of production function. The production cost of environmental service depends on farm characteristics such as geographic areas, soil type etc. making the prediction difficult (Classen and Horan, 2000).

The next approach of estimating the incentive payment depends on return from agricultural land (Shaikh *et al.* 2007). Relying on the amount of return also becomes inappropriate since it fails to accommodate nonmarket values, risk attitudes and unobservable transaction cost. Thus, determining the baseline payments needed by producers in response to establishing environmentally friendly production practices becomes a difficult task.

The measure of WTA has widely been used to evaluate compensation requirement to keep an individual's utility at his/her desired level. The method is extensively used for the goods lacking a clear market for the good in question. Either WTP or WTA can be employed to elicit the value that an individual assign for the goods.

Goldar and Misra (2001) estimated resident's WTA values to decrease the number of trees in a public park, while, Brox *et al.* (2003) estimated the values in the context of water pollution reduction. The majority of the existing literature focuses on estimating incentive payments for environmentally sound production or land use practices. Few examples included the studies on land conservation (Amigues *et al.*, 2002); forest and habitat development (Kline *et al.*, 2000; Shaikh *et al.*, 2007); water pollution reduction practices (Cooper, 1997; Brox *et al.*, 2003).

WTA produce valid estimates of individual's true compensation required to encourage adoption of environment friendly management practices (Goldar and Misra, 2001). Shaikh *et al.* (2007) employed WTA measures to evaluate the compensation required by farmers in order to convert marginal land into forest for carbon sequestration. The study found the lower value of WTA as compared to the value obtained by another approach. Their study concluded that the value elicitation using WTA benefits the government without hurting the utility of producers, while setting up the incentive payments.

The WTA values elicited using a contingent valuation technique raises the issues of hypothetical bias. Studies have focused on the appropriate approaches to deal with the hypothetical bias under the field (Goldar and Misra, 2001) as well as experimental settings (Nape *et al.* 2003). Under a field setting, Golder and Misra (2001) suggested using a functional form that accommodates positive bias along with random error to obtain valid estimates for WTA.

On the other hand, Nape *et al.* (2003) conducted an experiment to examine the presence of hypothetical bias on WTA value. The study found significant presence of bias on hypothetical market setting where individuals do not own the good in question. While the bias was not significant if the individuals possessed the good in question before the experiment started (Nape *et al.* 2003). Thus the result implied that the hypothetical bias is less if the concern is over a good which an individual possesses. I closely followed their concept on setting up the hypothetical market scenario (more will be discussed in the Method section) and involved a good in question that the farmer possess. I reduce such bias by incorporating the farmers owned good (the broiler production in which the individual's livelihood is based) in the hypothetical market description.

The contingent valuation approach is often condemned for eliciting the values that fail to represent the true WTP/WTB. In addition to hypothetical bias, zero bid value is very common for contingent valuation studies either at open ended or payment card option (Bowker *et al.* 2003, Goodwin *et al.* 1993). Failure to accommodate zero and missing values produces sample selection bias leading to biased and inconsistent parameter estimates.

Bowker *et al.* (2003) and Goodwin *et al.* (1993) treated zero bids as if the data was censored at zero and employed a tobit model to estimate WTP bid function. However, under the contingent valuation scenario, the zero responses are the result of non-observability rather than the true censoring (where the censoring at zero may represent some negative values). In that case, the use of a tobit model becomes inappropriate (Singelman and Zeng, 1999).

Strazzeria *et al.* (2003) allowed the zero values by estimating the model in two stages. The study employed a two-stage simultaneous equation model to correct for the bias caused by the zero responses. Similarly, in response to the existing bias, Amigues *et al.* (2002) permits the zero responses by estimating the model in two stages. The study found that the estimated hypothetical

WTP value better represented the true willingness to pay amount when the zero responses were treated separately in the model.

In general, the elicitation of a WTA value has been an accepted approach to assign monetary values for nonmarket goods, if estimated using an appropriate methodology. Thus, this chapter evaluates the WTA values that encourage broiler producers to participate in pollution reduction programs through production termination. This section accommodates a heckman's sample selection model to allow bias.

III. MODEL

Economic Model for WTA

Broiler production is assumed to be a component of an individual's utility function as it generates a portion or whole of their income and provides livelihood. Thus, terminating the existing production practices directly affect the individual's utility level. Therefore, a utility theoretic approach is preferred to examine broiler producer's preferences over current production level or reduced production level with an additional income of WTA value.

The farmers are considered to have strictly quasiconcave utility function defined over a quantity constrained good (flocks of broiler), a non-constrained good (numeraire) and money income M . The M represents the individual's household income consisted of farm as well as off-farm incomes. A broiler producer's utility function that accommodates an environmental component, respondent's socioeconomic characteristic and payment option is expressed as;

$$U^l = U(\mathbf{Z}, M + I^l, Q^l) \quad (4.1)$$

$U^l(\cdot)$ defines a broiler producer preferences over market goods and water quality improvement through reduction in litter production (measured by reduction in production size). \mathbf{Z} is a vector of variables containing farmer's as well as farm characteristics and I^l represents the WTA amount

under the proposed policy. I^l takes the value of zero under the current condition since there has been no effort made to reduce pollution production, thus no changes in income is required. Q^l represents the water quality which is assumed to be directly affected by production termination.

The broiler producers are now expected to maximize their utility function U^l with respect to a constrained budget. However, the individual is faced with the two options, whether to produce at the current scale or terminate the production practices with \$I as an incentive payment. The reduced broiler production is expected to reduce nutrient pollution production and help to obtain better water quality (Q^1).

The utility maximizing individuals desires to receive an incentive level that leaves him/her at least better off as he was before the change on production. Suppose, $U^1 = U(Z, M + I^1, Q^1)$ represents the utility level with new production level and positive income change assuming $l = 1$, while the utility level will be $U^0 = U(Z, M, Q^0)$ with no change in production level or at current state of production.

Then an individual will be willing to terminate the production process if the following holds;

$$U(Z, M + I^1, Q^1) \geq U(Z, M, Q^0) \quad (4.2)$$

Hanneman (1984) suggested that the individual's utility functions should be treated as random variables. Based on Hanneman's argument, the U^1 and U^0 are random utility function that can be expressed respectively as;

$$V(Z, M + I^1, Q^1) + \varepsilon^1 \text{ and } V(Z, M, Q^0) + \varepsilon^0 \quad (4.3)$$

$V(\cdot)$ in equation 4.3 represents the deterministic component and the ε^0 and ε^1 represent the random error of a respondent's utility function. $V(\cdot)$ is defined as individual's indirect utility function either after production termination with an I^1 increase in income, or under the existing production practices. It is assumed that the individual then evaluates their utilities at both

conditions and decide whether to terminate the production process at given payment of WTA value (which is defined as I^1).

The individual's decision on whether he/she would participate in a production termination program is observed with following probability distribution.

$$\begin{aligned} P\{Participate\} &= P\{V(\mathbf{Z}, M + I^1, Q^1) + \varepsilon^1 \geq V(\mathbf{Z}, M, Q^0) + \varepsilon^0\} \\ &= P\{\varepsilon^0 - \varepsilon^1 \leq V(\mathbf{Z}, M + I^1, Q^1) - V(\mathbf{Z}, M, Q^0)\} \quad (4.4) \end{aligned}$$

The terms ε^0 and ε^1 are assumed to be independently and identically distributed random errors. Once the individual decides whether to participate in the production termination program, he/she would decide the desired amount of incentive payment to terminate the production process.

Econometric Model for WTA

The survey collects information on WTA value from the individuals who are willing to participate in the production termination program, the observation may be nonrandom. In addition, the two responses, whether to participate in the program, and the value that the individuals desire to receive so as to terminate the production process, are correlated. Since the WTA values are observed only for the individuals who are interested to participate in the pollution reduction program, the elicitation of WTA becomes non-random. A regression on non-randomly selected samples produces inconsistent estimates of the parameters (Davidson and Mackinnon, 1993). Thus, the design of the WTA elicitation on the survey questionnaire requires an econometric modeling that fully accounts for the possible correlation between “Yes/No” answer of the participation question and the size of the WTA amount. The information elicitation design requires simultaneous explanation of participation decision and WTA function. Therefore, a Heckman's selection model is employed to examine farmers' decision to participate and pay to mitigate nutrient pollution.

Let's represent the decision to participate by a binary variable B_i for an individual i . If an individual records a positive WTA value on the survey question $B_i = 1$ is assigned while, if respondent state WTA value be zero then $B_i = 0$ is assigned indicating that he/she is not willing to participate in the proposed pollution reduction through production termination.

The variable W_i is the individuals' stated value representing the amount of incentive (WTA) that an individual would need to terminate one flock of broiler birds from his existing production practices.

$$B_i^* = \mathbf{Z}_{ib}\boldsymbol{\beta}_b + \varepsilon_{ib} \quad (4.5)$$

$$B_i = \begin{cases} 1 & \text{if } B_i^* > 0 \\ 0 & \text{if } B_i^* \leq 0 \end{cases}$$

$$W_i = \mathbf{Z}_{iw}\boldsymbol{\beta}_w + \varepsilon_{iw} \quad (4.6)$$

where $i = 1, 2, \dots, n$ represents the number of individuals in the sample. \mathbf{Z}_{ib} and \mathbf{Z}_{iw} represent the sets of explanatory variables on binary response equation (4.5) and WTA equation (4.6). There may be some overlap on variables on the vector \mathbf{Z}_{iw} and \mathbf{Z}_{ib} . The $\boldsymbol{\beta}_b$ and $\boldsymbol{\beta}_w$ are the unknown parameter vectors.

The respondent chooses to state $B_i = 1$ if the latent variable turns out to be positive. Otherwise, the respondent chooses to answer no to the participation question ($B_i = 0$). The explanatory variables (\mathbf{Z}_{ib} , \mathbf{Z}_{iw}) and the binary response variable, B_i are always observable while the willingness to pay value, W_i , is observed only when $B_i = 1$. This makes the error terms ε_{ib} and ε_{iw} to be correlated. Thus, $\varepsilon_{ib} \sim N(0,1)$ and $E(\varepsilon_{iw}/\varepsilon_{ib}) = \gamma\varepsilon_{ib}$.

$$\begin{bmatrix} \varepsilon_{iw} \\ \varepsilon_{ib} \end{bmatrix} \sim NID \left(0, \begin{bmatrix} \sigma^2 & \rho\sigma \\ \rho\sigma & 1 \end{bmatrix} \right) \quad (4.7)$$

σ is the standard deviation of ε_{iw} and ρ is the correlation between ε_{iw} and ε_{ib} . A nonzero correlation between the two equations is a result of dependence of B_i^* on the respondent's stated

WTA value (W_i). The negative correlation between the ε_{ib} and ε_{iw} implies that the individuals who are willing to participate in the production termination program demand smaller WTA as an incentive. However, the ε_{ib} and ε_{iw} are independent of the explanatory variables ($\mathbf{Z}_{ib}, \mathbf{Z}_{iw}$).

Maximum Likelihood Estimator

The conditional probability density function of an individual that chooses to participate in the production termination program is;

$$f(B_i|z) = [\Phi(\mathbf{Z}_{ib}\boldsymbol{\beta}_b)]^{B_i} [1 - \Phi(\mathbf{Z}_{ib}\boldsymbol{\beta}_b)]^{1-B_i}$$

If an individual accepts to participate in the production termination program, the probability density function of the amount of WTA will be;

$$f(W_i|B_i = 1, \mathbf{Z}) = \frac{P(B_i=1|W_i, \mathbf{Z}_w)f(W_i|\mathbf{Z}_w)}{P(B_i=1|\mathbf{Z}_w)}$$

$$(W_i|\mathbf{Z}_{iw}) \sim N(\mathbf{Z}_{iw}\boldsymbol{\beta}_w, \sigma_w^2)$$

and $B_i = \mathbf{Z}_{ib}\boldsymbol{\beta}_b + \sigma_{bw}\sigma_w^{-2}(W_i - \mathbf{Z}_{ib}\boldsymbol{\beta}_b + \epsilon)$

where ϵ is independent of $(\mathbf{Z}_{ib}, W_i) \sim N(0, 1 - \sigma_{bw}^2\sigma_w^{-2})$,

$$P(B_i = 1|W_i, \mathbf{Z}_{iw}) = \Phi\{[\mathbf{Z}_{ib}\boldsymbol{\beta}_b + \sigma_{bw}\sigma_w^{-2}(W_i - \mathbf{Z}_{iw}\boldsymbol{\beta}_w)](1 - \sigma_{bw}^2\sigma_w^{-2})^{-1/2}\}$$

Now combining all these and taking log of the likelihood function we get the following log likelihood function;

$$l(\boldsymbol{\theta}) = (1 - B_i) \log[1 - \Phi(\mathbf{Z}_{ib}\boldsymbol{\beta}_b)] + B_i \left(\log \Phi\{[\mathbf{Z}_{ib}\boldsymbol{\beta}_b + \sigma_{bw}\sigma_w^{-2}(W_i - \mathbf{Z}_{iw}\boldsymbol{\beta}_w)](1 - \sigma_{bw}^2\sigma_w^{-2})^{-1/2}\} + \log \phi[(W_i - \mathbf{Z}_{iw}\boldsymbol{\beta}_w)/\sigma_w] - \log(\sigma_w) \right) \quad (4.8)$$

IV. DATA

A hypothetical market scenario was developed in order to elicit farmers' WTA value. The respondents were given a scenario of proposed government regulations that require them to terminate a portion of production processes in order to meet the water pollution reduction. Then,

the respondents were asked how much they desire to receive as an incentive payment from the government if they were to comply with the proposed regulation. It is assumed that the individuals who answered the WTA questions positively are willing to cooperate with the proposed program, while the individuals who either did not respond to that question or listed zero as WTA values were assumed to be not interested in the program. Nearly 16% of the respondents were non-participants. The approach is consistent with Brox *et al.* (2003), who assume non-response as non-participants.

Dependent Variable for Participation Equation

In the first stage, the dependent variable represents whether an individual is interested to participate in the production termination program. The variable is operationally defined as 1 if the individual responded with a positive amount on WTA question and zero if otherwise.

Dependent Variable for the WTA Equation

WTA represented the amount that an individual is willing to accept as an incentive payment in order to trade one flock of broiler birds. The amount is elicited in dollars per flock that an individual would terminate the production so as to reduce nutrient pollution generation. The average WTA amount was about 4,000 dollars per flock that represents an individual's price to reduce water pollution.

Explanatory Variables

The variables that entered the final model are selected based on economics reasoning as well as on stepwise regression. A priori economic theory does not guide much about the variables affecting the willingness to participate and pay. Therefore, a stepwise selection process is employed along with economic reasoning to choose the final set of explanatory variables. Table 4.1 presents the list of variables used in the model and the summary statistics.

The Number of broilers represents the total number of broiler birds raised by an individual producer in 2003. The numbers of broilers are divided by 100,000 for easier computational purposes. A larger number of birds imply larger production size. The production size is found to be positively related to the willingness to participate in environmentally friendly farming practices (Shaikh *et al.*, 2007).

Herd size showed positive effect on probability of participation in the dairy termination program and negative effect on bid value (Gale, 1990) to terminate the dairy production. Similarly, the farm size affected the decision to terminate crop production to enroll the land in CRP, positively (Boisvert and Chad, 2005). Previous studies have also found that the larger the farm size the greater the land retired from the crop production to reduce the adverse effect of agricultural production on the environment (Lambert *et al.*, 2007).

The variable off-farm income measured whether an individual broiler producer has an additional income from non-farm activities. Having off-farm income implies additional income and therefore financially secured, to seek for other options to comply with pollution regulation rather than changing production level. The variable is often found to be significantly affecting individuals' decision to participate in environmentally friendly production practices. Respondent's off-farm income affected the decision to participate in environmentally sound practices negatively (Gillespie *et al.*, 2007).

Fraction of land owned by the broiler grower over total land operated is hypothesized to be negatively related to the participation decision as indicated by Rahelizatovo, (2002). Having more land allows broiler growers some flexibility on litter application with no or little restriction on litter spreading amount and frequencies. Individuals therefore, tend not to seek for other alternative solutions for water pollution control measures.

Farmer's own characteristics play a major role in the decision associated with production termination to reduce water pollution. The variable *Age* provided mixed results in previous studies. Age is positively associated with the likelihood of environmentally friendly dairy production practices (Gillespie *et al.*, 2007), while it is negatively related with production termination to enroll land into CRP (Kalaitzandonakes and Monson, 1994; Konyar and Osborn, 1990). Young farmers are found to be more knowledgeable and more risk taking due to longer planning horizons and therefore, are more likely to participate in agricultural practices that reduce the negative impact on environment (Adesina and Zinnah, 1993).

Table 4.1: Summary statistics of explanatory variables

Variable	Mean	Std Dev.	Min	Max
WTA value (\$ per flock of birds)	3961.21	3664.18	0	18750
Number of broilers/100,000	4.706	3.020	0.18	19
Individual has off-farm income =1	0.324	0.471	0	1
Perception that government should pay for water conservation, scale 1-5	3.292	1.378	1	5
If there are housing subdivision in nearby =1	0.108	0.313	0	1
Ownership of business; individual owner=1	0.726	0.449	0	1
Heard about BMP	0.811	0.394	0	1
Age of farmer at the time of survey	53.284	12.184	25	79
Farm income up to 49,999	0.315	0.468	0	1
Farm income from 50,000 to 99,999	0.356	0.482	0	1
Farm income greater than 99,999	0.233	0.426	0	1
Willing to participate on the program=1	0.838	0.371	0	1
Percentage of land owned by the grower	86.092	27.320	0	100

Business ownership is a dummy variable indicating whether the firm is individually or family owned. Individually owned businesses are assumed to have solo power to make decisions. The single ownership makes the individual decide easily but the variable may have either a positive or negative effect on participation decision.

Housing in surroundings is a dummy variable representing whether residential subdivisions are located nearby the broiler farm. Deterioration of air quality from the broiler litter is one of the major pollution issues associated with broiler production. Complaints of strong and objectionable odors have been voiced by the neighbors causing serious legal actions against broiler producers (<http://www.epa.gov/agriculture/anafobmp.html#Odors>; 20th May, 2008). Such threat from the nearby residents forces broiler producers to implement appropriate measures to reduce the smell problem. Presence of housing subdivisions in the neighborhood is therefore assumed to have a significant positive effect on likelihood of participation in pollution production termination decision. The variable may have either positive or negative effect on WTA amount.

The producers hesitate to accept that their production practices possess a pollution threat to the surface water as well as ground water. Therefore, the farmer's perception about government's role in pollution control is an important factor to decide whether to participate in the pollution control program through private effort of production termination (Hite *et al.*, 2002). In order to capture that effect, a scale of individuals' perception toward government role (1 being strongly disagreed and 5 being strongly agreed) is employed. The perception that the government should pay for water pollution control programs is treated as continuous which is consistent with the approach employed by Brox *et al.* (2003). The perception is hypothesized to affect the

participation decision negatively. In addition, the WTA amount to trade a flock is assumed to increase, if the producers don't see their production practices as a threat to the water resources.

Awareness about the alternative practices was constructed by employing a dummy variable to indicate whether an individual has heard about BMP. This represents whether the respondent has only heard about the BMP or has implemented the practices. The variable is then used as proxy for his/her general knowledge about the availability of alternative practices that can be implemented to reduce nutrient runoff. Thus, the availability of substitutes is assumed to have a negative effect on production termination.

Farm income is defined as the household income generated from the broiler industry. Based on the existing literature, it is not clear what effect the farm income has on the willingness to participate in a production termination program to secure better environmental quality. Farm income showed negative effect in accepting to participate on production termination to develop forest land (Shaikh, *et al*, 2007).

In this study, farm income is defined in five categories at the interval of \$50,000 starting from “negative profit up to \$50,000”, “\$0 to \$49,999”, “\$50,000 to \$99,999”, “\$100,000 to \$149,999” and “greater than or equal to \$150,000.” Producers with higher farm income are financially more secure as compared to others and are less interested in forgoing the production to reduce water pollution. The individuals with high farm income may spend on pollution abatement technology instead of termination of ongoing production practices. In addition, the farmer who generates more farm income expects higher incentive payment if he has to forgo his production to reduce nutrient generation.

V. RESULT AND DISSCUSSION

The data show that nearly 16% of respondents are willing to accept zero amounts in order to participate in the production termination program. The zero bid response is common for contingent valuation studies (Bowker *et al.*, 2003; Goodwin *et al.*, 1993). However, observing zero bid values in WTA to trade a flock with cleaner water quality may not imply that the respondents are willing to sell a flock of birds at zero prices.¹³

It is therefore assumed that the zero value originates from first stage of decision where an individual decides whether/not to participate in the pollution reduction program (Strazzera *et al.*, 2003, Cho, *et al.*, 2005). Then, at the second stage, the individual decides how much he/she requires as incentive payments to forgo their production practices. Thus, the respondents having zero bid values on contingent valuation questions are considered to be not interested in terminating the broiler production to reduce pollution generation. The term B_i^* is then considered to be unity if an individual responded positively to the WTA question and zero otherwise.

The WTA amount is observed only if the individuals are interested in participating in the program or if the $B_i^* > 0$. For the contingent valuation question the W_i represents the dollar amount that an individual desires to receive so as to terminate one flock of birds for better water quality. The average value of WTA is about \$3,960 whereas the profit from one flock is \$1,400 the latter of which is estimated by the Louisiana Agricultural Experiment Station.

The selection nature of data collection gives rise to an estimation problem since the errors in the two decision process (participation and WTA value) are correlated. Excluding the non-participants from the analysis, or using only the positive WTA values produces an inconsistent estimation of parameters (Cameron and Trivedi, 2005).

¹³ The exact format of WTA question as asked in the survey favors running a random effect probit model. However, respondents provided only a limited number of choices. Lack of variation was the main reason to abandon a RE probit model.

Davidson and MacKinnon (1993) suggest employing a heckman's selection model using two-step estimation process in order to test the hypotheses of a no selection bias. The hypothesis of "absence of selection bias" can be tested by checking whether the coefficient of inverse mills ratio is significantly different than zero. The result indicates that the coefficient is significantly different from zero at 10% level of significance. Since, the null hypothesis of "no sample selection effect" is rejected, the ordinary least square (OLS) process produces biased and inconsistent parameter estimates for WTA (Cameron and Trivedi, 2005; Baum, 2006).

With the rejection of sample selection hypothesis, and the nature of sample selection process in data collection, I used heckman's sample selection models for the analysis. It is recommended to employ maximum likelihood estimation of sample selection models (Davidson and MacKinnon, 1993) once the hypothesis of selection bias is rejected using two-step procedure.

A priori economic theory fails to provide enough guidance to decide which variable should be included either in participation or on WTA equation. Since, it is unlikely that the individual's decision to participate and his WTA amount are determined by the different sets of covariates, a variable selection model is also employed. The selection starts from the full set of variables. The variables significant at 0.30 were allowed in the Heckman sample selection model. In addition, the demographic variables that failed to generate the Z values of at least one were simultaneously dropped from the model. The process is consistent with variable selection process employed by Brox *et al.* (2003). In addition, the variables that were selected in the selection process but didn't meet the convergence criteria at maximum likelihood estimation approach were also dropped from the model. At the end of the variable selection trial, farm

income, broiler number, housing in nearby, asset liability ratio and age were kept for the first stage probit model. The results from the final model are presented on tables 4.2 and 4.3.

Table 4.2 provides the parameter estimates and their standard errors associated with the binary choice of participation decision. The first step of the analysis estimated the decision equation of whether to participate (or not to participate) on the proposed pollutant reduction program. The only variables that came out to be insignificant, on the first step probit regression, are farm size measured by broiler number and the dummy representing whether there is/are housing subdivision/s near the broiler farm.

Turning to the specific determinants of WTA value (Table 4.3) that motivates the individuals to participate on the program, it is noticed that production size, farm and off-farm income, individual's perception about government's role in water pollution, ownerships of farm, and knowledge about alternative pollution control programs are the significant factors affecting stated willingness to accept value. In fact almost all of the variables are significant at least at ten percent level of significance. The only variables that are not significant are the dummies for income level that falls between 50,000 to 99,999; existence of housing subdivisions in the surrounding areas and the age of principal operator at the time of survey.

The off-farm income is often found to be a significant variable in an individual's decision to participate in environmentally friendly production practices. This study also showed that the participation decision is negatively affected by the level of off-farm income. Lambart *et al.* (2007) also found the off-farm income is negatively associated with production termination decision. An individual, who has off-farm income, is less likely to participate in the conservation reserve program (Lambert *et al.*, 2007) by terminating their production practices. Further,

Gillespie *et al.* (2007) find a negative impact of individuals having off-farm income on implementing pollutant reducing agricultural practices.

The fraction of land owned over total land operated for agriculture was hypothesized to be negatively related to the participation decision as indicated by Rahelizatovo (2002). The result supported the hypothesis showing that a one percentage point increase in the fraction of owned land decreases the likelihood of participation in flock trading for pollution control program by 0.07. The individuals, who own a larger fraction of total operated land, are more flexible on spreading litter on their own crop and pasture land. Excess nutrients from broiler litter become a problem only if there are not enough crops and pasture lands to absorb the plant nutrient from applied litter. If a farmer owns enough land to absorb nutrient content from all the litter produced from broiler production, there is no need to terminate the broiler production. Therefore, the individuals who own a larger percentage of land tend not to participate in pollutant reduction programs through production termination.

Further, the result indicated that the older individuals are less likely to participate in the production termination to help reduce pollution production. The result is contradictory to the assumption that older individuals are near to the retirement and would be attracted by the concept of production termination. On the other hand, it is also true that older farmers have less flexibility in finding a job after terminating the ongoing farming operation. The older farmers have shorter time horizon for recouping the profession change, it is more likely for farmers to be less attracted toward terminating broiler production. The existing studies related to farmers' behavior to cope with pollution reducing programs also suggest that older farmers are less cooperative to the programs designed for achieving better environment (Gillespie, *et al.*, 2007;

Kalaitzandonakes and Monson, 1994). The result implies that the older farmers prefer not to modify the production practices with the tools that are designed for long term goals.

Table 4.2: The determinants of willingness to participate: binary variable B_i^*

WTA value (\$)	Coefficient	Std. Err.
Number of broilers/100000	0.158	0.109
Individual has off-farm income =1	-1.212**	0.635
Percentage of land owned by the grower	-0.066**	0.029
Ownership of business; individual owner =1	-1.011	0.635
Perception that government should pay for water conservation in the scale of 1-5	-0.614**	0.266
If there are housing subdivision in nearby =1	0.106	1.291
Age of farmer at the time of survey	-0.094***	0.036
Heard about BMP	-1.369**	0.615
Constant	14.532***	4.821
Pseudo R-square		0.419
LR chi2(8)		25.54
Prob > χ^2_8		0.001

Note: *, ** and *** represents the significance level at 0.10, 0.05 and 0.01 respectively.

The result showed that the perception among producers believe that government should pay farmers in order to encourage pollution reduction efforts and reduces the likelihood of farmers' participation. The individuals who strongly believe that government should pay for water pollution control programs are less likely to participate in the production termination program to mitigate water pollution problems. The result is supported by the finding of Hite *et al.* (2002) who found that the producers don't accept their production practices possess a pollution threat to the environment and should bear a responsibility for cleaning up. In addition,

the WTA amount to trade a flock for better water quality increases, if the producers don't see their production practices as a threat to the water resources. The result showed a significant positive impact of the perception on stated WTA value.

The proxy for an individual's knowledge (heard about BMP) about the availability of alternative practices showed negative effect on the likelihood of production termination. An individual who has heard about the BMP is less likely to participate in the proposed production termination program (Table 4.2) as compared to the ones who are not. Further, these individuals stated greater value to the willingness to accept the amount to trade one flock of broiler (4.3). The result implied that if the individuals who are aware of other alternatives (such as BMP) to reduce pollution tend not to participate in the production termination program and also state a greater amount of WTA.

The number of broiler raised in a year, which represented the size of the production is found to be an important variable to determine the level of incentive payment that an individual expects to receive. The result showed that the size of production is negatively related to the stated value of WTA (Table 4.3) and positively related to the likelihood of participation (Table 4.2). The result implies that the larger broiler producers are more likely to participate in the program and need lower incentive payments if they were to forgo their production practices either partially or fully to meet the pollution reduction goal.

The finding is consistent with Lambart *et al.* (2007) who find larger farmers have more flexibility with respect to land use decision. Therefore, they are willing to retire a larger portion of land from crop production. Production size was also found to be negatively affecting the incentive amount to enroll production land into the CRP program (Boisvert and Chang, 2005)

and positively affecting the likelihood of participation on CRP enrollment (Boisvert and Chang, 2005; McLean-Meynsse *et al.* 1994) and pollution reduction programs (Rahelizatovo, 2002).

Table 4.3: The determinants of WTA: Sample selection and no-selection models for (W_i)

Variables	OLS selection		OLS no-selection	
	Coefficient.	Std. Error	Coefficient	Std. Error
Number of broilers/100000	-274.557**	125.480	-192.035	138.061
Individual has off-farm income =1	2694.798***	878.997	1699.734	1156.593
Perception that government should pay for water conservation in the scale of 1-5	1058.141***	298.298	729.680**	337.543
If there are housing subdivision in nearby =1	507.206	1219.757	-732.914	1298.205
Ownership of business; individual owner=1	1575.931**	815.770	1608.133*	909.450
Heard about BMP	1992.005**	1039.751	2805.682***	1083.750
Age of farmer at the time of survey	-20.677	33.751	-53.384	40.207
Farm income upto 49,999	3469.184***	1408.545	3789.173**	1778.140
Farm income upto 50,000 to 99,999	1737.143	1398.063	1530.968	1437.255
Farm income greater than 99,999	2643.502*	1452.289	2354.555*	1473.871
Constant	-2681.595	2832.887	-822.357	3645.072
λ	1228.824	1036.837	----	----
ρ	0.474	0.418	----	----
σ	2589.440	257.116	----	----
No of observations	70		67	
Censored	11			
Uncensored	59			
Wald χ^2_{10}	50.55***			
$F_{10,56}$	2.34**			

Note: *, **, and *** represents the significance level at 0.10, 0.05 and 0.01 respectively.
 λ is significant at 0.069

In general, the result implies that the larger farmers are more responsive to the water pollution issues and potential government regulations to mitigate the nutrient pollution problem. Specifically, in the present context, the result may imply that the larger farmers fear from the potential government regulation (for example, CAFO affects the larger producers more than the smaller producers) and therefore, like to decrease the flock size at lower WTA value so as to avoid dealing with the regulations.

There are four income dummies in the regression model. The first level stated whether the firm is running at a loss and is employed as a reference group. The result showed that the individuals earning less than \$50,000 net farm income desire a higher amount of WTA value as compared to the individual who face up to \$50,000 loss per year. The third level of farm income also showed significant positive impact on WTA value. The producers who earn up to \$50,000 farm income per year require about \$3,470 per flock per year in order to terminate the production program as compared to the individuals who bear loss up to \$50,000. The farmers with more than \$100,000 farm profit also showed significant positive impact on stated value of WTA. Surprisingly, the second level of income category showed insignificant impact on stated value of WTA. It may be that these groups of farmers are indifferent between participating and nonparticipating as they are comfortable with their level of production and the income from the production.

The ρ , which represents the cross equation correlation, is positive. The result indicates that individuals are interested to terminate their production practices only if they receive a sufficient amount of incentive payment. The positive effect of perception that government should pay for water pollution control programs also supports this finding. The positive correlation is also consistent with the finding of Hite *et al.* (2002) who conclude farmers don't agree their

production practices contribute to nutrient pollution and hesitate to invest in pollution reduction practices. However, Brox *et al.* (2003) found a negative relationship between the decision to participate in pollution reduction program and stated WTA value.

In general the maximum likelihood approach is preferred to the two-step procedure for the sample selection model because of the non-identification and collinearity problem in two-step procedure. Identification problem of Heckman two-step procedure originates from the inclusion of inverse mill's ratio in second step estimation. It is also argued that the imprecision of the heckman's two-step estimation originates from severe collinearity originated from inclusion of inverse mills ratio (Leung and Yu, 1996; Wooldridge, 2002).

The two-step approach of heckman's selection model may not perform well when the selection equation (participation) and output equation (WTA) are highly correlated (Leung and Yu, 2000; Nawata, 1994). For the diagnosis of collinearity, the inverse mills ratio obtained from the first step probit selection model is regressed against explanatory variables on the WTA equation (Nelson, 1984; Leung and Yu, 1996). The R-square value from this regression is used to measure the magnitude of collinearity. The result showed the value of R square to form auxiliary regression to be 0.433 is the evidence of collinearity supporting the use of the maximum likelihood estimation (Leung and Yu, 1996). The regression of the inverse mills ratio on all explanatory variables and correlation matrix are presented in Appendix C.

Even though maximum likelihood estimation approach is preferred the analysis is also conducted using two-step procedure, because of following two reasons.

1. In a small sample, the maximum likelihood estimates tend to have larger parameter bias than those of two-step approach (Leung and Yu, 1996).

2. Hypothetical bias is a serious problem in contingent valuation studies. In presence of errors on measuring the dependent variable, MLE produces inconsistent estimates. On the other hand, using two-step procedures, the errors due to the hypothetical bias is absorbed into the disturbance term of the output (WTA) equation. Thus, the two-step procedure may provide better parameter estimates (Stapleton and Young, 1984) as compared to maximum likelihood estimates.

The results from the two step model produced similar conclusion while the standard errors are larger for some of the variables. The result from the two-step procedure is presented in Appendix C.

Expected value of WTA is estimated using the parameter estimates obtained from Heckman's MLE approach. The model estimated the broiler farmers' WTA value to terminate the production process to be \$4,720 with standard deviation of \$2,659. The average net income from one flock of broiler production is listed to be only \$1,400. The fixed cost associated with broiler houses and other fixed assets that can't be used for other production purposes might be the main reason to overestimate the cost of production termination.

VI. CONCLUSION

This study provides an insight over the factors to be considered before setting up the incentive payments which encourages broiler producers to terminate production practice. Establishing the appropriate baseline incentive payment is important to avoid unintended negative consequences of governmental incentive payments. The factors that affect broiler producer's decision to cooperate with water pollution reduction programs are evaluated using Heckman's sample selection model.

Size of the farm, measured by the number of broiler birds raised per year, significantly affected the size of WTA value. Larger farmers are more serious about water pollution and potential regulation and thus state a lower WTA values to help reduce water pollution. On the other hand, the significant positive effect of perception that government should pay farmers to participate in pollution abatement programs suggested that a sufficient economic incentive is required to encourage farmers to participate in environmentally friendly production practices.

This study will be novel in the area of environmental economics in the sense that it incorporated the farmers' attitude toward nutrient pollution reduction programs. However, past studies mainly focused on WTA for conservation programs. This analysis is also important because a very little is known about the broiler producers' attitude and willingness to participate in the pollution reduction programs. And the understandings of the factors that affect farmer's interest to participate on those programs are critical for the success of national and state level policy formulation in order to mitigate water pollution.

One of the strongest assumptions made in this chapter is that the individuals who have listed their WTA as zero value are assumed as non participants. This assumption carries a valid argument that the goods in question is flock of broiler birds and it is unconvincing that broiler producer would terminate production of a flock at zero price. In addition, with the small size of the dataset in hand and fear of losing valid statistical information, I decided not to drop the observations with zero value on WTA question.

The lack of response commonly originates from protest votes; incomplete information to the producers etc. Further, with the smaller sample size, the maximum likelihood estimates may produce biased parameter estimates than those obtained from two step estimation process. Therefore, the estimates from two-step estimation approach are also presented in Appendix C,

however the conclusion drawn is not different from that obtained using maximum likelihood method.

This study focuses on whether broiler producers are willing to participate on production termination program to mitigate water pollution and what would be the incentive level that suffices to encourage farmers to participate in the programs. However, this study does not focus in the magnitude of pollution reduction from the level of production termination. The question of how many flocks should be cut off to achieve desired level of water quality is determined by the target of water quality requirement in a given watershed, which is beyond the scope of this study.

While using this result one should be cautious about the level of incentive payment on the unintended effect of larger incentive on production termination. Studies have also indicated larger incentive payments may produce unwarranted negative effect on production termination.

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CHAPTER FIVE

BROILER PRODUCERS' WILLINGNESS TO PAY TO REDUCE WATER POLLUTION

I. INTRODUCTION

The Conservation Reserve Program (CRP), Wetland Reserve Program (WRP) and Environmental Quality Incentive Programs (EQIP) encourage farmers to participate in pollution control programs. The NRCS/USDA provides technical and/or financial support to help implement environmentally friendly production practices. Besides voluntary adoption of environmentally friendly practices, broiler producers also face regulations for Concentrated Animal Feeding Operations (CAFO) and Animal Feeding Operations (AFO) which require them to follow pollution control measures and restrict the level of pollution. The common goal of these policy instruments and regulations is to bring polluters on pollution reduction processes. The current environmental policy encourages farmers to implement pollution control practices voluntarily unless the farmers are CAFOs or AFOs.

It is widely accepted that the economic incentives/disincentives play a major role in encouraging producers to participate in environmentally benign production practices (Tarui and Polasky, 2005). In this chapter, I examined the level of economic disincentives that encourage (force) farmers to internalize the pollution control measures into their production practices. I assessed the concept of disincentives for polluters to enforce pollution control efforts on polluters' production decision. For the purpose, I estimated the maximum dollar amount that can be charged as pollution abatement cost for an individual allowing him/her to be indifferent from existing utility level. The amount is represented by the individual's willing to pay (WTP) value for pollution control/abatement measures and continue his production practices at the current scale.

It is well established that the amount representing the producer's affordability or willingness to pay to control water pollution becomes difficult to derive through market transactions. Therefore, I employed a contingent valuation approach to examine the affordability (or willingness to pay for water pollution control measures) of Louisiana broiler producers based on their household income; their perception about the need of environmental regulations; and other farm level characteristics.

The broiler producer's desired willingness to pay level can be evaluated through a clear understanding of their utility function. The contingent valuation approach elicits the amount that the individual would be willing to pay and remains on his/her existing utility level. Using contingent valuation approach, I created a hypothetical scenario of potential governmental regulation that can be implemented if the broiler producers fail to accommodate environmentally friendly production practices. Afterward, I obtained the individual's bid amount for controlling water pollution. It is assumed that the individuals' stated WTP value will be an appropriate approximation of disincentive/tax payment that can be imposed to internalize pollution control effort into producers cost function.

II. LITERATURE REVIEW

The continuous and evolving nature of environmental regulations and its adverse effect on profit level forces farmers to search for alternative solutions to mitigate increased water pollution. Increased number of regulated CAFO/AFO operations and strengthened permit requirements (EPA, 2003) for these operations are the examples of government being more stringent on water quality regulations. Meantime, the BMP adoptions and obeying the CAFO and AFO regulations are the examples of farmers being more concerned about the regulation and

standards. Thus, the perceived threat of stringent regulation convinced the producers to implement environmentally friendly production practices with no/partial amount of cost-share.

Large scale producers falling under CAFO and some AFO operations are forced to employ environmentally benign production practices to comply with the permit requirements (EPA, 2003). Even though the increased number of regulated CAFO and AFO showed ambiguous results on reducing water pollution (Mullen and Center, 2004) the producers are required to abide by these regulations. In order to avoid the potential punishment, agricultural producers attempt to invest on environmentally friendly practices. This implies that the farmers are willing to pay (forced to pay) some amount in order to avoid potential harsh governmental regulations (to reduce water pollution) and continue the existing production practices.

The question remains how much the broiler producer will be willing/ able to afford to reduce water pollution. The contingent valuation approach (WTP) measure has been employed in a wide variety of research where non-market goods are involved (Urama and Hodge, 2006; Whitehead, 2006; Cho *et al.* 2005; Strazzer, *et al.* 2003; Hudson and Hite, 2003; Hite *et al.*, 2002; Roach, *et al.*, 2002; Whitehead *et al.*, 2001; Stevens *et al.*, 2000; Loomis *et al.* 1998; Hanemann, 1984).

The approach has also been employed to elicit an individual's willingness to pay amount for water quality improvements (Whitehead, 2006; Brox *et al.* 2003; Hite *et al.* 2002; Whitehead, 2002; Cooper 1997). Whitehead (2006) examined the WTP value for water quality improvement from the consumer's point of view accommodating heterogeneity due to perceived water quality levels. On the other hand, Hite *et al.* (2002) evaluated the value of water quality improvement, from the producers' point of view.

The CV technique is based on the assumption that the maximum amount of money that an individual desires to pay represents their maximum WTP value for the purpose of controlling water pollution. Hite *et al.* (2002) found that the producer's marginal willingness to pay for pollution reduction decreased with an increased level of desired pollution reduction. According to Hite *et al.* (2002) the decrease in marginal WTP is due to the fact that the agricultural producers tend not to believe their production practices contribute enough to cause water pollution problems. In addition, the authors state that the level of direct benefit received from water quality improvements also affected the amount of stated WTP by farmers.

It can be argued that the producers are motivated enough (either due to regulation threat or voluntarily) to pay for pollution control measures. Then, the contingent valuation approach becomes a relevant tool to extract the actual amount that an individual farmer is willing to pay to avoid harsh environmental regulations. For a non-market commodity like water pollution, this approach is a satisfactory technique to elicit the present value of a proposed policy even though Hoen and Randall (1987) assert that the approach as “not a flawless approach”.

The main concern with the contingent valuation approach becomes the development and framing of the questionnaire. The contingent valuation questions usually follow dichotomous choice responses where individuals are asked whether to vote (yes/no) for the proposed bid options (Herriges and Shogren, 1996). The dichotomous choice questions are found to be suffering from the anchoring effect (Herrisen and Shogren, 1996) drawing invalid conclusion.

With the anchoring effect in consideration, multiple bound questions gained popularity in the recent years (Welsh and Poe, 1998; Alberini, *et al.* 2003). The multiple bound questions provide a list of bid amounts from where a respondent chooses to represent his WTP value. Some authors argue that providing a list of alternative bids reduces the focus of respondents on

single bid or sequential bids and therefore reduces the anchoring effect (Whitehead, 2002; Roach and Boyle, 2002; Rowe *et al.*, 1996). In addition, literature also established that the double and multiple bound questioning approaches increase the efficiency of parameter estimates (Whitehead 2002; Alberini *et al.* 2003).

In double and multiple bound questions, given the dichotomous type response, logit or probit models have mostly been used in contingent valuation studies (Whitehead *et al.*, 2001). Alberini *et al.* (2003) used a random effect logit model to estimate the WTP value from the multiple bound contingent valuation technique. The main goal of the study however, was to understand questionnaire design rather than estimating the expected value of WTP for open-water fishing.

Brox *et al.* (2003) estimated willingness to pay to improve water quality and allowed a non-response bias in the model. The respondent's WTP value was elicited using the payment card approach and heckman's two step model was employed to correct the observed sample selection bias. Urama and Hodge (2006) estimated WTP for mitigating soil and water degradation problems focusing on the effect of education on WTP values.

Similarly, Whitehead (2002) employed random effect probit models on double, triple and multiple bound questions. The precision of WTP value increased with multiple bond questions in the contingent valuation approach (Whitehead, 2002). Whitehead focused that the double bound questionnaire format provided better estimates for true WTP when a starting value of an individual's bid is difficult to assign to represent the distribution of WTP values. Roach *et al.* (2002) also claimed an increased efficiency in parameter estimates with multiple bound questionnaire setting.

Along the vein of Whitehead (2002), providing starting value of WTP to the broiler producers while eliciting WTP becomes relatively difficult since no guideline exists to suggest potential value that an individual would be willing to pay. Due to such facts and also because of the anchoring effect in a single bound question, a multiple bound question format was found to be attractive in this study.

III. MODEL

Economic Model for WTP

A rational broiler producer (i) is expected to choose a combination of market goods (z) and water pollution control measures to maximize utility given a limited budget (M). A simple utility function that accommodates an environmental component, the respondent's demographic characteristics, net income, as well as a payment vehicle defines the broiler producers' preferences over market goods and environmental quality. Given the utility framework, an individual's utility function is explained by;

$$U^l = U(\mathbf{Z}, M - T^l, Q^l) \quad (5.1)$$

The M represents the individual's household income, which includes farm as well as off farm income net of existing tax. \mathbf{Z} represents a vector of variables describing the characteristic of individuals as well as their farm. T^l is the change in tax under the proposed water pollution reduction policy and Q^l represent of water quality level under current condition or proposed policy.

Hanemann (1984) developed a utility theoretical framework to derive WTP and WTA from a dichotomous choice discrete response in contingent valuation studies. Based on Hanemann's argument, let's assume two possible levels of water quality represented by $l =$

$(0, 1)$. $l = 0$ represents an initial or the existing level of water quality whereas, and $l = 1$ represents the level of improved water quality.

At the status quo of no water pollution reduction effort, the broiler producers receive utility $U^0 = U(\mathbf{Z}, M, Q^0)$. For water quality at the the current conditions since no changes in payment are required, the T^l becomes zero. Accordingly, for proposed policy, a change in net income is expected which changes the utility function as $U^1 = U(\mathbf{Z}, M - T^1, Q^1)$. This represents the broiler producer's utility function with improved water quality and change in net income through change in tax (T^1).

Hanemann (1984) argues that an individual know his/her utility function while it is unknown to the researchers. Therefore, an individual's utility function is consisted of empirically measureable component $V(\cdot)$ and stochastic econometric error ε^l . Thus, individuals' standard utility functions with (equation 5.2) and without (equation 5.3) proposed change are expressed as;

$$U^1 = V(\mathbf{Z}, M - T^1, Q^1) + \varepsilon^1 \quad (5.2)$$

$$U^0 = V(\mathbf{Z}, M, Q^0) + \varepsilon^0 \quad (5.3)$$

It is assumed that broiler producers compare the utilities under current (equation 5.3) and proposed water quality and net income scenario (equation 5.2). The underlying reasoning of the individual's choice of whether to maintain status quo of no water pollution or undertake a water pollution control measures to improve water quality is based on the following condition;

$$V(\mathbf{Z}, M - T^1, Q^1) + \varepsilon^1 \geq V(\mathbf{Z}, M, Q^0) + \varepsilon^0 \quad (5.4)$$

The model implies that an individual compares the proposed improvement on water quality and change in net income, with current condition, and evaluates the difference on utilities under both of the plans. It is assumed that the individual then decides whether to pay or how

much to pay for the proposed program so as to keep the utility level unchanged (negligibly changed). The difference in utility under current and proposed conditions can be expressed as;

$$\begin{aligned}
 dU &= V(\mathbf{Z}, M - T^1, Q^1) + \varepsilon^1 - V(\mathbf{Z}, M, Q^0) + \varepsilon^0 \\
 &= V(\mathbf{Z}, M - T^1, Q^1) - V(\mathbf{Z}, M, Q^0) - (\varepsilon^0 - \varepsilon^1) \\
 &= dV - (\varepsilon^0 - \varepsilon^1)
 \end{aligned} \tag{5.5}$$

Where the errors ε^0 and ε^1 are assumed to be identically and independently distributed with zero means.

Econometric Models for WTP

a) Ordered Response Model

It is assumed that the broiler producers compare the proposed water quality improvement with the existing water quality. They, then assess the difference in utility from the two water quality levels. The individual producers then define their utility difference in terms of WTP. Based on this criterion, an individual respondent decides the amount of dollars that he/she is willing to pay.

The broiler producers are given three payments intervals (less than \$300; \$300-\$500; and greater than \$500) and asked where their WTP value falls. Suppose the payment levels are represented by an ordinal scale j . If the respondents' WTP value is below \$300 then j takes a value of 1; if the utility difference falls within \$300 and \$500, j is 2; and if the WTP value is greater than \$500 then j takes the value of 3. The data allows estimation of parameters using probit models (Boccaletti and Nardella, 2001; Jin *et al.*, 2008).

For econometric purpose, the latent value of WTP takes the three values as follows (Johnston, 1999; Jin *et al.*, 2008);

$$WTP_i = 1 \quad \text{if} \quad WTP^* \leq \gamma_1$$

$$\begin{aligned}
WTP_i &= 2 & \text{if } \gamma_1 < WTP^* \leq \gamma_2 \\
WTP_i &= 3 & \text{if } WTP^* > \gamma_2
\end{aligned} \tag{5.6}$$

Where γ represents unobserved threshold parameters that outline the interval where utility difference falls and the WTP^* represents the utility difference. The γ_j determines the boundary where the value of WTP map into the given differences in utility (Davidson, 1993).

Let the WTP^* is defined by;

$$WTP_i^* = \mathbf{Z}_i \boldsymbol{\beta} + \varepsilon_i \tag{5.7}$$

$$\begin{aligned}
\mathbf{Z}_i \boldsymbol{\beta} &= \beta_0 + \beta_1 \text{highschool} + \beta_2 \text{collage} + \beta_3 \text{offincome} + \beta_4 \text{age} + \beta_5 \text{litterland} \\
&\quad + \beta_6 \text{contact} + \beta_7 \text{perception}
\end{aligned}$$

Where, the stochastic error ε_i is assumed to have standard normal distribution with mean zero and variance of one. The errors are assumed to be independent and identically distributed. The $\boldsymbol{\beta}$ represents a vector of parameters to be estimated and \mathbf{Z}_i represents a vector of individual as well as farm characteristics.

Now based on the equations 5.2 to 5.7 the probability that the utility difference falls in a given interval of WTP value is expressed as;

$$\begin{aligned}
P(WTP_i = 1) &= P(WTP_i^* < \gamma_1) \\
&= P(\mathbf{Z}_i \boldsymbol{\beta} + \varepsilon_i < \gamma_1) \\
&= P(\varepsilon_i < \gamma_1 - \mathbf{Z}_i \boldsymbol{\beta}) \\
&= \Phi(\gamma_1 - \mathbf{Z}_i \boldsymbol{\beta})
\end{aligned}$$

Similarly, the probability that $y_i = 2$ is;

$$\begin{aligned}
P(WTP_i = 2) &= P(\gamma_1 \leq WTP_i^* < \gamma_2) \\
&= P(\gamma_1 \leq \mathbf{Z}_i \boldsymbol{\beta} + \varepsilon_i < \gamma_2) \\
&= P(\varepsilon_i < \gamma_2 - \mathbf{Z}_i \boldsymbol{\beta}) - P(\varepsilon_i < \gamma_1 - \mathbf{Z}_i \boldsymbol{\beta})
\end{aligned}$$

$$= \Phi(\gamma_2 - \mathbf{Z}_i\boldsymbol{\beta}) - \Phi(\gamma_1 - \mathbf{Z}_i\boldsymbol{\beta})$$

And the probability that $y_i = 3$ is;

$$\begin{aligned} P(\text{WTP}_i = 3) &= P(\text{WTP}_i^* \geq \gamma_2) \\ &= P(\mathbf{Z}_i\boldsymbol{\beta} + \varepsilon_i \geq \gamma_2) \\ &= P(\varepsilon_i \geq \gamma_2 - \mathbf{Z}_i\boldsymbol{\beta}) \\ &= \Phi(\mathbf{Z}_i\boldsymbol{\beta} - \gamma_2) \end{aligned} \quad (5.8)$$

where, P is probability operator. Provided all these probability density functions for ε_i , the unknown model parameters can be estimated by maximizing the following log likelihood function;

$$\begin{aligned} \ell(\gamma_1, \gamma_2, \boldsymbol{\beta}) &= \sum_{\text{WTP}_i=1} \log[\Phi(\gamma_1 - \mathbf{Z}_i\boldsymbol{\beta})] + \sum_{\text{WTP}_i=2} \log[\Phi(\gamma_2 - \mathbf{Z}_i\boldsymbol{\beta}) - \Phi(\gamma_1 - \\ &\quad \mathbf{Z}_i\boldsymbol{\beta})] + \sum_{\text{WTP}_i=3} \log[\Phi(\mathbf{Z}_i\boldsymbol{\beta} - \gamma_2)] \end{aligned} \quad (5.9)$$

The effects of changes in explanatory variables on the probability of WTP falling in a given range are not explained by the estimated coefficients (Greene, 2008) in case of probit/logit models. It is therefore, the effects of explanatory variables are expressed in terms of marginal effects which can be derived as follows;

$$\begin{aligned} \frac{\partial P(\text{WTP}=1|z)}{\partial z} &= -\phi(\mathbf{Z}_i\boldsymbol{\beta})\boldsymbol{\beta} \\ \frac{\partial P(\text{WTP}=2|z)}{\partial z} &= (\phi(-\mathbf{Z}_i\boldsymbol{\beta}) - \phi(\gamma - \mathbf{Z}_i\boldsymbol{\beta}))\boldsymbol{\beta} \\ \frac{\partial P(\text{WTP}=3|z)}{\partial z} &= \phi(\gamma - \mathbf{Z}_i\boldsymbol{\beta})\boldsymbol{\beta} \end{aligned} \quad (5.10)$$

The marginal effect is the slope of curve that relates an explanatory variable to $P(\text{WTP} = j|z)$ controlling the effects of other variables (Long, 1997).

b) Interval Regression Model

The boiler producer's WTP value in this study is coded by an interval where an individual's latent value y_i^* falls. The upper and lower limits of the interval are known to the respondent as well as to the researcher. Such data collection approach replaces the unknown γ by known cell limits, a_1 and a_2 and define WTP as in equation 5.11. Wooldridge (2002) suggests an interval regression to estimate $E(y^*|\mathbf{z})$ when the upper and lower limits of the intervals are known (Whitehead *et al.*, 2001; Doorslaer and Jones, 2003). Instead of estimating β and γ as in ordered logit/probit model, the interval regression estimates the parameters β and σ^2 , where $\sigma^2 = Var(WTP^*|\mathbf{z})$. The model assumes $y^*|\mathbf{z} \sim \text{Normal}(\mathbf{z}\beta, \sigma^2)$ instead of standard normal for probit and logistic for logit regressions.

The likelihood function given in equation 5.9 changes into the following form when the upper and lower limits of the interval are known.

$$\begin{aligned} \ell(\beta, \sigma^2) = & \sum_{WTP_i=1} \log \left[\Phi \left(\frac{a_1 - \mathbf{z}_i\beta}{\sigma^2} \right) \right] + \sum_{WTP_i=2} \log \left[\Phi \left(\frac{a_2 - \mathbf{z}_i\beta}{\sigma^2} \right) - \Phi \left(\frac{a_1 - \mathbf{z}_i\beta}{\sigma^2} \right) \right] + \\ & \sum_{WTP_i=3} \log \left[\Phi \left(\frac{\mathbf{z}_i\beta - a_2}{\sigma^2} \right) \right] \end{aligned} \quad (5.11)$$

IV. DATA

The third section of the data provide three bid categories where broiler producer's willingness to pay values falls. The multiple bound questionnaire setting seems appropriate in this context at least for the following two reasons;

- The tendency of yea saying to the given value even though the true WTP is less/greater than the provided can be reduced (Roach *et al.* 2002),
- The double and multiple bounded dichotomous choice models provide better parameter estimates than the single bounded model (Whitehead, 2002; Hanemann, *et al.* 1991).

The individuals' chosen WTP is assumed to represent the amount that the broiler producers were willing to pay if the money would be implemented on pollution abatement. The amount is elicited in dollars per flock. The amount per flock is asked as there is too much asset specificity in broiler production and an integrator makes decision on whether to put more birds or not after each flock based on the performance of broiler producers (Vukina and Leegomonchai, 2006).

Explanatory Variables

It is assumed that individuals gain utility both from water quality improvements as well as from his/her net income. The observable characteristics that have positive/negative impact on an individual's preferences for water quality control measures include socioeconomic as well as farm characteristics.

Farmer's demographic characteristics play a major role in the decision associated with water pollution and environmentally friendly production practices. Based on previous studies, respondent's *Age* is one of the important factors to impact the WTP decision (Hanemann, 1991). The age measures the producer's age at the time of data collection and is found to have mixed effect.

Koundouri *et al.* (2006) found the age of the respondent affected the willingness to invest on producing better environment quality, negatively. Younger farmers were more knowledgeable and more risk taking due to a longer planning horizon and therefore, were more likely to participate in environmentally friendly agricultural practices in a study conducted by Adesina and Zinnah (1993). The argument is also supported by Brox *et al.* (2003).

Level of education and contact with extension agents are employed to capture the effect of information effect on WTP value. The producers who have better information on issues and

importance of water quality through education are more likely to contribute toward environmental practices (Koundouri *et al.*, 2006). As Hite *et al* (2002) suggested that farmers have propensity not to believe their existing production practices contribute to a water pollution problem. Therefore, the education through school or through contact with extension agents becomes crucial factors determining the level of WTP value. Education is measured in three categorical variables (high school or lower, college, and graduate degree) represented by two dummy variables in the regression model.

In addition the farmers who have visited extension agents and talked about farmer's contribution to water pollution are more likely to contribute to water pollution control measures. Exposition of individual producers to the extension services is believed to generate awareness about ongoing nutrient pollution issues in the local areas. The variable is assumed to have positive effect on WTP value. Contact with extension agents was constructed using the information obtained indicating whether an individual has visited the extension agents in last year. The variable is then used as proxy for his/her general contact with the extension service providers.

The respondents were also asked about their perception regarding the necessity of water pollution control measures or regulations. Individuals' responses are recorded using a Likert scale, where five represents an individual strongly agrees with the statement "water pollution control measures and regulation are badly needed". Brox *et al.* (2003) also measured the perception about existing water quality on a WTP study using the Likert scale and treated as a continuous variable. The perception about existing water quality significantly increased the willingness to pay on their study. Similarly, the broiler producers who believed the water

pollution control measures and regulations are badly needed are assumed to state higher WTP value.

Farmers' off-farm income represents whether the principal operator (owner) of a broiler farm has income from other jobs except from broiler production. The individuals who have off-farm income are not constrained to remain on the business by paying an extra amount for water pollution control. Therefore, the individuals with off-farm income are believed to pay a lower amount as compared to the ones who solely depend on broiler production to generate household income. Gillespie *et al.* (2007) finds the farmers with off-farm income are less responsive to water pollution control measures.

Land available to litter application represents the total acreage available to spread the broiler litter on individual's land. Smaller area to litter application implies higher nutrient concentration and runoff to the surface water or transportation litter. In order to avoid a fear of governmental regulations and the problems associated with litter transportation; these producers are likely to pay more in the form of pollution abatement tax. Therefore the variable is assumed to be negatively related to the WTP amount.

V. RESULT AND DISCUSSION

Producer's WTP function is estimated using ordered probit and interval regression approaches. A summary statistics of the variables used in the analysis are presented in table 5.1. Nearly 69 percent of the farmers hold only a high school degree. About 24 percent were college degree holders and only 7% of the broiler producers have graduate level education. Similarly, about 32% of the broiler farmers had off farm income. More than 60% of the farmers had contact with extension agents in previous year. On an average, 46% of the total land is used to spread broiler litter.

Table 5. 1: Summary statistics for the variables used

Variables	Std.			
	Mean	Dev	Min	Max
High school degree =1	0.689	0.466	0	1
College degree =1	0.243	0.432	0	1
Graduate degree =1	0.068	0.253	0	1
Individual has off farm income =1	0.324	0.471	0	1
Age of farmer at the time of survey	53.284	12.184	25	79
Percentage of total land, where litter is usually applied	0.460	0.489	0	3.125
Individual has contact with extension agents	0.608	0.492	0	1
Perception that "Water pollution control measure is badly needed" in the scale of 1-5	3.775	1.124	1	5

Table 5.2 presents the estimated coefficients and their standard errors obtained from maximizing the two equations at 5.9 and 5.11. The model significance and the R square values are also presented at the end of table 5.2. Table 5.3 presents the marginal effects along with their standard errors. The ordered probit model is significant at 0.069 percent. Socioeconomic or the demographic variables such as age, education, and incomes are included in the model in order to capture the variability in individual-specific characteristics.

Most of the demographic variables are significant with expected signs, while the perception of an individual regarding the water quality regulations shows no effect on WTP amount. The perception about existing water quality showed no significant effect on willingness to pay to improve minor water quality problems in a study conducted by Brox, *et al.* (2003). However, the same study showed a significant effect of the perception on WTP value, while the proposed policy addressed major water quality problems.

Table 5.2: Parameter estimates using ordered response models on stated WTP range¹⁴

Independent Variables	Ordered probit	Interval regression
	Coefficients	Coefficients
College degree = 1	1.024** (0.455)	98.228** (43.829)
Graduate degree = 1	1.248** (0.518)	133.624** (58.375)
Individual has off farm income =1	-1.005** (0.500)	-90.939*** (36.179)
Age of farmer at the time of survey	0.043** (0.020)	3.484** (1.451)
Percentage of total land, where litter is usually applied	-0.771 (0.553)	-53.945* (30.455)
Individual has contact with extension agents	0.231 (0.363)	18.124 (35.654)
Perception that "Water pollution control measures are badly needed" scale of 1-5	-0.075 (0.149)	-0.921 (16.073)
constant		86.943 (115.019)
γ_1	2.443 (1.323)	
γ_2	3.816 (1.329)	
Number of observations	59	59
Pseudo R square	0.217	0.203
Prob. > F	0.069	0.0001

Note: *, ** and *** represents the significance level at 0.10, 0.05 and 0.01 respectively.
The numbers in parenthesis are robust standard errors.

¹⁴ Due to small sample and significant number of missing observation in each category j , the model became inestimable when "Respondent's income" was allowed in the model.

The insignificant effect of water quality perception and the need of regulation originate from the fact that the agricultural producers fail to realize their production practices contribute enough to cause a water pollution problem (Hite *et al.* 2002). Thus, the producers' WTP value may not be affected by the perception of water quality if the producers perceive water quality problems as minor (Brox, *et al.*, 2003).

It is assumed that farmers with higher education are knowledgeable about the negative impact of water pollution on human health as well as on the natural ecosystem (Urama and Dodge, 2006). Therefore, the educated producers are more responsive to water pollution control measures. As expected the result indicated the individuals with higher education tend to pay greater amounts for water pollution control measures as compared with individuals having less than a high-school degree. Both dummy variables for education; the *college degree* and *graduate degree*, are significant at 0.05 and 0.01 percent level of significance.

The marginal effects (table 5.3) of education levels show a negative effect on the first level of WTP, while it is positive for higher WTP values (level 2 and 3). Thus, the individuals who hold either a college or higher degree are willing to pay more for water control measures than those with only a high-school degree at most. For individuals with graduate degree, the probability of paying <300 decreases by 0.465, however, probability of paying \$300-500 and >\$500 increases by 0.285 and 0.180 respectively (However, the variable is significant at 0.16 for WTP value >\$500).

Individual farmers who have off-farm income significantly increases the probability of paying less dollars (<\$300) for pollution control measures. At the same time, having off-farm income decreases the probability of paying higher WTP. The result showed that the probability of choosing WTP less than \$300 is 0.280 greater for individuals with off-farm income as

compared to the ones without off-farm income. In contrary, the probability of stating WTP in between \$300 and \$500 is 0.239 lower for individuals with off-farm income as compared to the ones without the off-farm income.

Table 5.3: Marginal effects of ordered probit models on stated WTP ranges

Variables	Marginal Effects			Mean
	P(WTP=1)	P(WTP=2)	P(WTP=3)	
College degree =1	-0.366** (0.155)	0.271** (0.117)	0.095 (0.068)	0.254
Graduate degree =1	-0.465*** (0.176)	0.285*** (0.104)	0.180 (0.124)	0.068
Individual has off farm income =1	0.280*** (0.102)	-0.239*** (0.096)	-0.041 (0.027)	0.305
Age of farmer at the time of survey	-0.014** (0.006)	0.012*** (0.006)	0.002 (0.002)	52.966
Percentage of total land, where litter is usually applied	0.251 (0.169)	-0.210 (0.151)	-0.041 (0.033)	0.464
Individual has contact with extension agents	-0.074 (0.115)	0.062 (0.096)	0.012 (0.020)	0.627
Perception that "Water pollution is badly needed" in the scale of 1-5	0.024 (0.049)	-0.020 (0.042)	-0.004 (0.008)	3.746

Note: *, ** and *** represents the significance level at 0.10, 0.05 and 0.01 respectively. The numbers in parenthesis are robust standard errors.

Age is an important variable contributing toward WTP decision (Brox, *et al.*, 2003). Age is positively associated with the likelihood of environmentally friendly management practices (Gillespie *et al.*, 2007). At the same time, it is also found that the older individuals tend to spend less on water pollution control measures (Brox, *et al.*, 2003). The result of this study showed age is significantly and negatively associated with the choice of less than \$300 as their WTP value. However, the probability of paying a larger amount (WTP in between \$300 and \$500) for water

quality control measure increases with age. A ten year increase in respondent's age increases the probability of paying in between \$300 and \$500 by 0.12 and decreases the probability of paying less than \$300 by 0.14. Thus, older individuals are willing to spend more on water quality control measures, similar to the finding of Gillespie *et al.* (2007). The result showed individuals who have contacted the extension agent in the past year tend to pay more for water pollution control measures. However, the estimated parameter is not statistically significant.

As the WTP value on data represented an interval where the true WTP falls, an interval regression was also employed (Whitehead, *et al.* 2001). The interval regression is similar to the ordered logit model when the threshold values are known to the researchers. The conclusion using interval regression is not different from that using the ordered probit model. All the variables significant on the ordered probit model are also significant on interval regression model. Additionally, the parameters have the same signs in both models.

The effects of variables are interpreted as in case of ordinary regression. An individual with a graduate degree pays about \$98 more than the counterpart with only high-school degree. Similarly, one year older broiler producers pay \$3.48 more to control nutrient pollution control measure.

Employing the ordered logit model for WTP, the threshold parameters are not allowed to vary depending on the respondent's farm as well as individual characteristics. Effectively, separate equations are run for each of the WTP categories with the assumption that the slope parameters are same among the equations but not the intercepts. With this parallel regression assumption, the estimated coefficients are similar in each equation.

However, the assumption may not be unrealistic if the stated WTP varies based on the explanatory variables. The estimated parameters may lead to incorrect, incomplete and

misleading results (Williams, 2006). A Wald test for the parallel regression assumption is used in order to examine whether the slope coefficients differ for each category of stated WTP.

Table 5.4: Coefficient estimates using generalized ordered probit model

Variables	Coefficients	Coefficients
	P(WTP=1)	P(WTP=2)
College degree =1	1.087** (0.478)	1.087** (0.478)
Graduate degree	1.440*** (0.522)	1.440*** (0.522)
Individual has off farm income =1	-0.949* (0.530)	-0.949** (0.530)
Age of farmer at the time of survey	0.035* (0.020)	0.035** (0.020)
Percentage of total land, where litter is usually applied	-0.933* (0.576)	-0.933* (0.576)
Individual has contact with extension agents	0.106 (0.379)	0.106 (0.379)
Perception that "Water pollution is badly needed" in the scale of 1-5	-0.199 (0.163)	0.960* (0.570)
constant	-1.492 (1.375)	-7.844*** (2.762)
Number of observations	59	
Pseudo R square	0.28	

Wald χ^2 (Prob. > χ^2) 18.66(0.016)

Note: *, ** and *** represents the significance level at 0.10, 0.05 and 0.01 respectively.
The numbers in parenthesis are robust standard errors.

The Wald test statistics (Chi square with 6 df = 19.57) was significant indicating violation of the parallel regression assumption. Further analysis detected that the perception about the need for environmental regulation violated the assumption. Therefore, a generalized

ordered probit model is employed to relax the parallel regression assumption only for the perception variable. The estimated coefficients and their standard errors obtained generalized ordered logit are presented in Table 5.4.

Now, the perception variable is allowed to have different effects on different categories of stated WTP values. The result showed that individuals' perception significantly and positively affected the likelihood of paying higher amounts (\$300 to \$500) for water pollution control and decreased the probability of paying less (< \$300). However, the effect of the perception is not statistically significant for the WTP category < \$700

Table 5.5: Marginal effects estimated from the generalized ordered probit model

Variables	Marginal Effects		
	P(WTP=1)	P(WTP =2)	P(WTP =3)
College degree =1	-0.386*** (0.160)	0.356*** (0.140)	0.030 (0.048)
Graduate degree	-0.528*** (0.163)	0.438*** (0.154)	0.090 (0.098)
Individual has off farm income =1	0.263*** (0.109)	-0.255** (0.109)	-0.008 (0.013)
Age of farmer at the time of survey	-0.011* (0.006)	0.011* (0.006)	0.000 (0.001)
Percentage of total land, where litter is usually applied	0.301* (0.172)	-0.290* (0.170)	-0.011 (0.018)
Individual has contact with extension agents	-0.034 (0.120)	0.033 (0.116)	0.001 (0.005)
Perception that "Water pollution is badly needed" in the scale of 1-5	0.064 (0.054)	-0.075 (0.056)	0.011 (0.014)

Note: *, ** and *** represents the significance level at 0.10, 0.05 and 0.01 respectively.
The numbers in parenthesis are robust standard errors.

In addition, the generalized ordered probit model showed the portion of land available for litter spreading significantly affects the WTP value (the variable was not significant with ordered probit specification). So, having a larger portion of land to spread broiler litter increases the likelihood of a paying less for pollution abatement and decreases the probability of choosing to pay higher amount (\$300 to \$500). The farmers spread broiler litter as fertilizer for crops production, the crops demand for fertilizer may utilize a larger portion of poultry litter (if not all produced by broiler production practices) and therefore less pollution runoff. The individuals with a larger portion of land available for litter application believe the pollution runoff should not be a problem for their land. Thus, their production practices doesn't contribute enough nutrient pollution to pollute the nearby water sources. Therefore, these farmers are less likely to pay a larger amount for water quality control measures.

The mean WTP value was calculated using the parameter estimates from the interval regression model. The estimated average WTP value that a broiler producer would like to pay in order to control water pollution is \$260.955.

VI. CONCLUSION

The broiler production is operated by farmers where the integrators provide chicks and feed to the producers and the producers raise chicks to marketable weight. The farmers are paid based on performance which depends on production efficiency and the integrators take the responsibility of marketing final product. However, none of the beneficiaries takes the responsibility of litter management to reduce excess nutrient flow. Such fact forces the government to regulate the broiler production in order to reduce the inverse effect of meat production on environment. In fact the broiler production is under a threat of stringent government regulation (MacDonald, 2008) which, Segerson and Miceli (1998) believe, is

important to protect the environmental quality. Therefore, the concept of punishing/charging CAFOs and AFO if it fails to meet the desired level of pollution abatement efforts seems important to mitigate nutrient pollution contributed by broiler producers.

The question of “how much” and “what should be considered” before setting up a standard payment level, remains vague. In this study, I evaluated the concept of providing negative incentives for polluters to enforce pollution control efforts on their production decision. A contingent valuation approach is employed to examine the affordability (or willingness to spend on water pollution control measures) of the farmers based on socioeconomic as well as farm level information. Result indicated that the broiler producers are willing to pay about \$260 per flock per year as pollution abatement cost. This compares to almost 20% of their net profit from broiler production per flock in Louisiana.

The value will be useful at the policy level to understand the amount that a farmer is willing to pay/bear for pollution control measures above which an incentive level can be fixed to enforce environmentally friendly production practices. This will reduce the adverse effect of higher incentive payment on production practices. For example, larger incentive payments provided to help reduce pollution may divert producers’ interest from production toward receiving subsidy. This will also reduce the government expenditure on incentive payments. Thus, the policy instruments such as a pollution abatement tax that are levied beyond the farmers, WTP value may reduce cost to the government and unintended effect of incentive payment on production decision.

One drawback in this study is the failure of the ordered logit model to estimate the dollar amount that an individual can afford to reduce the negative impact of his/her production practices. The returned survey did not produce enough observations to use an individual’s dollar

value of WTP. Therefore, WTP value is measured using intervals where the individual's true values may fall. As this study is based on farmers' value of the better environment, lack of complete information about the negative effects of pollution on the health and ecosystem and enough knowledge about the proposed tax policy may have resulted into failing to provide the exact amount of WTP value.

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CHAPTER SIX

CONCLUSION

The large volume of litter produced by confined broiler production forces excessive use of broiler litter on available crop and pasture land producing adverse effects on human as well as the ecosystem. The negative economic incentives associated with litter transportation and litter management forces broiler producers to intensify the repetitive application exacerbating the nutrient accumulation and runoff.

The broiler producers in Louisiana fail to accommodate pollution reduction effort on their production decision mainly due to the byproduct nature of pollution production and externality nature of water pollution. In addition, the producers fail to realize their production process contributes enough nutrient pollution to nearby water-bodies. The producers thus, hesitate to contribute toward the pollution control programs (Hite, *et al.* 2002; Poe *et al.*, 2003). Thus, the issue of how to best manage agricultural nutrient runoff becomes an important concern mainly among policy makers.

Economists advocate the economic tool is the most cost effective approach to mitigate the harmful effects of nonpoint source pollution (Freeman, 2003). Accordingly, my dissertation evaluated economic aspects of three litter management options to reduce nutrient pollution originated from broiler productions. Lyon and Maxwell (2002) support the presumption that voluntary adoption of environmentally friendly production practices is socially beneficial as compared to others. However, the adoptions of such practices (BMP) have been very slow, questioning the effectiveness of the voluntary effort to mitigate water pollution.

The first chapter of this dissertation evaluated the factors contributing to the slow diffusion of the voluntarily adopted BMPs. It is true that the adoption of a single BMP may suffice to reduce water pollution and may not require another approach for some farms. For

others, using a BMP may not reduce pollution production to desired levels and require other practices to be adopted as the complements. An implementation of a second practice thus depends on the characteristics of previously adopted practices and level of pollution reduction from the first one. These characteristics of BMP adoptions require an in-depth understanding of the effect of previously adopted practices before intending to adopt another one. The result of this study also supports the argument by showing an existence of dependence among multiple BMP adoptions.

On evaluating the factors supporting/hindering the adoption of BMPs, this study found a significant correlation among the multiple BMPs adopted by an individual. Therefore the conditional frailty model that allows for such correlation is employed to obtain consistent and efficient parameter estimates in the presence of event dependence and shared individual characteristics. The result from first chapter showed a presence of individual level heterogeneity and /or correlation among multiple BMP adoptions. The larger variance of the random effect parameter either originated from event dependence or individual specific characteristics shared among the adoptions by an individual producer. Therefore, the study also implies that a deep understanding of how the adoption of a BMP affects the adoption of another BMP while designing policy tools and strategies to encourage voluntary/mandatory BMP adoptions.

The adoption of BMPs in Louisiana shows an initial stage of “S” shaped pattern of technology adoption where the number of adoption significantly increased after the year 1992. As the theory of technology transfer suggests, the rate of BMP adoption increased once the producers became more informative about the BMPs, either through neighbors, extension educations or through the advertisement. The result supports the argument showing that the more informed farmers, through school education and/or contact with extension agents, adopt BMPs

faster than their counterparts. Thus, farmers' education through extension services and the programs such as master farmer programs become important factors to be considered in order to increase the rate of BMP adoptions.

At the same time, the existing studies claim that the voluntary practices are effective only if implemented as complementary to other pollution reduction approaches such as environmental regulation or standards. This requires a search for other alternative pollution reduction mechanisms in order to obtain desired level of pollution reduction. In this regards, this dissertation evaluated two other economic tools to enforce broiler producers to participate on the pollution reduction goals. The fourth and fifth chapter evaluated the factors associated with farmers' desire to participate in pollution reduction programs.

The forth chapter focused on whether the broiler producers are willing to participate on production termination program to mitigate water pollution and what would be the incentive level that suffices to encourage farmers to participate in the programs. It assumes that the nutrient pollution can be reduced through terminating broiler production either full or partially. From the policy perspective, it provides an insight over the factors to be considered before setting up incentive payments that encourage broiler producers to cooperate with pollution reduction goal.

This study finds that the size of the farm, significantly affects the size of incentive payment, represented by the willingness to accept (WTA) value, desired by the broiler producers. The larger farmers are more serious about water pollution and potential regulations and thus state a lower WTA values to help reduce water pollution. Larger farmers are also found to be early adopters of BMPs and are willing to participate on production termination programs. This implies that the larger farmers are willing to cooperate with pollution reduction program. Larger

farmer are more responsive to water pollution regulation may be due to the fact that the CAFO and AFO regulations are harsh on the large farms and therefore, farmers like to avoid the consequence of dealing with the harsh environmental/governmental regulations.

On the other hand, the significant positive effect of perception that government should pay farmers to participate in pollution abatement programs suggested that a sufficient economic incentive is required to encourage farmers to participate in environmentally friendly production practices. Individuals with larger crop and pasture land to spread litter are less likely to terminate the production. In addition the analysis of willingness to pay study in chapter five showed that the individuals with larger crop and pasture land are willing to pay less for pollution control effort. Therefore, for these individuals, adopting BMP may become the low cost pollution control option.

Further, contact with extension agents and education are found to have positive effect on cooperating with the pollution reduction programs. Chapter three shows contact with extension agents increases the likelihood of adopting BMPs earlier than their counterpart; chapter five showed these individuals pay more dollars to improve water quality. The chapter four showed individual who know about the alternative approaches of pollution reduction are less likely to terminate the broiler production. This result suggests that the farmers are reluctant to terminate the production if alternative approaches are available. Chapter three that the farmers near to the age of retirement are hesitant to adopt BMPs. However, the older farmers are likely to pay more for water pollution control measures. Thus, the study implies that policy tools that require farmers to pay for pollution reduction are more effective with the older farmers.

Chapter four and five will be novel in the area of environmental economics in the sense that it incorporates the farmers' attitude toward nutrient pollution reduction programs.

Establishing the appropriate baseline incentive payment based on the farmers' anticipated amount to receive and pay to mitigate water pollution avoids the unintended negative consequences of governmental incentive payments. The estimated WTP and WTA values will serve as add-on to setting up incentive payments either as direct subsidy for producer to reduce the litter production through curtailing the broiler production or through paying pollution abatement cost. In addition, the incentive payments can also be established to enhance the BMP adoptions. Thus, the second section of this dissertation carries more weight when it comes to policy implication on setting up the incentive levels to encourage pollution reduction efforts. These chapters are important because very little is known about the broiler producers' attitude and willingness to participate in the pollution reduction programs. And the understandings of the factors that affect farmer's interest to participate in those programs are critical for the success of national and state level policy formulation in order to mitigate water pollution.

The third chapter will be novel in the area of BMP adoption as it allows the correlation among the multiple adoptions while evaluating the dissemination of pollution abatement best management practices. In fact, the adoptions of multiple BMPs are common in practice and the adoptions are interconnected with one another and tools that accounts for the interconnection among BMPs should be employed to examine the diffusion process of BMP to reduce nutrient pollution. The analytical process carries more weight because the process can be replicated to examine any kind of technology adoption to improve the profit level of farming operations.

This study does not provide insight into the magnitude of pollution reduction through the implementation of BMPs or through production termination. The questions such as how much pollution can be reduced by implementing a specific BMP is not addressed in this dissertation. Also, the question of how many flocks should be cut off to achieve desired level of water quality

is determined by the target water quality requirement in a given watershed, which is beyond the scope of this study. While using the estimated value of WTA representing incentive that the farmers need, one should be cautious about unintended effects of larger incentive on production termination. Examining the amount that the individuals are willing to pay (WTP) for reducing water pollution, this study suggests that the incentive payments can be established beyond the WTP. Doing so reduces the cost of pollution control for the government as well as the unintended adverse effect of larger incentive payments to the society and the environments.

The main shortcoming of this dissertation is the limited number of observation. Since the data was provided for the analysis, improving the response rate or the number of observation become outside the scope of this study. It should also be noticed that the standard errors of the estimated parameters are based on the small sample therefore, one should be cautious about the interpretation of the exact estimates. However, the methodology applied in this dissertation is well suited and can be applied in the similar studies in other fields.

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APPENDIX A: TREND IN MEAT CONSUMPTION

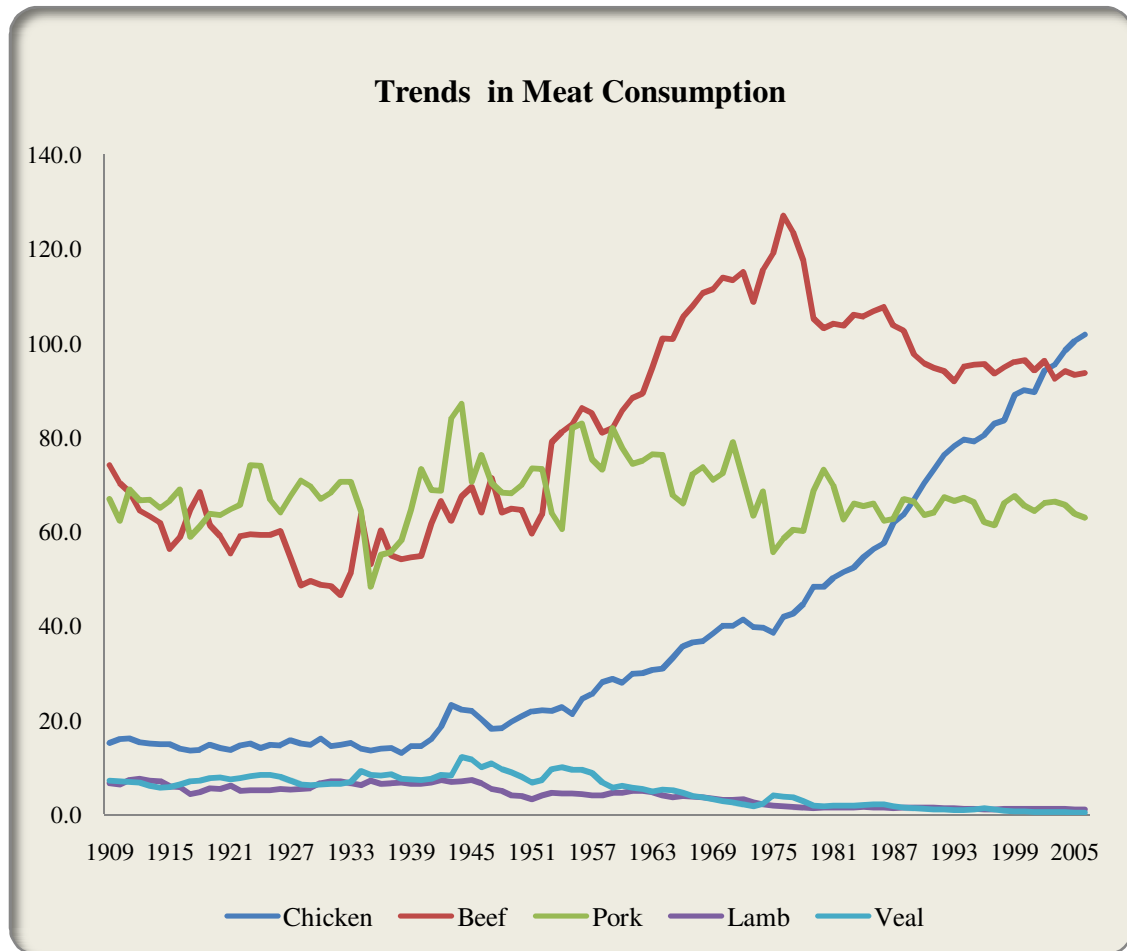


Figure A1: Trend in Meat Consumption Over Ninety Five years

Data Source: <http://www.ers.usda.gov/Data/FoodConsumption/spreadsheets/mtpcc.xls#carcass!a1>

APPENDIX B: PROPORTIONAL HAZARD RESIDUAL PLOTS AND TESTS

The probability of chi-square value is larger than 0.05 which implies that the proportional hazard assumption holds for each variable.

Table B1: Test of proportional-hazards assumption

Variables	rho	chi2	Prob>chi2
Broiler numbers	0.18352	1.53	0.2154
Experience	0.35913	5.93	0.0149
Education	-0.11799	0.57	0.4494
Age	0.09061	0.28	0.5973
Farm income	0.24339	1.92	0.166
Contd. after	-0.09532	0.53	0.4685
Ownership	0.19337	1.05	0.3057
Policy	-0.08272	0.3	0.5826
Contact with	-0.02069	0.02	0.9019
Global test		13.34	0.1478

The scaled schoenfeld residual are plotted to examine the assumption of Cox proportional hazard model. Few of them are listed on the following figure.

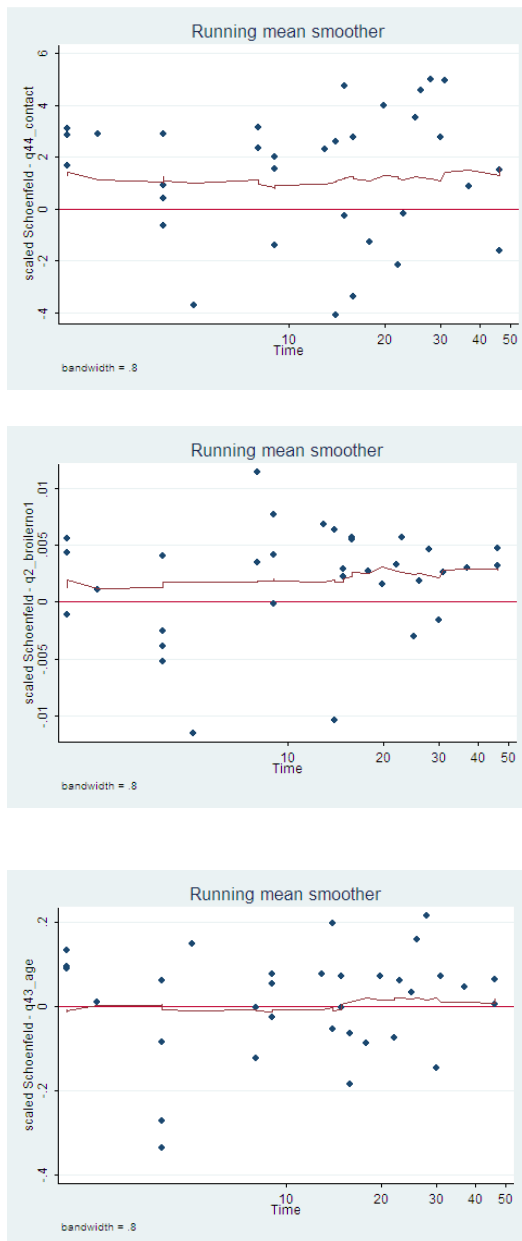


Figure B1: Residuals plots to check the whether the proportional hazard assumption hold for each variable used in the model.

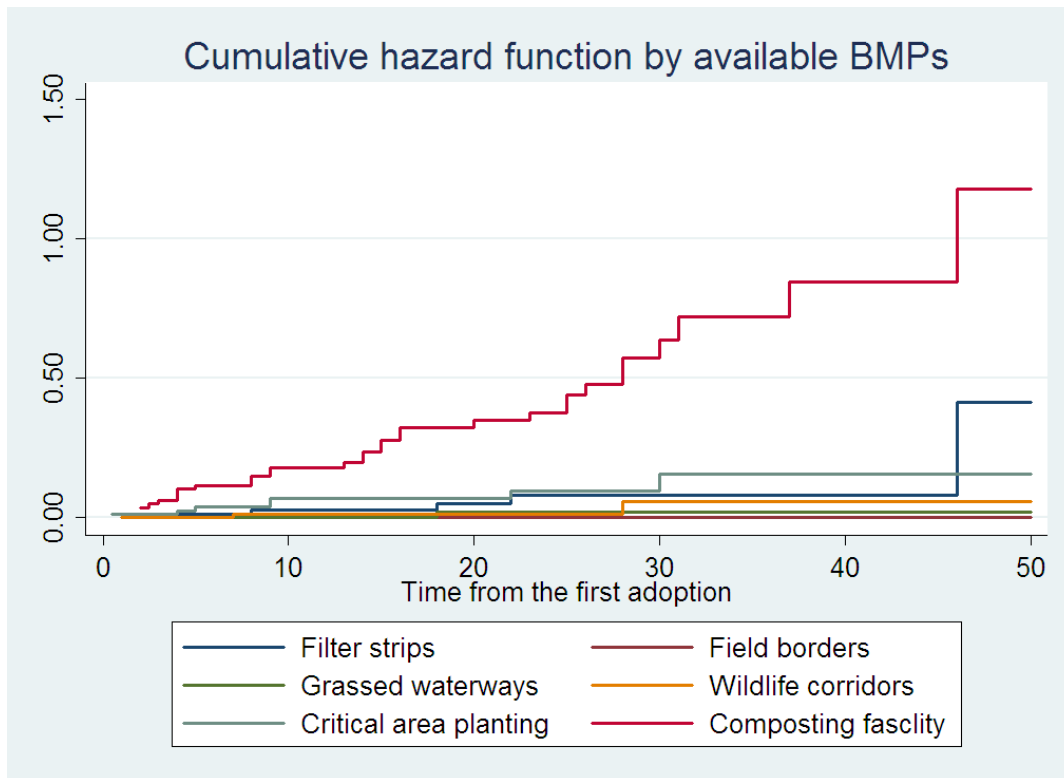


Figure B2: Nelson Aalen cumulative hazard function for BMP adoption differentiated by type of available BMPs

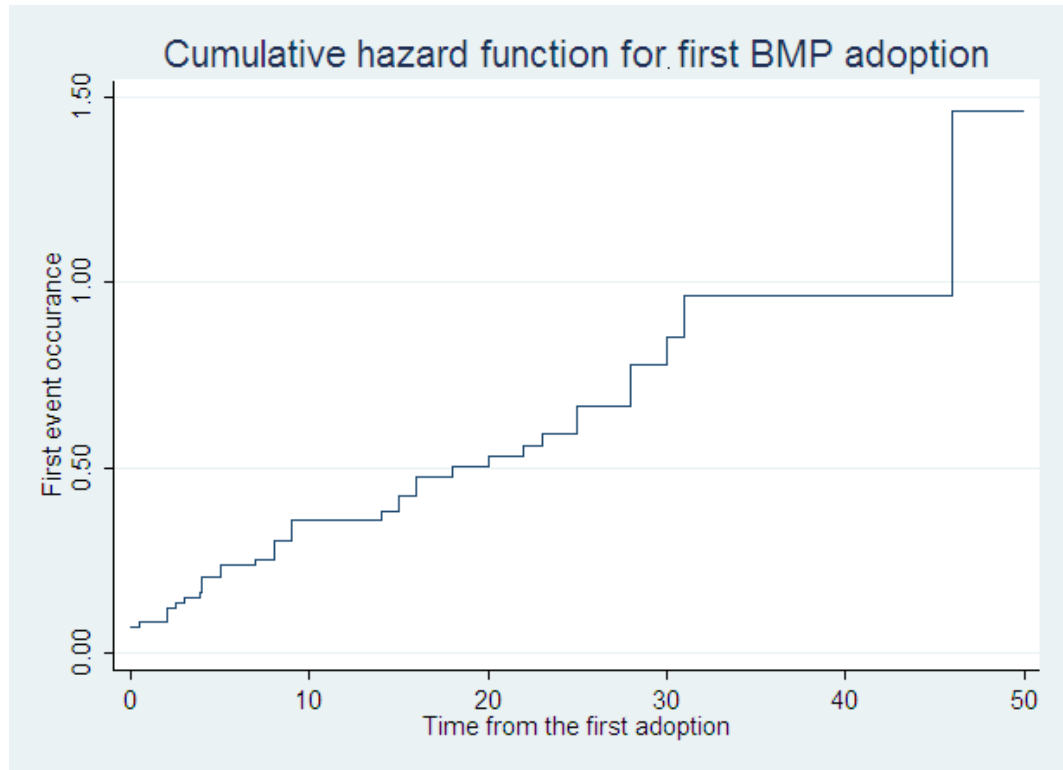


Figure B3: Nelson Aalen cumulative hazard function for first BMP adoption for an individual

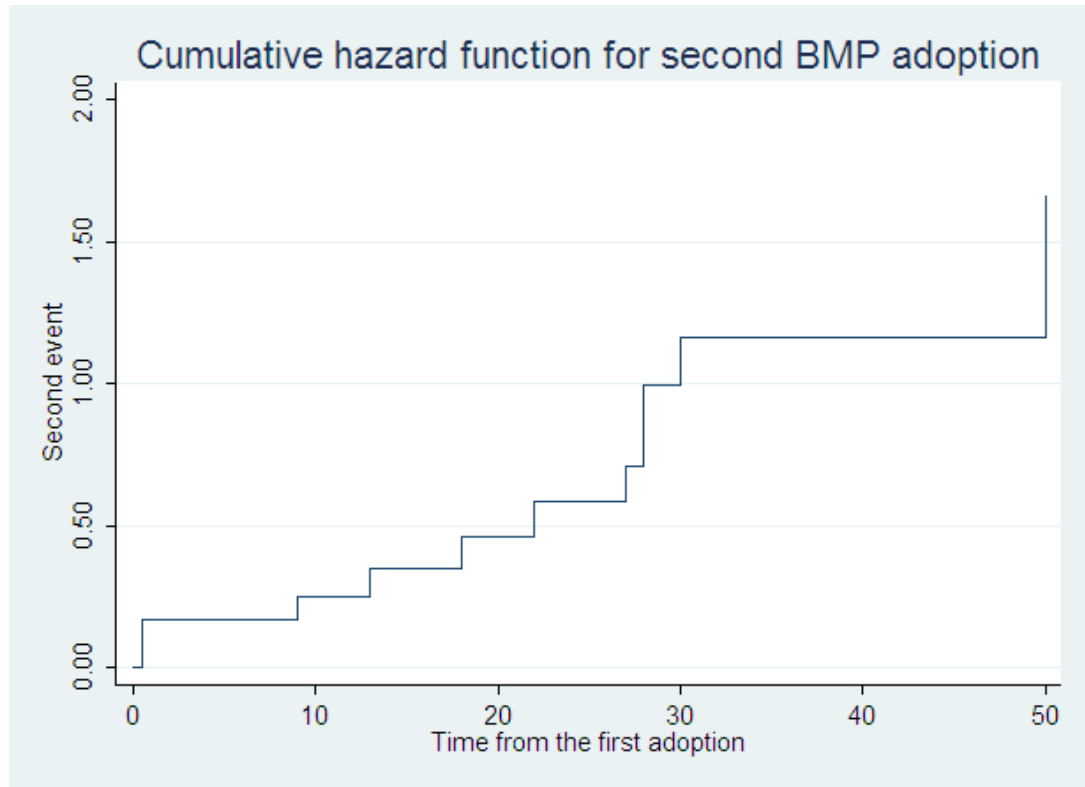


Figure B4: Nelson Aalen cumulative hazard function for second BMP adoption for an individual

Covariance Structure of Variance Corrected Models

The variance correction model are based on the following setting of covariance matrix: The variance corrected models are based on robust standard errors which accounts for interdependence across repeated or heterogeneous events. The regular variance-covariance matrix is obtained by:

$$V = -\left(\frac{\partial^2 \ln L}{\partial \beta^2}\right)$$

The robust standard error is;

$$V_{robust} = V \sum_{i=1}^n (u_i u_i) V'$$

And the cluster corrected standard error to allow for the heterogeneity can be stated as;

$$V_{cluster} = V \sum_{j=1}^g \left[\left(\sum_{i=1}^{n_j} u_{ij} \right) \left(\sum_{i=1}^{n_j} u_{ij} \right) \right] V'$$

Where g is number of clusters. u_i is the contribution of individual i to the score function

$\frac{\partial \ln L}{\partial \beta}$ evaluated at β .

Table B.2: Data setting for conditional frailty model

Serial no	event	Adoption yr	start	end	duration1	Event no	broilerno1	year	Experience	age
1	1	2000	0	46	46	1	500	15	5	25
1	0	2004	46	50	4	2	500	15	5	25
2	1	1998	0	14	14	1	600	20	20	50
2	0	2004	14	20	6	2	600	20	20	50
3	1	1994	0	15	15	1	384	10	25	64
3	0	2004	15	25	10	2	384	10	25	64
4	1	2002	0	2	2	1	750	12	4	52
4	0	2004	2	4	2	2	750	12	4	52
5	1	2003	0	2.5	2.5	1	500	30	14	48
5	0	2004	2.5	3.5	1	2	500	30	14	48
6	0	2004	0	4	4	1	657.6	35	4	42
7	0	2004	0	24	24	1	284.8	5	24	61
8	0	2004	0	30	30	1	240	0	30	63
9	0	2004	0	24	24	1	550	10	35	53
10	1	1996	0	2	2	1	595	0	10	64
10	0	2004	2	8	6	2	595	0	10	64
11	0	2004	0	6	6	1	800	25	9	32
12	1	1995	0	3	3	1	880	0	12	79

APPENDIX C: HECKMANS SAMPLE SELECTION MODEL USING TWO-STEP PROCEDURE AND RESULT

Two-step Estimator

Conditional expected value of W_i given $B_i = 1$ is;

$$E(W_i|B_i = 1) = \mathbf{Z}_{iw}\boldsymbol{\beta}_w + \lambda(\mathbf{Z}_{ib}\hat{\boldsymbol{\beta}}_b),$$

$$\lambda(r) = \phi(r)/\Phi(r),$$

Where r is a real number ranging over $(-\infty, \infty)$ and ϕ and Φ represents the density and distribution functions of the standard normal distribution, respectively. The expected value of WTA, for an individual i , is now expressed as follows, given that $B_i = 1$;

$$E(W_i|B_i = 1) = \mathbf{Z}_{iw}\boldsymbol{\beta}_w + \lambda(\mathbf{Z}_{ib}\hat{\boldsymbol{\beta}}_b) + \varepsilon_i \quad (4.9)$$

The Heckman's two-step estimator is obtained based on equation 4.9. At the first stage, the probit maximum likelihood approach is employed to estimate consistent estimates of $\boldsymbol{\beta}_b$. The $\boldsymbol{\beta}_b$ is replaced by estimated maximum likelihood estimator $\hat{\boldsymbol{\beta}}_b$. Then ordinary least square approach is used to estimate $\boldsymbol{\beta}_w$.

At the first step, the model endogenizes the respondents' participation decision to estimate the probability of selection (participation). Then, at the second step, the estimated probability (through mills ratio or cdf and pdf of the participation decision) is used while estimating the expected value of WTA.

**Table C1: The determinants of willingness to participate: binary variable B_i
(Two step)**

WTA seen	Coef.	Std. Err.
Number of broilers/100000	0.171	0.106
Individual has off-farm income =1	-1.290	0.576
Percentage of land owned by the grower	-0.066	0.029
Ownership of business; individual owner=1	-1.079	0.622
Perception that government should pay for water conservation in the scale of 1-5	-0.559	0.249
If there are housing subdivisions in nearby =1	0.222	1.233
Age of farmer at the time of survey	-0.086	0.035
Heard about BMP	1.381	0.616
Constant	0.171	0.106
Wald chi2(8)	47.91	
Prob > chi2	0.000	

Table C2: The determinants of WTA: The sample selection model for W_i (Two step)

Variables	Coefficients	Std. Errors
Number of broilers/100000	-241.124	133.348
Individual has off-farm income =1	2515.122	911.290
Perception that government should pay for water conservation in the scale of 1-5	973.166	314.715
If there are housing subdivisions in nearby =1	562.233	1265.308
Ownership of business; individual owner=1	1453.298	851.696
Heard about BMP	2080.730	1067.652
Age of farmer at the time of survey	-32.350	36.402
Farm income up to 49,999	3576.696	1372.426
Farm income up to 50,000 to 99,999	1876.217	1418.725
Farm income greater than 99,999	2814.687	1453.112
Constant	-2260.043	2928.690
λ	2623.107	1440.103
ρ	0.958	
σ	2738.576	
Pseudo R-square	0.419	
No of obs.	70	

Table C3: Regression of estimated inverse mills ratio to examine correlation

Variables	Coefficients	Std. Errors
Number of broilers/100000	-0.040**	0.0157
Individual has off-farm income =1	0.364***	0.097
Perception that government should pay for water conservation in the scale of 1-5	0.121***	0.035
If there are housing subdivision in nearby =1	0.156**	0.149
Ownership of business; individual owner=1	0.229	0.101
Heard about BMP	-0.174	0.121
Age of farmer at the time of survey	0.017***	0.004
Farm income up to 49,999	0.0428	0.175
Farm income up to 50,000 to 99,999	0.028	0.170
Farm income greater than 99,999	0.124	0.177
Constant	-1.039***	0.346
R-squared		0.433

Table C4: Correlation table with inverse mills ratio

	mill	bn	off_inc	govt_pay	housing	owner	bmp	age	inc50K	inc100K	inc more
mill	1.00										
bn	-0.21	1.00									
Off_inc	0.22	0.04	1.00								
gov_pay	0.15	0.22	-0.12	1.00							
housing	-0.01	0.11	-0.01	-0.11	1.00						
owner	0.16	0.05	-0.16	0.20	0.10	1.00					
bmp	-0.22	0.05	0.09	0.01	0.05	0.02	1.00				
age	0.32	-0.10	-0.12	-0.34	-0.10	-0.15	-0.23	1.00			
Inc50K	0.11	-0.16	-0.02	-0.03	-0.11	-0.09	-0.37	0.16	1.00		
Inc100K	-0.06	-0.08	-0.12	-0.04	0.04	0.14	0.24	0.05	-0.50	1.00	
Inc more	0.03	0.01	0.09	0.03	-0.07	-0.13	0.19	-0.85	-0.36	-0.42	1.00

APPENDIX D: DISTRIBUTION OF VARIABLES USED

Table D1: Distribution of dependent variable

WTP categories	Freq.	Percent	Cum.
WTP < 300	43	69.35	69.35
300< WTP < 500	15	24.19	93.55
500< WTP < 700	4	6.45	100
Total	62	100	

Table D2: Education attained by respondents

Education level	Freq.	Percent	Cum.
Less than high school	51	68.92	68.92
College	18	24.32	93.24
Graduate	5	6.76	100
Total	74	100	

APPENDIX E: STATA PPROGRAM

APPENDIX E1: CODES USED IN CHAPTER THREE

```
clear
set more off
capture log close
set logtype text

*log using "C:\Documents and Settings\Ashish\My Documents\ndevkol$ on 'Agec-
server1' (Z)\dissertation1\Adoption\analysis\stata\result_June4th.doc",
replace

insheet using "C:\Documents and Settings\Ashish\My Documents\ndevkol$ on
'Agec-server1' (Z)\dissertation1\Adoption\analysis\stata\
data_stata3.txt"

***      RUN THIS ONLY TO GET GRAPH OF ADOPTION OVER TIME
*keep if event ==1
*sort adoptionyr
*gen n=_n
*keep serialno adoptionyr n
*graph twoway line  n adoptionyr

***      HOUSING      *****
replace q43_housing=. if q43_housing>1

***      POLICY      *****
gen policy1996=0
replace policy1996=1 if adoptionyr>1996
replace policy1996=. if adoptionyr==.

***      EDUCATION      *****
*list q43_educ if q43_educ==0

gen educ1=0 if q43_educ==1
replace educ1=0 if q43_educ==2
replace educ1=0 if q43_educ==3
replace educ1=1 if q43_educ==6
replace educ1=1 if q43_educ==4
replace educ1=0 if q43_educ==5

replace educ1=. if q43_educ==0
replace educ1=. if q43_educ==.

***      AGE      *****
*list q43_age if q43_age==0
replace q43_age=. if q43_age==0
replace q43_age=25 if q43_age==2.5
replace q43_age=. if q43_age==.

***      OWNERSHIP      *****
*list q43_ownership if q43_ownership==5
*list q43_ownership if q43_ownership==4
```

```

gen q43_ownership1=1 if q43_ownership==0
replace q43_ownership1=1 if q43_ownership==1
replace q43_ownership1=1 if q43_ownership==2
replace q43_ownership1=2 if q43_ownership==3
replace q43_ownership=. if q43_ownership==5
replace q43_ownership=. if q43_ownership==4
replace q43_ownership=. if q43_ownership==.

*** MARITAL *****
list q43_marital if q43_marital==0

gen q43_marital1=1 if q43_marital==3
replace q43_marital1=0 if q43_marital != 3
replace q43_marital1=. if q43_marital==0
replace q43_marital1=. if q43_marital==.

*** GENDER *****
*list q43_gender if q43_gender==2

replace q43_gender=. if q43_gender==2

*** RACE *****
list q43_race if q43_race==0
gen q43_race1 =1 if q43_race ==4
replace q43_race1 =0 if q43_race !=4
replace q43_race1 =. if q43_race ==.

*** RETIRE *****
*list q43_retire if q43_retire==1

gen q43_retire1=1 if q43_retire ==1
replace q43_retire1=0 if q43_retire==2
replace q43_retire1=0 if q43_retire==3
replace q43_retire1=. if q43_retire==0
replace q43_retire1=. if q43_retire==.

*** ASSET LIAB *****
*list q43_assetliab if q43_assetliab==6
replace q43_assetliab=. if q43_assetliab==0

*** PERCENTAGE OF INCOME FROM BROILER *****
replace q43_perfarminc=. if q43_perfarminc==0

**** FARM INCOME *****
*** there no 6 in the category
*list q43_farmincome if q43_farmincome==1

gen q43_farmincome1=0 if q43_farmincome==5
replace q43_farmincome1=0 if q43_farmincome==4
replace q43_farmincome1=1 if q43_farmincome==3
replace q43_farmincome1=1 if q43_farmincome==2
replace q43_farmincome1=1 if q43_farmincome==1

replace q43_farmincome=. if q43_farmincome==0
replace q43_farmincome=. if q43_farmincome==.

```

```

corr q2_broilerno1 q30_bmp q7_litterac q43_exper q43_age q43_educ
    q43_gender q43_marital1 q43_race1 q43_farmincome1 q43_retire1
    q43_housing q43_ownership1 q43_assetliab policy1996

    stset duration, failure(event)
    stsum, by(bmp)

***    NELSON ALLEN CUMMULATIVE HAZARD FUNCTION
    sts list, na
    sts graph, na

***    id(serialno)

***    PROPORTIONAL HAZARD MODEL
xi:    stcox q2_broilerno1 q43_exper i.educ1 i.q43_farmincome1 q43_retire1
    q43_ownership1 policy1996 q44_contact, efron nolog tvc(q43_age)
    stcox, nohr

***    CLUSTER CORRECTED MODEL
xi:    stcox q2_broilerno1 q43_exper i.educ1 i.q43_farmincome1 q43_retire1
    q43_ownership1 policy1996 q44_contact, efron cluster(serialno) nolog
    tvc(q43_age)
    stcox, nohr

***    WLW MODEL
xi:    stcox q2_broilerno1 q43_exper i.educ1 i.q43_farmincome1 q43_retire1
    q43_ownership1 policy1996 q44_contact, efron strata(bmp)
    cluster(serialno) nolog tvc(q43_age)
    stcox, nohr

***    SHARED FRAILITY MODEL
xi:    stcox q2_broilerno1 q43_exper i.educ1 i.q43_farmincome1 q43_retire1
    q43_ownership1 policy1996 q44_contact, frailty(gamma) shared(serialno)
    efron nolog tvc(q43_age)
    stcox, nohr

***    TESTING ASSUMPTION OF COX PROPORTIONAL HAZARD
xi:    stcox q2_broilerno1 q43_exper i.educ1 q43_age q43_farmincome1
    q43_retire1 q43_ownership1 policy1996 q44_contact, efron nolog noshow
    schoenfeld(sch*) scaledsch(sca*)

    stphtest, log detail
    stphtest, log plot(q2_broilerno1 ) yline(0)
    stphtest, log plot(q43_exper ) yline(0)
    stphtest, log plot(q43_age ) yline(0)
    stphtest, log plot(_Ieduc1_ ) yline(0)
    stphtest, log plot(q43_farmincome1 ) yline(0)
    stphtest, log plot(q43_retire1 ) yline(0)
    stphtest, log plot(q43_ownership1 ) yline(0)
    stphtest, log plot(policy1996) yline(0)
    stphtest, log plot(q44_contact) yline(0)
    stphtest, log plot(q43_marital1 ) yline(0)

```

R CODES FOR CONDITIONAL FRAILTY MODEL

```
library(survival)
data<-read.table("C:\\Documents and Settings\\Ashish\\My Documents\\ndevko1$
  on 'Agec-server1' (Z)\\dissertation1\\Adoption\\analysis\\R\\data for
  r21.txt", header = TRUE)
cond.frailty.gamma<-coxph(formula = Surv(start, end, event) ~ broilerno1 +
  exper + age + educ1 + farmincomel + retire1 + ownership1 + policy1996 +
  contact + strata(eventno) + frailty.gamma(serialno), data = data)
beta.cond.f.gamma<- cond.frailty.gamma$coef
naivese.cond.f.gamma<- sqrt(diag(cond.frailty.gamma$var))
se.cond.f.gamma<-sqrt(diag(cond.frailty.gamma$var2))
loglike1.cond.f.gamma<-cond.frailty.gamma$loglik[[1]] #
loglike1.cond.f.gamma
loglike2.cond.f.gamma<-cond.frailty.gamma$loglik[[2]] #base
loglike2.cond.f.gamma
theta.cond.f.gamma<-cond.frailty.gamma$history[[1]]$theta
theta.cond.f.gamma
ll.cond.f.gamma<-cond.frailty.gamma$history[[1]]$c.loglik
ll.cond.f.gamma
summary(cond.frailty.gamma)
)
```


APPENDIX E2: CODES USED IN CHAPTER FOUR

```
version 10.0

*****
****  HECKMAN 2 STEP PROCEDURE
*****

capture log close
set more off

insheet using "C:\Documents and Settings\Ashish\My Documents\ndevkol$ on
'Agec-server1' (Z)\dissertation1\WTP and WTA\analysis\WTP\data\
DATA_ORDLOGIT_SAS.txt", clear

log using "C:\Documents and Settings\Ashish\My Documents\ndevkol$ on 'Agec-
server1' (Z)\dissertation1\WTP and WTA\analysis\WTA\
result_dec_30th_heckman_final.doc", replace text

****  DEPENDENT VARIABLE FOR SELECTION MODEL      *****

***  WHO ANSWERED ZERO TO THE WTA QUESTION ARE NON-PARTICIPATOR AND ARE
      SELECTED OUT FROM THE WTA MODEL.

***  DUE TO OUTLIER THE UPPER END OF WTA IS TRUNCATED AT Q3+*2 INTERQUARTILE
      RANGE;
      replace wta=0 if q24_minwta==0 & q24_minwta!=.
      gen wtaseen=1 if q24_minwta>0
      replace wta=. if q24_minwta==.
      replace wtaseen=0 if q24_minwta==0
      replace wtaseen=0 if q24_minwta==.
      list wtaseen q24_minwta wta

***  MARITAL STATUS      *****

***  Q43_MARITAL: 1= SINGLE; 2=DIVORSED; 3=MARRIED; 4=WIDOWED
***  THERE ARE NO OBSERVATIONS ON 2
***  THERE ARE 5 INDIVIDUALS WITH 5 AND THESE ARE CODED AS 0
***

      drop married
      *list q43_marital if q43_marital==5
      gen married=1 if q43_marital==3
      replace married = 0 if q43_marital!=3
      replace married = . if q43_marital==.
      *list married q43_marital

***  SPOUCE-INCOME      *****
***  Q43_SPOUCEINCOME=1 IF SPOUCE HAS INCOME ELSE 0
***

      *list q43_spouceincome if q43_spouceincome==1

*****MARRIED*SPOUCEINCOME*****

      gen married_sincome=married*q43_spouceincome
      *list married married_sincome q43_spouceincome
```

```

***** ASSET LIABILITIES *****

*** Q43_ASSETLIAB: 1=NO DEBT; 2=1-20%; 3=21-40%; 4=41-60%; 5=>60%
*** THERE ARE 4 INDIVIDUALS THAT HAVE 0 AND ARE CODED AS 1
***
*list q43_assetliab if q43_assetliab==5
drop assetliab
gen assetliab=1 if q43_assetliab==0|q43_assetliab==1|q43_assetliab==2
replace assetliab=0 if
q43_assetliab==3|q43_assetliab==4|q43_assetliab==5
*list assetliab q43_assetliab

***** OWNERSHIP *****

*** Q43_OWNERSHIP: 1=INDIVIDUAL; 2= FAMILY; 3=FATHER-SON; 4=OTHERS
*** THERE ARE NO OBSERVATIONS ON 3
*** THERE ARE 5 INDIVIDUALS WITH 0 AND ARE CODED AS 1

*list q43_ownership if q43_ownership==3
gen ownership=1 if q43_ownership==0
replace ownership=1 if q43_ownership==1
replace ownership=0 if q43_ownership==2
replace ownership=0 if q43_ownership==4
replace ownership=0 if q43_ownership==3

***** OFF_FARM INCOME *****

*** Q43_OFFINCOME: 1= OWNER HAS OFF FARM INCOME TOO
***
*list q43_offincome if q43_offincome==1

*** Q43_FARMINCOME *****

*** Q43_FARMINCOME: 1= >100000 2=50000-99999; 3=0-49999; 4=LOSS <25000; 5=
LOSS 25000-50000; 6=LOSS>50000
*** THERE ARE NO OBS ON 6
*** 3 AND 4 ARE CHANGED TO ONE CATEGORY TO MAKE EQUAL INTERVAL
***
*list q43_farmincome if q43_farmincome==6

gen farm_income =1 if q43_farmincome==4 | q43_farmincome==5
replace farm_income =2 if q43_farmincome==3
replace farm_income=3 if q43_farmincome==2
replace farm_income =4 if q43_farmincome==1

*list farm_income q43_farmincome

*** Q43_EDUCATION *****

*** Q43_EDUC: 1= > H SCHOOL; 2= HIGH SCHOOL; 3=COLLEGE; 4=UNDERGRAD;
5=GRADUATE; 6= VOCATIONAL
*** THERE IS NO OBSERVATION ON 6
***
drop educ
*list q43_educ if q43_educ==6
gen educ =1 if q43_educ==1 | q43_educ==2
replace educ=2 if q43_educ==3 | q43_educ==4

```

```

replace educ=3 if q43_educ==5
*list q43_educ educ

*** Q43_HOUSING *****
*list q43_housing if q43_housing==1

*** Q43_RETIRE *****
*list q43_retire if q43_retire==3

*** Q2_BROILERNO *****
*** NUMBER OF BROIER IN 100,000
***
gen bn=q2_broilerno/100000

*** Q43_PERS ENVIRONMENTAL PERCEPTIONS *****
*** pay = Q43_PERS11-15= GOVT SHOULD PAY FARMERS FOR WATER CONSERVATION
PRACTICES 5=STONGLY AGREEE
*** Q43_PERS16-20 = GOVT SHULDNOT BE INVOLVED IN AGRICULTURE 5=STONGLY
AGREEE
*** Q43_PERS21-25 = GOVT INVOLVED IN AG HELPS FARMERS 5=STONGLY AGREEE
*** THERE IS ONE OBS WITH GOVT_PAY==6 THAT IS CHAGNED T0 5

egen govt_pay = rowtotal(q43_pers11-q43_pers15)
replace govt_pay=5 if govt_pay==6
replace govt_pay =. if govt_pay==0
egen govt_inv=rowtotal(q43_pers16-q43_pers20)
replace govt_inv =. if govt_inv==0
egen govt_ag = rowtotal(q43_pers21-q43_pers25)
replace govt_ag=. if govt_ag==0

*****
*** CORRELATION CHECK
xi: corr wta wtaseen bn q43_offincome govt_pay q43_housing ownership
q30_bmp q43_age i.farm_income per_own ownership

*** VARIABLE SELECTION FOR WTASEEN FROM STEPWISE PROBIT
*****

xi: stepwise, pr(.30): probit wtaseen bn educ per_own per_littuse ownership
q30_bmp assetliab q43_age q43_firmage q43_offincome q43_housing
q44_contact q41_year q43_exper q40_plantosp govt_pay

*** SELECTED VARIABLES FOR WTASEEN FROM STEPWISE PROBIT
*bn q43_offincome per_own ownership govt_pay q43_age q30_bmp

*** VARIABLE SELECTION FOR WTA FROM STEPWISE REGRESSION

xi :stepwise, pr(.30): reg wta bn educ per_own per_littuse ownership
q30_bmp assetliab q43_age q43_firmage q43_offincome q43_housing
q44_contact q41_year q43_exper q40_plantosp govt_pay i.farm_income

*** SELECTED VARIABLES FOR WTA FROM STEPWISE REGRESSION
*bn q43_offincome govt_pay q43_housing ownership q30_bmp q43_age
i.farm_income

sum wta bn q43_offincome govt_pay q43_housing ownership q30_bmp q43_age
farm_income

```

***** HECKMAN'S SELECTION MODEL**

*** SUMMARY STATISTICS *****

```
xi: sum wta bn q43_offincome govt_pay q43_housing ownership q30_bmp  
    q43_age i.farm_income wtaseen per_own q41_year  
xi: corr mill bn q43_offincome govt_pay q43_housing ownership q30_bmp  
    q43_age i.farm_income
```

***** HECKMAN MODEL SAMPLE SELECTION MODEL (TWO STEP)**

```
xi: heckman wta bn q43_offincome govt_pay q43_housing ownership q30_bmp  
    q43_age i.farm_income, select(wtaseen =bn q43_offincome per_own  
    ownership govt_pay q43_housing q43_age q30_bmp) first twostep  
    mills(mill)  
    predict ycond, ycond  
    sum ycond  
xi: reg mill bn q43_offincome govt_pay q43_housing ownership q30_bmp  
    q43_age i.farm_income  
    vif
```

***** HECKMAN SAMPLE SELECTION MODEL (MLE)**

```
xi: heckman wta bn q43_offincome govt_pay q43_housing ownership q30_bmp  
    q43_age i.farm_income, select(wtaseen =bn q43_offincome per_own  
    ownership govt_pay q43_housing q43_age q30_bmp) first  
    predict ycond1, ycond  
    sum ycond1  
xi: reg wta bn q43_offincome govt_pay q43_housing ownership q30_bmp q43_age  
    i.farm_income, robust  
    predict xb  
    sum xb
```

*** OLS of wta

```
xi: reg wta bn q43_offincome govt_pay q43_housing ownership q30_bmp q43_age  
    i.farm_income, robust
```

APPENDIX E3: CODES USED IN CHAPTER FIVE

```
version 10.0
set more off
clear
capture log close
insheet using "C:\Documents and Settings\Ashish\My Documents\ndevkol$ on
'Agec-server1' (Z)\dissertation1\WTP and WTA\analysis\WTP\data\
DATA_ORDLOGIT_SAS.txt", clear
*log using "C:\Documents and Settings\Ashish\My Documents\ndevkol$ on 'Agec-
server1' (Z)\dissertation1\WTP and WTA\analysis\WTP\
result_ologit_6TH_NOV.doc", replace text

***  MARITAL STATUS      *****

drop married
***  Q43_MARITAL: 1= SINGLE; 2=DIVORSED; 3=MARRIED; 4=WIDOWED
***  THERE ARE NO OBSERVATIONS ON 2
***  THERE ARE 5 INDIVIDUALS WITH 5 AND THESE ARE CODED AS 0
***

*list q43_marital if q43_marital==5

gen married=1 if q43_marital==3
replace married = 0 if q43_marital!=3
replace married = . if q43_marital==.
*list married q43_marital

***  SPOUCE-INCOME      *****
***  Q43_SPOUCEINCOME=1 IF SPOUCE HAS INCOME ELSE 0
***

*list q43_spouceincome if q43_spouceincome==1

*****MARRIED*SPOUCEINCOME*****

gen married_sincome=married*q43_spouceincome
*list married married_sincome q43_spouceincome

***  ASSET LIABILTIY      *****

***  Q43_ASSETIAB: 1=NO DEBT; 2=1-20%; 3=21-40%; 4=41-60%; 5=>60%
***  THERE ARE 4 INDIVIDUALS THAT HAVE 0 AND ARE CODED AS 1
***

*list q43_assetliab if q43_assetliab==5

drop assetliab
gen assetliab=1 if q43_assetliab==0|q43_assetliab==1|q43_assetliab==2
replace assetliab=0 if
q43_assetliab==3|q43_assetliab==4|q43_assetliab==5
*list assetliab q43_assetliab

****  OWNERSHIP      *****

***  Q43_OWNERSHIP: 1=INDIVIDUAL; 2= FAMILY; 3=FATHER-SON; 4=OTHERS
***  THERE ARE NO OBSERVATIONS ON 3
```

```

***   THERE ARE 5 INDIVIDALS WITH 0 AND ARE CODED AS 1

      *list q43_ownership if q43_ownership==3
      gen ownership=1 if q43_ownership==0
      replace ownership=1 if q43_ownership==1
      replace ownership=0 if q43_ownership==2
      replace ownership=0 if q43_ownership==4
      replace ownership=0 if q43_ownership==3

***   OFF_FARM INCOME          *****

***   Q43_OFFINCOME: 1= OWNER HAS OFF FARM INCOME TOO
***
      *list q43_offincome if q43_offincome==1

***   Q43_FARMINCOME          *****

***   Q43_FARMINCOME: 1= >100000 2=50000-99999; 3=0-49999; 4=LOSS <25000; 5=
      LOSS 25000-50000; 6=LOSS>50000
***   THERE ARE NO OBS ON 6
***   3 AND 4 ARE CHNAGED TO ONE CATEGORY TO MAKE EQUAL INTERVAL
***
      *list q43_farmincome if q43_farmincome==6

      gen farm_income =1 if q43_farmincome==4 | q43_farmincome==5
      replace farm_income =2 if q43_farmincome==3
      replace farm_income=3 if q43_farmincome==2
      replace farm_income =4 if q43_farmincome==1

      *list farm_income q43_farmincome

***   Q43_EDUCATION          *****

***   Q43_EDUC: 1= > H SCHOOL; 2= HIGHSCHOOL; 3=COLLEGE; 4=UNDERGRAD;
      5=GRADUATE; 6= VOCATIONAL
***   THERE IS NO OBSERVATION ON 6
***
      drop educ
      *list q43_educ if q43_educ==6
      gen educ =1 if q43_educ==1 | q43_educ==2
      replace educ=2 if q43_educ==3 | q43_educ==4
      replace educ=3 if q43_educ==5
      *list q43_educ educ

***   Q43_HOUSING          *****

      *list q43_housing if q43_housing==1

****   Q43_RETIRE          *****

      *list q43_retire if q43_retire==3

*****   Q43_PLANTOSP          *****
***   Q40_PLANTOSP: 1=NONE; 2=<20000; 3= 20000-50000; 4= >50000
***
      *list q40_plantosp if q40_plantosp==4
      gen plantosp=1 if q40_plantosp==1
      replace plantosp=2 if q40_plantosp==2

```

```

replace plantosp=3 if q40_plantosp==3
replace plantosp=4 if q40_plantosp==4
*list plantosp if q40_plantosp==4

***      Q2_BROILERNO      *****
***      NUMBER OF BROIER IN 100,000
***
gen bn=q2_broilerno/100000

***      Q43_PERS ENVIRONMENTAL PERCEPTIONS      *****
***      pay = Q43_PERS11-15= GOVT SHOULD PAY FARMERS FOR WATER CONSERVATION
PRACTICES 5=STONGLY AGREEE
***      Q43_PERS16-20 = GOVT SHULDNOT BE INVOLVED IN AGRICULTURE 5=STONGLY
AGREEE
***      Q43_PERS21-25 = GOVT INVOLVED IN AG HELPS FARMERS 5=STONGLY AGREEE
***      Q43_PERS1-5 = LAWS AND REGULATION ARE BALY NEEDED 5=STONGLY AGREEE
***      Q43_PERS5-10 = WATER CONSERVATION PRACTICES ARE OFTEN CARRIED TOO FAR
5=STONGLY AGREEE

***      THERE IS ONE OBS WITH GOVT_PAY==6 THAT IS CHAGNED TO 5

egen reg_needed = rowtotal(q43_pers1-q43_pers5)
replace reg_needed =. if reg_needed ==0

egen prog_carried= rowtotal(q43_pers10-q43_pers15)
replace prog_carried=. if prog_carried==0

egen govt_pay = rowtotal(q43_pers11-q43_pers15)
replace govt_pay=5 if govt_pay==6
replace govt_pay =. if govt_pay==0

egen govt_inv=rowtotal(q43_pers16-q43_pers20)
replace govt_inv =. if govt_inv==0

egen govt_ag = rowtotal(q43_pers21-q43_pers25)
replace govt_ag=. if govt_ag==0

***      EDUC * OFFINCOME      *****
gen offinc_educ=q43_offincome*educ

list q27_d1 q29_maxwtp if q27_d1==. & q29_maxwtp != .
replace q27_d1=1 if q27_d1==. & q29_maxwtp != .

***      SUMMARY STATISTICS      *****

Corr  q27_d1 bn per_own wtp per_littuse q19_litterprodn q30_bmp
q40_plantosp q41_year q43_exper q43_age q43_firmage q43_educ q43_gender
q43_marital q43_offincome q43_spouceincome q43_farmincome q43_assetliab
q43_retire q43_housing q43_worth q43_perstotal q44_contact
sum  q27_d1 broilerno per_own wtp per_littuse q19_litterprodn q30_bmp q39_e
q39_b q39_m q40_plantosp q41_year q42_relative q43_exper q43_age
q43_firmage q43_educ q43_gender q43_marital q43_offincome
q43_spouceincome q43_farmincome q43_assetliab q43_retire q43_housing
q43_worth q43_perstotal q44_contact married married_sincome

```

```

xi:  stepwise, pr(.25): ologit q27_d1 bn reg_needed prog_carried per_own
    per_littuse q30_bmp q40_plantosp q41_year q43_exper q43_age farm_income
    i.educ q43_gender q43_marital q43_offincome q43_spouseincome
    q43_assetliab q43_housing q43_worth q43_perstotal q44_contact govt_pay
xi:  omodel logit q27_d1 q43_age govt_pay q43_perstotal i.educ per_littuse
    q43_offincome i.plantosp

***  ORDERED LOGIT

xi:  sum q27_d1 i.educ q43_offincome q43_age per_littuse q44_contact
    reg_needed
    tab educ
    tab q27_d1

xi:  ologit q27_d1 i.educ q43_offincome q43_age per_littuse q44_contact
    reg_needed, robust
    mfx, predict(outcome(3))
    mfx, predict(outcome(2))
    mfx, predict(outcome(1))

xi:  omodel logit q27_d1 i.educ q43_offincome q43_age per_littuse
    q44_contact reg_needed
xi:  gologit2 q27_d1 i.educ q43_offincome q43_age per_littuse q44_contact
    reg_needed, autofit(0.1) lrforce robust
    mfx2

*****  BELOW IS THE ANALYSIS FOR INTERVAL REGRESSION MODELS
gen q27_dldown=0 if q27_d1==1
gen q27_dilup =299 if q27_d1==1
replace q27_dldown=300 if q27_d1==2
replace q27_dilup =499 if q27_d1==2
replace q27_dldown=500 if q27_d1==3
replace q27_dilup =. if q27_d1==3
list q27_d1 q27_d q27_dldown q27_dilup

xi:  intreg q27_dldown q27_dilup i.educ q43_offincome q43_age per_littuse
    q44_contact reg_needed, robust
    fitstat
    predict yhat

sum yhat

```


VITA

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