Quebec hog producers' willingness to accept carbon credit revenue for adopting management practices that reduce greenhouse gas emissions

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Abstract

Canada's commitment to the Kyoto Protocol provides agricultural producers with an opportunity to supply carbon offset credits to a domestic carbon market and receive revenue from the sale of these credits. This study employed the multiple bounded discrete choice method to estimate Quebec hog producers' willingness to accept compensation to adopt two management practices that reduce carbon emissions; i.e. reduced protein feeding and adopting a manure storage cover. The average willingness to accept compensation for reduced protein feeding was $46.71 per tonne of CO_2 equivalent and for the manure storage cover was $40.40 per tonne of CO_2 equivalent. In addition, hog producers were asked what cost they would be willing to bear if they received $20 per animal unit in carbon offset credit revenue. The average cost they were willing to bear was $11.88. Key factors that influenced producers' decisions were identified. Results can be used to improve the institutional rules and public policy associated with developing a domestic carbon emission trading mechanism. Starting-point and sequencing bias were tested for with the convolution approach. Starting-point bias was found in all the hypothetical situations; while sequencing bias was not found.

Résumé

L'engagement du Canada envers le Protocole de Kyoto donne aux producteurs agricoles la possibilité de fournir des crédits compensatoires à un marché de carbone domestique et ainsi recevoir les revenus découlant de la vente de ces crédits. L'étude suivante utilise la méthode d'évaluation contingente par choix multiples limités (multiple bounded dichotomous choice) pour estimer la volonté d'accepter (willingness to accept) des producteurs de porc québécois pour l'adoption de deux changements de pratique qui réduisent les émissions de carbone; la diminution du taux de protéines dans les aliments et l'adoption d'un recouvrement pour les structures d'entreposage des déjections animales. Les producteurs accepteraient en moyenne un revenu de 46,71$ par tonne de dioxide de carbone équivalent pour la diminution du taux de protéines dans les aliments et accepteraient en moyenne 40,40$ par tonne de dioxide de carbone équivalent pour celles recouvrement des structures d'entreposage. De plus les producteurs de porc ont été approchés pour savoir quel coût ils seraient prêts à débourser afin de recevoir éventuellement 20$ par animal en revenus de crédit compensatoire de carbone. Le coût moyen qu'ils seraient prêts à débourser était de 11,88$ par animal. Les facteurs clés qui influencent la prise de décision des producteurs ont été identifiés. Les résultats peuvent être utilisés pour améliorer les règles institutionnelles et politiques publiques associées avec le développement d'un mécanisme domestique d'échange du carbone. Les biais statistiques concernant le point de départ et la séquence ont également été examinés en utilisant l'approche des convolutions. Alors que l'écart concernant le point de départ a été observé pour tous les scénarios hypothétiques, aucun écart n'a été observé concernant la séquence.

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Chapter 1: Introduction

1.1 Background

International recognition of climate change started as early as the late 1980s when the UN Intergovernmental Panel on Climate Change (IPCC) estimated and projected the future climate impact of an increase in the concentration of greenhouse gases (GHG) (IPCC, 1990). GHG were defined by the IPCC to include water vapor, ozone, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), as well as some other industrial gases. As a result of these concerns, the Rio Earth Summit introduced the United Nations Framework Convention on Climate Change, which agreed to stabilize GHG emissions globally.

International climate action continued with the signing of the Kyoto Protocol in 1997. This international agreement established legally binding targets and a timeframe for the 38 industrialized countries listed in Annex B to reduce their GHG emission levels (UNFCCC, 1998). Canada signed the Kyoto Protocol and committed to reduce its average annual GHG emissions to 6% below its 1990 levels during the first commitment period (2008-2012). This equates to a reduction of 240 megatonnes (Mt) of carbon dioxide equivalent (CO_2e) from Canada's projected business-as-usual (BAU) emission level in 2010 (Government of Canada, 2002).

In response to its pledge in the Kyoto Protocol, the Canadian federal government developed the Climate Change Plan for Canada in 2002 (Government of Canada, 2002). In this plan the large final emitters (LFE), which include the oil and gas sector, mining, thermal electricity, and manufacturing sectors, were expected to reduce their emissions by 55 Mt CO_2e. A domestic emission trading (DET) system was proposed so that LFEs could trade carbon credits. A price cap on carbon credits of $15 per tonne was also introduced. The plan identified agriculture, forests, and landfills as having the potential to develop new activities to reduce GHG emissions or increase carbon sequestration. Carbon sequestration occurs when carbon is removed from the atmosphere and placed in a sink; such as soil or trees. Carbon reductions or removals from the forestry, agriculture, or landfill sectors are called carbon offset credits because these sectors do not have regulated GHG emission reductions.

Carbon trading provides an economic incentive for LFEs to initiate carbon reduction strategies. For the offset sectors, it provides an economic incentive to initiate projects that reduce or remove carbon. Projects would be awarded "offset credits" for net GHG reductions or removals if the reductions or removals occur during the first commitment period and have been registered and verified. An offset credit would be issued when 1 tonne of carbon dioxide equivalent has been reduced or removed as a result of implementing a specific management activity. The carbon trading system, and the offset system in particular, was proposed in the plan as a cost-effective GHG mitigation option. This is because high cost abaters could buy credits from low cost abaters and thus reduce the total abatement costs for a given emission reduction level.

A LFE could meet its reduction target through different means: reducing its own emissions, purchasing the reductions from other LFEs in the DET, purchasing Kyoto compliant units, or purchasing offset credits. Under the Kyoto Protocol (KP) countries are encouraged to reduce their GHG emissions, however, the KP does recognize these other flexible mechanisms as a means to fulfill a country's commitment. For example, Kyoto compliant units can be generated using the Clean Development Mechanism to reduce GHG emissions. In this case, projects that reduce GHG emissions in developing countries can generate compliance units once the project has been accepted, and the GHG emissions have been monitored, and verified. To illustrate this, on August 26th 2004 TransAlta Corp., a Canadian energy company, purchased 1.75 million tonnes of CO_2 credits for $9 million US from a Chile hog project that reduced and captured their methane emissions.

1.2 Problem statement

The problem to be addressed in this research is to estimate hog producers' willingness to accept (WTA) compensation to change management practices that would decrease carbon emissions from their hog operations. More specifically, this research will study the factors that influence the adoption of best management practices (BMPs) as well as to investigate the price of carbon credits that would be required for producers to switch their practices. In other words, this research will explore the incentives provided by the institutional structure of the DET system to encourage hog producers to adopt BMPs that reduce or remove GHG emissions.

1.3 Objectives

This research will focus on the following objectives:

1. To estimate hog producers' mean WTA compensation for changing their management practices to generate carbon offset credits.

2. To explore the key factors that influence hog producers adoption of best management practices.

3. To identify those factors that impact a producer's WTA compensation, in terms of carbon credit revenue, from an offset project.

4. To investigate the carbon market institution that encourages hog producers to participate.

1.4 Hypothesis

This research hypothesizes that hog producers' WTA compensation will be positively related to the offset credit price level, and other parameters such as enterprise size, numbers of animals, awareness of the carbon offset market and BMPs, income, and education level.

1.5 The scope of this research

This research uses a survey instrument to measure hog producers' WTA compensation through the carbon offset credit price to adopt carbon reducing projects on their farms. The survey was administrated to hog producers in Quebec who were members of the Fédération des Producteurs de Porcs du Québec (FPPQ). This research required a pre-testing of the survey instrument on hog producers and a mail survey. Enterprise names and addresses of hog producers were provided by the FPPQ. Quebec is the largest pork producing province in Canada.

1.6 Structure of this thesis

The second chapter presents the literature review of the research. The first section introduces GHG emissions in the Canadian hog industry and BMPs that reduce GHG emissions. The second section reviews welfare measures used in economic theory. The last section reviews the contingent valuation method.

The third chapter presents the survey methodology, design, and implementation, as well as the discrete choice valuation model. An outline of the convolution method is also given.

The fourth chapter provides the descriptive statistical analysis of the responses. Mean WTA compensation for each model are calculated, followed with the regression analysis results. A convolution analysis is also conducted to detect potential survey design bias. Finally, this chapter discusses the associated policy and methodology implications.

The last chapter summarizes the findings of this study and draws conclusions based on the results. Some limitations of the study are identified and suggestions for future study are recommended.

Chapter 2: Literature Review

2.1 GHG emissions and Canadian hog industry

2.1.1 Overview

The agricultural sector contributes approximately 10-12% of the GHG emissions in Canada and the livestock component of the sector contributes 42-50% of these emissions. The GHG emissions of the hog industry are the third largest after beef cattle and dairy cattle, and contribute almost 20% of the agricultural emissions, which is 3% of the national emissions (Environment Canada, 2005).

The Climate Change Secretariat of Canada initiated Action Plan 2000 and allocated $21 million to a three-year program called the Greenhouse Gas Mitigation Program. This program was designed for the Canadian agriculture sector to address GHG emission reductions and removals in the areas of soil, nutrient, and livestock management. The program objectives were twofold (AAFC, 2002):

1. To reduce GHG emissions in the agriculture and food sectors in three primary areas: soil, nutrient and livestock management, and to increase carbon sinks through carbon sequestration.
2. To help meet Canada's Kyoto commitment for reducing GHG emissions.

Four organizations split the administrative responsibilities for this program. They were the Canadian Cattlemen's Association, Diary Farmers of Canada, Canadian Pork Council (CPC), and the Soil Conservation Council of Canada. The inclusion of these partners allowed the program to be tailored specifically to individual commodity producers, as well as to provide an opportunity for the entire sector to work together to find solutions to reducing GHG emissions (MacLeod, 2005a).

The GHG Mitigation Program for Canadian Agriculture (GHGMP) identified best management practices (BMPs) that would reduce GHG emissions, increase awareness, and involve producers in fostering the adoption of practices that reduced GHG emissions. Elements of this program included: making recommendations, increasing awareness, measuring and verifying reductions. GHG reductions from BMPs projects were measured, verified, and the results were to be used to optimize existing BMPs for their GHG reduction potential. BMPs in the program included fertilizer formulation and application practices, livestock feeding and manure handling practices, and soil management practices including carbon sink management (AAFC, 2002).

This mitigation program had several BMPs demonstration projects for the hog industry across Canada. Examples included:

- Provincial education and demonstration programs for the use of shelterbelts around hog barns (Federation des producteurs de porcs du Quebec, FPPQ).
- Greenhouse gas mitigation through fertilizer and manure nitrogen

management in Quebec.

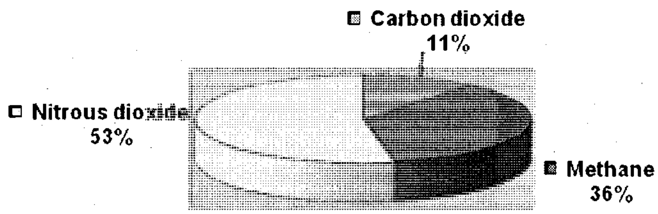
- On-farm demonstration of technology for recovering and eliminating methane produced in liquid manure storage (FPPQ).
- Demonstration of GHG mitigation practices for swine production operations in Ontario (Ontario Pork with the University of Guelph).

These BMP demonstration sites and the development of associated technology increased pork producers awareness of BMPs and technological options associated with carbon offsets (Canadian Pork Council, 2002a).

2.1.2 Greenhouse gas emissions in the Canadian hog industry

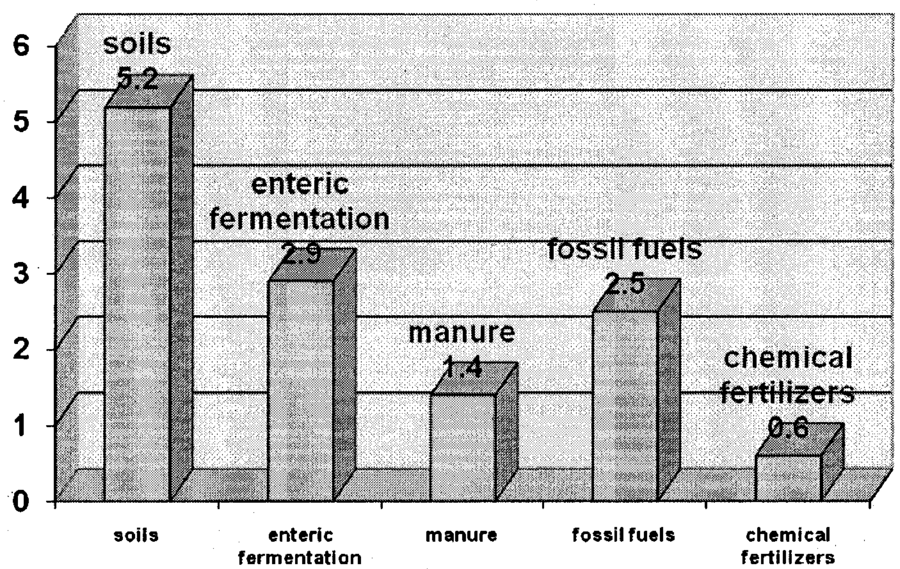
The three major GHGs emitted from the agricultural sector in Canada are: carbon dioxide — 11%, methane — 36%, and nitrous oxide — 53% (Figure 2.1). Agricultural GHG emissions are generated from enteric fermentation by domestic animals, manure management, fertilizer application, and crop production. Livestock-related emissions are from: enteric fermentation from domestic animals (i.e., digestive processes that release CH_4), manure management (which releases CH_4 and N_2O), and the combustion of fossil fuels (Figure 2.2). These emissions accounted for 49% of the total agricultural GHG emissions in 2003 (Environment Canada, 2005).

Figure 2.1 Three major GHGs in agriculture sector



Source: Environment Canada, 2005

Figure 2.2 The proportion of livestock sector GHG emissions with respect to the national emissions



Source: Environment Canada, 2005

Unlike most industrial sectors whose main GHG is carbon dioxide, the GHG emissions from agriculture are mostly from nitrous oxide and methane. Nitrous oxide and methane can generate 310 and 21 times more GHG effect than carbon dioxide. It is estimated that 62% of the Canadian hog sector GHG emissions come from methane and 20% from nitrous oxide (Environment Canada, 2006). Methane is produced when anaerobic bacteria consume the carbon in liquid manure storage. This occurs because of the lack of oxygen in liquid manure. Manure management accounts for 82% of the hog industry GHG emissions (Environment Canada, 2006).

Nitrous oxide is generated when manure and/or commercial fertilizer is applied to cropland. Oxygen is limited in saturated soils, such as after spring snow melt, and because of this soil bacteria consume nitrate nitrogen (NO_3) to utilize oxygen and thus produce nitrous oxide as a byproduct (Macleod, 2005a). Table 2.1 provides an illustration of the weights from different emission sources in the hog sector. Enteric fermentation only generates 9% of the Canadian hog sector GHG emissions, which is significantly different from ruminants such as beef cattle and dairy cattle.

Table 2.1 1996 Emissions from the Canadian hog industry (Tg CO_2 equivalent)

Source	**CH_4**	**N_2O**	**Total**
Manure	2.47	0.81	3.27
Enteric fermentation	0.37		0.37
Leaching		0.23	0.23
Atmospheric deposition		0.12	0.12
Total	**2.84**	**1.16**	**4**

Source: Canadian Pork Council, 2002b

2.1.3 Best management practices

If a carbon market is established, then a producer who changes a management practice that reduces GHG emissions, and can verify these reductions, could be eligible to receive carbon offset credits that could be sold in the market (Voss, 2005). The GHG Mitigation Advisory Committee (GHGMAC) was assigned to identify BMPs that would reduce GHG emissions and some BMPs were associated with hog production. A number of scientific experiments were undertaken on farms, such as Doug Small's test on four barns (800 weaners) in Manitoba in 2006. This experiment achieved carbon reductions by adopting wet/dry feeders, phytase enriched feed rations, countercurrent heat exchange, pit separations, and a night setback device. It was estimated that a reduction of 2.92 tonnes of CO_2e per barn was generated, which can be extrapolated across Canada to be 36.7 million tonnes of potential GHG emission reductions (Small et al., 2006).

2.1.3.1 Barn management

Barn management focuses on maximizing barn operating efficiency. This can include reducing the GHG production in the barn operation both directly and indirectly. According to Macleod (2005a) and Small et al. (2006), there are three main areas in barn management where a hog producer might reduce GHG emissions.

- Barn climate control

Maintenance, such as cleaning the fans and heating system, can save energy while keeping the barn atmosphere clean and warm. This reduces GHG emissions from reduced fossil fuel combustion. A good illustration of this is the Counter Flow Heat Exchanger designed for a minimum ventilation rate in Small's experiment. Climate control systems that use electricity, propane or natural gas can also save energy.

- Water management

Water conservation can improve feed efficiency and reduce water waste. Wet/dry feeding systems reduce the manure volume significantly; 29% manure reduction in Prairie swine research (Macleod, 2005a) compared with dry feed or nipple drinkers. Moreover, wet feed can also provide a higher feed conversion rate than dry feed. Other options to save waste water involve low-cost drinker bowls that control the drinking flow rate, etc.

- Barn scraper system

Scraper systems increase the frequency of manure removal from the barn and thus reduce GHG emissions. Some new scraper designs can separate urine and faeces at the time of production.

2.1.3.2 Feeding strategies

Macleod (2005a) proposed several feeding options for reducing GHG emissions:

- Feeding should be designed to minimize feed waste, and deliver higher feed conversation efficiency, which reduces the feed carbon not used by the animal and transferred into the manure.
- Adjusting the content of rations also reduces GHG emissions. Adding phytase

to rations can reduce the phosphorus in excretion, which also delivers more frequent slurry spread in the barns and improves hog digestion (Small et al., 2006). Reducing fibre intake or increasing fibre digestibility can reduce the methane produced during bacterial fermentation as well as in the manure.

- Split-sex and phase feeding programs provide rations that are more precisely formulated to meet the pigs' nutrient requirements and minimize subsequent over- or under-feeding of nutrients that may reduce growth performance. These practices can increase feed efficiency and reduce the nitrogen in manure. Increasing the number of feeding phases can also reduce the feed crude protein with the lowest impairment in animal performance.
- Reducing feed crude protein can reduce the carbon and nitrogen content in manure. By reducing the dietary crude protein content of rations by 1%, manure nitrogen excretion is reduced by approximately 10%. In the Prairie swine research, low protein diets can generate a nitrogen reduction of 26%-40% in the manure (Macleod, 2005a). According to the Canadian Pork Council, nitrogen excretion reduction can also be obtained through the following options (Canadian Pork Council, 2002b):

a) A more precise protein intake to meet the nutrient requirements, avoiding protein over-feeding.

b) Increasing the quality of diet protein and reducing the amount of protein intake.

c) Phase-feeding, which changes the nutrient content in a series of diets formulated to meet animal nutrient requirements more precisely at a particular stage of growth (USDA, 2003a).

d) Finding the optimal dietary rations for both economic and environmental perspectives.

Table 2.2 illustrates the nitrogen output reduction for 1000 feeders raised from 50 lbs to 220 lbs, if the crude protein in feeds is reduced by 0.5%. An intake dietary protein reduction of 20% will reduce nitrogen in the excretion by 20 to 30% and the carbon dioxide by 5%, which leads to a greater reduction in nitrous oxide and methane release from manure application to croplands. These reductions could be achieved with little or no additional costs, and without impairing animal performance. Thus, reducing dietary protein intake is recognized to be the most efficient way of reducing swine GHG emissions.

Table 2.2 Manure nitrogen output on two feed crude protein levels

Ration	**High CP (%)**	**Low CP (%)**
Grower	19.5	19
Finisher I	17.5	17
Finisher II	17	16.5
Manure Nitrogen	**5,678 (kg)**	**4,220 (kg)**

Source: Macleod, 2005a

2.1.3.3 Manure storage management

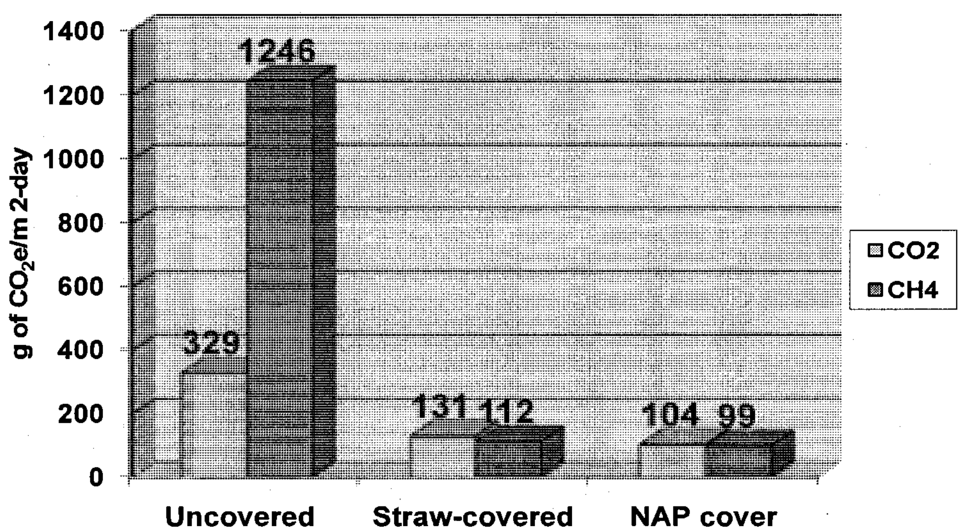
Conventional ways of storing manure in slurry or solid form generate GHG emissions. GHGs are produced when bacteria decomposes liquid manure carbon into methane because of the lack of oxygen. Several factors affect GHG emissions from manure such as: moisture and temperature conditions for the microbes, manure storage type (slurry or solid form, closed or open container, manure cover system), and the animals' diet.

Rapid transfer of manure by scraper or belts systems to storage facilities can reduce GHG emissions in the barn. Composting manure also reduces GHG emissions during storage and application. It is a biological process where dry carbon-rich material is added to balance its humidity and Carbon/Nitrogen ratio, and thus transfers manure into a stable, clean and organic-rich product (Canadian Pork Council, 2002b). Guelph University has experimented with combining liquid manure and chopped barley straw in a composter, and keeping the composted material at a high temperature for a certain number of days. As a result, the emission of methane was significantly reduced after the composting (De Vos et al., 2003).

Synthetic storage cover systems can capture methane, ammonia, and odor while keeping the manure from being diluted by rainwater. Technologies for manure cover systems include: non-air-tight covers, air-tight covers, and anaerobic digester systems. Figure 2.3 identifies the significant GHG emission reductions from using a straw cover and a negative air pressure cover respectively. Concentrating methane from manure allows it to be burnt and can generate a twenty-fold reduction in emissions as methane is converted to CO_2 (Macleod, 2005b).

Anaerobic digestion systems, which produce highly concentrated methane by heating and stirring the slurry manure continuously, generate a large amount of methane that can be combusted to provide heating or electricity for the farm. Some carbon markets, such as the Chicago Climate Exchange (CCX), accept the use of anaerobic digestion systems as a means of generating GHG reductions. However anaerobic digesters require a significant investment, which can be in excess of $500,000 for every 1000 animal-space on the farm, compared with $85,000 for an air-tight cover and $40,000 for a non-air-tight one.

Figure 2.3 GHG emissions reduction under covers



Source: Macleod, 2005b

2.1.3.4 Manure application

Nitrous oxide (N_2O) accounts for over 50% of agricultures' GHG emissions (Environment Canada, 2006). It is generated after manure is applied to cropland when the temperature is warm, especially in late fall or the subsequent spring.

Efficient manure nitrogen application avoids spreading manure when the soil is saturated. This change in practice will reduce a farm's N_2O emissions. For example, spreading manure right after crop emergence, when the crop can consume the nitrogen immediately, can improve the nitrogen efficiency. Applying manure in the fall should be avoided. Ploughing-down of nitrogen-rich crops, such as legumes, also has to be scheduled carefully.

Other examples of better cropland nitrogen application practices include (Canadian Pork Council, 2002b):

- Matching fertilizer to plant needs.
- Avoiding excess manure applications.
- Improving soil aeration.
- Using better fertilizer formulations.
- Using appropriate fertilizer placement by injecting fertilizer close to the crop roots.
- Employing nitrification inhibitors.

Growing shelterbelts and having grasslands around a hog farm have been proposed as an indirect means of reducing GHG emissions because plants can sequester carbon dioxide from the atmosphere and store it in the soil. Shelterbelts protect the soil from wind erosion; and reduce GHG emissions from fossil fuel combustions for heating and ventilation.

Macleod (2006a) developed a list of the top ten BMPs for Canadian hog producers (Table 2.3). This list was generated so that producers could evaluate their operation for potential management changes.

Table 2.3 Top 10 Best Management Practices for Canadian hog producers

Increase feed conversion rate
Lower hog ration crude protein levels
Reduce overall barn water use
Install a manure storage cover
Regularly monitor manure and soil nutrient levels
Apply manure nitrogen at agronomic rates only, offer excess nitrogen for sale to others
Switch manure application timing from fall to spring/early summer
Apply manure using injection techniques for small grain, forage and row-crops
Install manure flow rate meters on application equipment to achieve accurate application rates
Install an anaerobic digestion system to produce on-site green heat and electrical energy

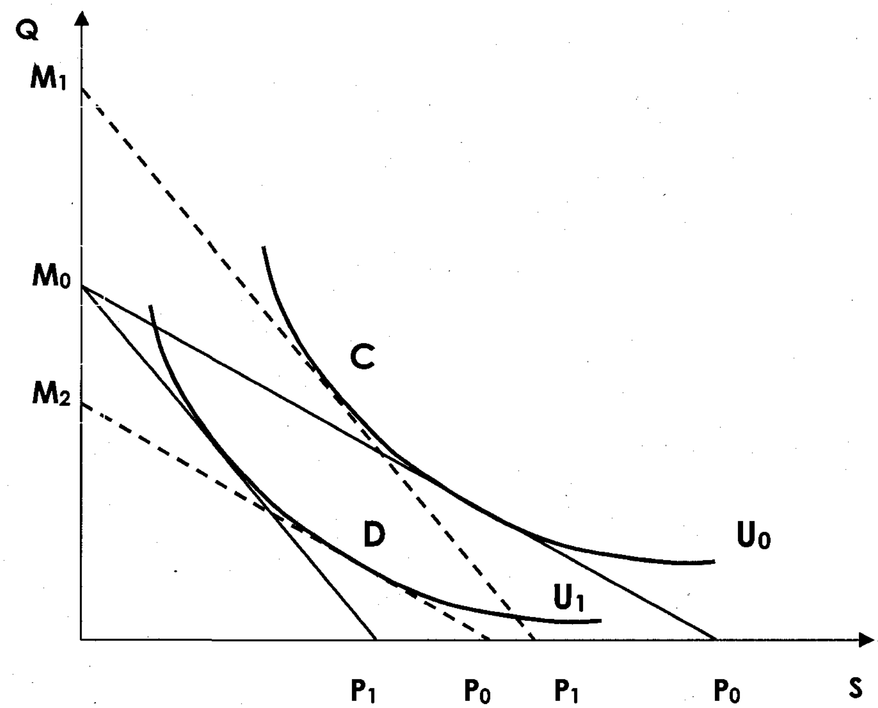
Source: Macleod, 2006a

2.2 Measures of welfare

2.2.1 Welfare theory

In economics individual welfare is measured with utility. A rational person optimizes his/her welfare by maximizing their utility. A change in a hog producer's management practice would affect their utility level. This can be measured with either the Marshallian demand curve or the Hicksian compensated demand curve. Marshallian demand curves can be used to estimate consumer surplus, while Hicksian compensated demand curves generate compensating variation and equivalent variation.

Figure 2.4 Compensating and equivalent variation for a price increase



Source: Johansson, 1991, p.50

An illustration of compensation and equivalent variation is given in Figure 2.4. On the axes are two goods; Q and S. The individual's initial situation is given by the subscript "0". The individual maximizes utility at the point of tangency between their budget constraints; M_0P_0; and their indifference curve U_0. Suppose there's a price increase for good S, which moves the budget line from M_0P_0 to

M_0P_1. The higher price brings the individual down to a lower utility level U_1, which is tangent to the new budget line M_0P_1. Compensating variation (CV) is defined as the amount of income that is needed to restore the individual to the original utility level U_0. This is illustrated with an upward shift of the budget line M_0P_1 to a parallel budget line M_1P_1, which is tangent to the original indifference curve; U_0. The income difference between budget lines M_1P_1 and M_0P_1 represents the CV.

The Equivalent Variation (EV) is measured at the original price level P_0, assuming that the price of good Q doesn't change. EV is defined as the decreased income from the utility change from U_0 to U_1. In Figure 2.4, EV is illustrated by a downward shift of the budget line M_0P_0 to make a new parallel budget line M_2P_0, and tangent to the new utility level U_1 at point D. EV can be measured by the income difference between M_0 and M_2 on the axis of good Q.

If the price of good S changes, it will generate an inverse effect on CV and EV, compared with the price change of good Q. That is, the compensating variation of a price increase is equal to the equivalent variation of a price decrease, and vice versa. Moreover, if there is only an income change, without a price change, then CV equals EV.

2.2.2 Welfare economics and Canadian livestock producers

If the existing management decisions of livestock producers maximize their utility, then a change in management will result in a welfare loss. This would correspond to a downward shift to a lower indifference curve due to the cost of the new management practice, where costs could be in terms of income, time, or risk. Therefore, to encourage producers to adopt management practices that reduce GHG emissions, they should be compensated for their welfare loss. A potential vehicle for making this compensation payment is revenue generated from the sale of carbon offset credits.

The Contingent Valuation Method (CVM) can be used to value non-market goods. It involves asking people, in a survey, to estimate their willingness to pay (WTP) or willingness to accept (WTA) compensation for a good or environmental service. The WTP is the maximum amount an individual is willing to pay to acquire some good or service. The WTA is the minimum amount of compensation an individual is willing to accept in exchange for giving up some good or service, or to change to a lower utility level.

2.3 Contingent valuation method (CVM)

2.3.1 History and development of CVM

Ciriacy-Wantrup (1947) first introduced the idea of using a direct interview method to elicit the value of natural resources. Davis (1963) was the first to apply this method to value a non-market good. His study interviewed hunters to estimate their value for big game hunting. Since then, CVM has become a popular survey-based method for valuing non-market goods such as pubic goods and environmental amenities or services.

Cummings, Brookshire, and Schulze (1986) and Mitchell and Carson (1989) made recommendations to improve the quality of CVM studies. Some of the recommendations included having respondents become familiar with the commodity that was being valued and that the survey should take into account respondent uncertainty. Through the 1980s to the early 1990s, CVM was used to estimate the value of a variety of non-market goods. One of its most controversial uses was to estimate the amount of compensation for environmental damage from the Exxon Valdez oil spill. The controversy over the estimated compensation resulted in the establishment of a Blue Ribbon Panel of economists to investigate the reliability of the approach. The panel, established by the National Oceanic and Atmospheric Administration (NOAA, 1993), accepted this approach for non-market valuation but made recommendations on its use. These recommendations included an extensive and specific set of guidelines for contingent valuation survey design, administration, and data analysis.

2.3.2 Mechanism of CVM

Mitchell and Carson (1989) defined the CVM framework to include sampling, questionnaire and scenario design, survey implementation and data collecting, statistical analysis and elicitation of WTA or WTP, and finally a validity analysis. Specifically, they defined a well-designed contingent valuation study to comprise three major components (Mitchell and Carson, 1989):

1. A detailed description of the good or service being valued and the hypothetical circumstance under which it is made available to the respondent.

CVM researchers create and develop a hypothetical market in which the good is valued. This market description should be realistic and in enough detail. Items to be included are: a description of the good, the baseline provision level, the structure and rules of the provision, and the payment vehicle.

2. Questions should elicit individuals' WTP/WTA for the goods or service. The purpose is to facilitate the valuation process without introducing WTP/WTA biases.
3. Questions should be asked about the respondents' characteristics; such as their demographic information, their preference towards the good being valued, and their use of the good.

2.3.2.1 Population and sampling

Once the good and policy change are specified, the affected population can be identified. The survey population consists of all individuals, households, or organizations, to which one wants to generalize the survey results to (Dillman, 2000).

CVM studies try to find the aggregate value of the good or service for the target population associated with the policy change. In order to do this, a random sample needs to be selected. Sampling is particularly important because it directly impacts the elicitation of WTP/WTA as well as the statistical analysis. To reach the statistical precision and reliability, Mitchell and Carson proposed two ways of sampling (Mitchell and Carson, 1989): (1) to use a sufficiently large sample size, and (2) to use robust statistical techniques to offset the outliers.

Mitchell and Carson (1989) note that CVM requires large sample sizes due to the large variance in the responses. The standard error of mean WTP/WTA is:

$$SE_{WTP/WTA} = \frac{\sigma}{\sqrt{n}}$$

Where σ is the standard deviation, n is the sample size. For a given variance, the standard error can be reduced by increasing the sample size. Much of the CVM variance is the result of the diversity of opinion in large heterogeneous populations. The variance of WTP/WTA is expected to be smaller from homogeneous subgroups (such as agricultural producers) than from the general population. Another consideration when selecting a large sample is the expected response rate.

Dillman (2000) suggests that the following items should be considered when selecting a statistical sample. First, a correctly defined sampling frame must be determined. Second, the sampling frame must coincide with the population. Finally, each individual in the population must have an equal and positive probability of being selected in the sample.

2.3.2.2 Survey types

Sample selection is also affected by the type of survey to be implemented. Surveys can be distributed via mail, telephone, or in person. The choice of survey type is determined by the nature of the research, the characteristics of the sample, and the research budget. In person surveys can achieve a high response rate but require significant human and financial resources. Telephone and mail-in surveys are more cost-effective and allow for a widespread distribution. Mail-in surveys are widely adopted for large sample size CVM studies.

The drawbacks of this method are a low response rate, high non-item response rates, and time delays (Dillman, 2000).

2.3.2.3 Scenario design

The scenario design of a contingent valuation study must be understandable, realistic, and incentive compatible in order to offset its hypothetical nature. In order to do this the following four elements should be included: a) a description of the good being asked to value, b) the hypothetical market, c) the payment vehicle, and d) the elicitation method (Mitchell and Carson, 1989).

The research literature clearly indicates that a specific and accurate description of the good being valued is necessary to elicit credible responses. The NOAA panel proposed an accurate description of the good as one guideline for reliable contingent valuation estimates (NOAA, 1993). The description of the good effects the value estimates because it relates to the personal relevance of the good to the individual (Ajzen, Brown, and Rosenthal, 1996). Bishop et al. (1995) suggest several items that should be included for an accurate description of the good. These are: the attributes of the good, reference and target levels, the source of policy change, the extent and time of the change, and the certainty of the change (Bishop et al., 1995).

Failure to define the good can lead to misspecification bias, which means the good being valued by the respondents is not the actual good (Mitchell and Carson, 1989). Testing draft scenarios in focus groups can help to avoid this type of bias. Focus group testing allows the researcher to learn if respondents use the information provided, understand and believe the information, and base their valuation on the actual change being valued (Champ et al., 2003).

The second component of the scenario design is a description of the hypothetical market. It usually begins with a definition of the property rights. Based on the property rights and the nature of the good, markets can be either private or public.

The payment vehicle is a mechanism or policy design through which the monetary payment or compensation will be made. Mitchell and Carson suggested that the payment vehicle should be realistic but also prevent rejection responses (Mitchell and Carson, 1989). The respondents may reject the valuation if they think the payment vehicle is not believable. Various payment vehicles have been applied by CVM researchers (Table 2.4).

Table 2.4 Recent examples of payment vehicles selection

Payment Vehicle	
Income taxes	Loomis and du Vair, 1993
General increase in prices and taxes	Boyle et al., 1994
Admission fee	Lunander,1998
Utility bill	Powell, Allee, and McClintook, 1994
Recreation trip cost	Duffield, Neher, and Brown, 1992
Donations	Champ et al. 1997

Source: Champ et al., 2003

Studies show that the payment vehicle can significantly influence WTP/WTA estimates. Therefore Sutherland and Walsh (1985) argue that the payment vehicle should be neutral with respect to the good in order to not influence the WTP/WTA values. The design of the payment vehicle can also be refined through a focus group pretest.

2.3.3 Elicitation methods of CVM

2.3.3.1 Continuous and discrete choice methods

Different contingent valuation elicitation methods can result in divergent welfare value estimates. Elicitation methods are classified as continuous or discrete choice methods. Studies indicate systematic and significant differences in the values obtained from different elicitation methods (Champ et al., 1996).

Continuous methods include the open-ended (OE) format, bidding game (BG), and payment card (PC). Early contingent valuation studies used either OE or BG. The OE format directly asks the respondents to write down their maximum WTP/minimum WTA for the good. The BG format starts by asking whether they would pay/accept a bid for a good or a policy change, whereby the respondents can either accept or reject this initial bid $X. If the respondent accepts it, the bid will be increased until they say no (in a WTP case). If they reject the initial bid, the bid will be decreased until they say yes. The PC method lists a series of values from which the respondent chooses one value that best represents their maximum WTP.

BGs are no longer used in light of the evidence that the final bid is significantly correlated with the initial bid, i.e., the higher the initial bid the higher the final bid on which the respondents would accept (Boyle et al., 1985).

OE is still used in some studies.

In contrast with continuous methods, discrete choice methods give respondents a discrete bid value and ask for their WTP/WTA. The most widely used discrete choice methods are the dichotomous choice model (DC) and the multiple bounded discrete choice model (MBDC).

DC was first introduced by Bishop and Heberlein (1979). It asks respondents to pay a bid price for a good or policy change. It generates a binomial distribution of yes/no answers to see if their WTP is greater or less than the set amount. Recent studies have used double-bounded dichotomous choice questions that include a second round of bidding. Some researchers prefer DC while others argue that the lack of consistency across values is problematic (Welsh and Poe, 1998). Most of the studies comparing OE with DC found that DC tends to consistently estimate higher WTP than OE.

Many studies compare the continuous elicitation methods with discrete methods. Ready et al. (1996) suggest that continuous methods such as OE and PC are able to elicit more information of WTP/WTA, and are statistically more efficient because they make direct point estimates, whereas discrete methods only generate estimate intervals of WTP/WTA.

Champ et al. (2003) argue that each of the methods has strengths and weaknesses (Table 2.5). They consider DC as having "desirable properties for incentive compatible revelation of preferences" (Champ et al., 2003, p.137), compared with continuous methods where respondents can state their willingness at a very high or very low dollar amount. Both PC and DC require bid designs. Alberini (1995) suggests the ideal number of bids is 5 to 8, with a median equal to the median WTP/WTA. In terms of estimating central tendency, OE provides the most efficient estimates while DC provides the least efficient ones (Champ et al., 2003).

Table 2.5 Comparison of contingent valuation methods

	OE	PC	DC
Theoretically incentive compatible	No	No	Has some desirable properties
Bid design required	No	Yes	Yes
Responses statistical efficiency	Continuous	Interval	Interval
Potential problems	Zero bids, fair share responses	Anchoring	Anchoring, yea saying, voting as good citizen

Source: Champ et al., 2003, p.137

Although continuous elicitation methods are considered advantageous and statistically more efficient over discrete methods, their estimates may yield high variability due to unimportant information provided in the scenario (Arrow et al., 1993). This is because the respondent is usually unfamiliar with the good or policy change. Therefore, they are believed to result in an unusually high percentage of $0 responses (Carson et al., 2000).

Both PC and DC face an anchoring problem associated with the bids interval design, that is, respondents consider the given bid amount to be a good estimate of the true value of the good or policy being valued (Mitchell and Carson, 1989). OE is therefore supported by some researchers to avoid anchoring on bid amounts (Green et al., 1998). Another disadvantage of DC is "yea saying", which means some respondents say yes to any bid amount presented regardless of their true willingness. This results in a higher WTP estimates than OE. To avoid bias by anchoring and yea saying of conventional DC, the double bounded dichotomous choice method (DBDC) was introduced. Rather than simply looking at the WTP to be greater or lower than a set amount, some following-up questions are included in the DBDC to narrow down the range of respondents' true value. Studies have shown an improvement of statistical efficiency by using DBDC over conventional DC (Hanemann et al., 1991).

All of the above methods, OE, BG, PC, DC, DBDC, are based on an assumption that respondents are certain about their true WTP. However in reality, people may be uncertain about their own preferences or utility functions. To bring uncertainty into CVM studies, Ready et al. (1995) proposed the polychotomous choice method, which allows respondents to express their degree of certainty with respect to each dollar amount by choosing six scales: definitely yes, probably yes, maybe yes, maybe no, probably no, and definitely no. Ready et al. (1995) found that respondents tend to choose scales conservatively, and a broader range of dollar amounts better reflects respondents' uncertainty levels.

2.3.3.2 Multiple bounded discrete choice method

The Multiple bounded discrete choice model (MBDC) was first introduced by Welsh and Bishop (Welsh and Bishop, 1993). It employs a two dimensional matrix as the elicitation question, whereby the rows delineate a range of referendum thresholds, and the columns list different levels of voting certainty associated with each dollar threshold, such as "definitely yes", "probably yes", "not sure", "probably no", and "definitely no".

An advantage of MBDC is that it incorporates respondents' uncertainty levels into the study, and therefore it's more efficient from a statistical point of view, because the statistical analysis can reflect different certainty degrees. For example, a low certainty level of respondent can be recognized when choosing the switch interval from "probably no" to "do not know", and vice versa, a high certainty level can be recognized when the switch interval is from "probably yes" to "definitely yes". A switch interval from "do not know" to "probably yes" would be considered as an intermediate certainty level. The broader the range from "definitely no" to "definitely yes", the more uncertain the respondent is.

Welsh and Poe (1998) did a comparison between MBDC and other formats such as OE, PC, and DC. They found that while MBDC maintains the discrete choice technique, it allows estimates of various mean WTP that would be obtained by other elicitation methods. Furthermore, MBDC provides "higher levels of precision and at the same time avoids many of the difficulties associated with the choice of offers required to implement either a single bounded or double bounded model" (Welsh and Poe, 1998, p.182). Moreover, MBDC bid design allows respondents to see the full range of bids at the beginning so that they are able to strategize their response to generate a consistent valuation (Loomis and Ekstrand, 1997).

Despite all these advantages, MBDC has potential drawbacks. MBDC implicitly assumes that all respondents use the same criteria to choose the certainty levels, which is not necessarily true (Loomis and Ekstrand, 1997). MBDC is also subject to the range bias found in PC applications, starting point bias (Boyle et al, 1985; Whitehead, 2002; Alberini et al., 2003; Vossler et al., 2004), and sequencing bias (Hanemann, 1994; Halvorsen, 1996; Dupont, 2003).

2.3.4 Validity

Mitchell and Carson (1989) defined validity to be the degree to which the CVM measures the theoretical construct, that is the maximum payment the respondents would actually pay if the hypothetical market did exist. They incorporated three types of validity from the psychological literature.

Content validity, also named face validity, deals with the extent that the CVM implementation reflects the market structure and the scenario description of the good. It usually contains a qualitative examination of the survey instrument, that is, the wording of the scenario design. The content validity needs to be assessed by a panel of experts in that domain.

Criterion validity exams the degree to which the CVM measure is consistent with existing criteria of other alternative measures. Studies found that simulated markets trading public or quasi-private goods may provide such criterion. Mitchell and Carson (1989) employed a series of hypothetical-simulated market (HSM) experiments to compare the hypothetical markets with simulated markets, and found this criterion validated the private and quasi-private good studies. However they also found a lack of validity for CVM that measured pure public goods because of the hypothetical nature of CVM studies.

Construct validity refers to the extent to which the CVM relates to other theoretical measures (Mitchell and Carson, 1989). It includes convergent validity and theoretical validity. Convergent validity measures the convergence between CVM and other measures of the same construct. Mitchell and Carson (1989) found strong convergence validity after examining results of CVM with that of travel cost and hedonic pricing models. Bishop and Heberlein (1984) also found consistent results between them. Theoretical validity measures the consistency of CVM results with economic theory. It is assessed by estimating a regression analysis of the WTP/WTA based on socioeconomic variables that theory suggests may influence WTP/WTA.

Chapter 3: Methodology

3.1 The population and sample

Statistics Canada's 2006 Agricultural Census reported that there were 1,932 hog farms in Quebec (Statistics Canada, 2007a). A sample of 1,371 hog farms were used in the survey. Names and addresses of the hog farms were provided by the FPPQ. The difference between the sample number and the population number is due to the fact that many Quebec hog farms are aggregated. The FPPQ only provided one name and address for an aggregation instead of each individual farm within the aggregation. Therefore the 1,371 sample is believed to cover all the 1,932 hog farms in Quebec.

The sample was divided into four categories; with each category receiving a different questionnaire version. A-1, A-2, and D-1 versions of the survey were mailed to 343 addresses, while version D-2 was mailed to 342 addresses. Addresses were randomly selected and assigned to the different versions.

3. 2 The survey instrument

3.2.1 Questionnaire development

The questionnaire was developed using the Tailored Design Method (Dillman, 2000). This method aims at maximizing response rate and minimizing non-response errors. The survey was a booklet of 8 pages with the title "Les émissions de gaz a effet de serre et le secteur porcin" and a picture of a hog farm provided by the FPPQ on the cover page. The second page contained the instructions of how to fill out the questionnaire (Appendix 1).

Pages 3 to 8 included 20 questions with 3 hypothetical scenarios. It was divided into 5 parts: basic information, scenario 1, scenario 2, scenario 3, and other information.

The basic information provided a definition of a carbon offset credit. It was defined as a credit for a management decision that removes or reduces an amount of greenhouse gas emission from the operation. Carbon offset credits would be measured in terms of 1 tonne of Carbon Dioxide Equivalent (CO_2e). Following this were scientific facts about GHG emissions in hog operations and the potential of generating a revenue flow from adopting BMPs was briefly introduced to the respondents. Question 1 asked their choice of charity they would like to support, in appreciation of their completion of the survey. Question 2 and 3 asked their type of operation and the numbers of different types of hogs on the farm. These questions were designed to provide information about the producer's operation and business size. Question 4 asked about their knowledge of management practices that reduce GHG emissions, where respondents could choose their knowledge level on a scale from 1 to 5. Question 5 asks them to choose one or more government initiatives that would best encourage them to adopt BMPs.

Scenario 1 describes a hypothetical BMP that reduces crude protein feeding. It then asks producers to identify their WTA compensation to change from their existing feeding strategy to this new feeding strategy. The scenario starts with an all-in-and-all-out operation for all respondents. More than 80% of Quebec hog farms operate as all-in-and-all-out, i.e., the animals come in and exit the barn at the same time and new animals only come in after previous ones are shipped out. The rest, less than 20% of Quebec hog farms, use a rotational operation. All-in-and-all-out operations do not require additional facilities for changing feeding strategies; such as decreasing the crude protein content, while rotational operations may require more feeding capacity to prepare the additional feeding rations.

Scenario 1 presents the respondents with an all-in-and-all-out operation and requires a decrease in feeding crude protein content by 3%; i.e. from 17% to 14%. This results in a feed cost savings of $1.15 per ton of feed because of the lower cost of the ingredient, after deducting the additional milling cost. This feed cost saving was estimated by consulting academic and industry experts. Adopting this management practice would generate carbon offset credits, however there would be additional administrative costs; such as submitting a change in management plan, approval costs, monitoring and verification costs. Therefore, net carbon credit revenue for hog producers can be formulated as:

$$\text{NET CARBON OFFSET REVENUE} = \text{Carbon Offset Credit Revenue} - \text{Administrative Costs}$$

Question 6 elicits producers' WTA compensation for adopting this feeding strategy. A multiple bounded discrete choice method was used to solicit the WTA compensation. The rows of the matrix contained six bid thresholds of "net carbon offset revenue per animal space per year": \$0.009, \$0.18, \$0.27, \$0.45, \$0.90, and \$1.80, which respectively corresponds to a carbon offset credit price of: \$0.50, \$10, \$15, \$25, \$50, \$100 / tonne of CO_2e. It is worth mentioning that "animal space" is equal to a producer's barn capacity. For example, if one has a 100-sow barn, it equals 100-animal spaces; and for a 2,000-head finisher barn, this equals 2,000-animal spaces. The columns of the matrix had six different certainty levels: definitely yes, maybe yes, neutral, maybe no, definitely no, and not sure. Producers were asked to select a certainty level for each net carbon offset revenue level. The net carbon offset revenue was measured on a "per animal space" basis as a response to producers' requests during the pre-test and focus group meetings.

Question 7 gathers data on the crude protein level that producers currently use. Question 8 asks their attitudes towards the new feeding strategy and whether they would be willing to adopt it or not. Question 9 explores their concerns for not adopting this management practice if they choose a negative answer in Question 8. Five reasons were listed.

Placing a manure storage cover system is the change in management strategy in scenario 2. It starts by describing the reduction in methane emissions that would occur with a manure cover system. The manure cover system in the scenario was a non-air-tight synthetic cover system that costs \$40,000 per 1,000 animal spaces and had a life span of at least 10 years. Non-air-tight synthetic covers include negative air pressure covers for earthen base storage and non-air-tight tank covers specifically designed for round concrete tank storage widely used in Quebec. Allocating the cost over its life span; 10 years, was $4 per animal space per year. Additionally, based on the calculation of Macleod (2006b), the nitrogen fertilizer value of the manure will almost double by installing a synthetic cover system. As with Scenario 1, there are administrative costs associated with this change in practice in Scenario 2, and the net carbon offset revenue was set equal to the difference between the carbon offset revenue and the administrative costs.

Question 10 elicits the producers' WTA compensation for installing a non-air-tight synthetic cover system. A multiple bounded dichotomous choice method was used to solicit the WTA compensation. The rows listed six bid values of net carbon offset revenue per animal space: $7.00, $17.50, $35.00, $42.00, $52.50, and $70.00, respectively corresponding to a carbon credit price of $10, $25, $50, $60, $75, and $100 per tonne of CO_2e. The bid range starts at a higher level because the significant investment required at the beginning results in higher risk and uncertainty associated with this BMP, therefore producers' WTA compensation was expected to be higher. The columns of the matrix represented six certainty levels from definitely yes to definitely no.

Question 11 gathers information whether the respondent already has a cover system and the type of system in use. Question 12 asks about their attitudes toward adopting this management practice. Questions 13 lists five concerns for those who responded negatively in Question 12. This question was added because some respondents were concerned about the creditable life span of synthetic covers during the pretest.

Scenario 3 used a different approach to estimate the producers' willingness to change management practices. Instead of asking producers' WTA compensation from a carbon offset revenue flow, Scenario 3 poses the question in terms of their willingness to absorb costs in order to receive a certain level of carbon offset revenue. This scenario was expected to examine respondents' consistency with the above two revenue scenarios. The baseline carbon offset revenue generated from the change in management was $20 per animal space per year, with a carbon offset credit price trading at $20 per tonne of CO_2e.

Question 14 is the elicitation matrix that seeks to reveal producers' willingness to bear the costs for the new revenue. The rows are seven bid values of total cost per year per animal space: $1, $5, $10, $15, $20, $22, and $25. The columns contain six certainty levels. Respondents were asked to check one certainty level for each total cost level.

The last part of the questionnaire asks other information from the producers. Question 15 asks the producer's preference between the two management practices presented in Scenario 1 and 2. Adopting a manure cover system has a longer time horizon associated with it, higher risk and uncertainty levels, and a higher carbon offset revenue reward as compared to the reduced protein feeding scenario. Therefore, those who preferred the manure cover were expected to have a stronger willingness to adopt a new management practice for carbon offset credit revenue. Respondents could specify their reasons for their preference. Questions 16 through 19 ask the producer's gender, age, highest education level, and family income before tax in 2006. The last question, Question 20, collects comments from producers about the survey.

The questionnaire was designed in four different versions: A-1, A-2, D-1, and D-2, in order to investigate the influence on the WTA estimates resulting from the order of scenarios and ascending-descending sequence of the carbon credit bid amounts. A and D represent Ascending and Descending sequencing of bid values; while 1 and 2 represent different orders of Scenario 1 and Scenario 2. Since the survey was undertaken only in Quebec, all questionnaire versions and introduction letters were in French.

3.2.2 Questionnaire delivery

The survey was conducted in a multiple mailing fashion based on the Tailored Design Method (Dillman, 2000). Prepaid envelopes were included with the questionnaires to encourage responses. All mailings were conducted from the FPPQ's office in Longueuil, Quebec.

The first mailing was mailed out in the middle of May 2007. It contained the questionnaire and an introduction letter that stated the objectives, the confidentiality, and the voluntary nature of the study. Approximately 2 months after, a thank-you letter plus reminder was sent out to all respondents. Almost 3 weeks after, a third mailing was sent out to those who had not responded. It contained a replacement questionnaire and a cover letter that emphasized the importance of completing it.

3. 3 Specification of the model

3.3.1 Definition of variables

Dependent variable

For the reduced protein feeding and manure cover scenarios, the dependent variable was the probability that a hog producer would reject a carbon credit bid amount as the WTA compensation for adopting a best management practice. For the cost scenario, the dependent variable was defined as the probability that a producer would accept a cost level in order to gain $20 of carbon offset revenue. The dependent variable was assumed to be a logistic cumulative distribution, which implies that as the bid price increases, the probability of rejecting it decreases. Producers' WTA compensation can be estimated according to the logistic distribution.

Order 1 (Ord1)

This was a dummy variable that represents the ascending / descending order of the carbon credit bid price. Ascending order was assigned the value of "0" while a descending order was given the value of "1". The impact of this variable was not known in advance.

Order 2 (Ord2)

This was a dummy variable that represents the different sequences of the scenarios; i.e., reduced protein feeding or manure storage cover. If the reduced protein feeding scenario appeared first in the questionnaire, then a value of "0" was assigned. If the manure storage cover scenario appeared first, then a value of "1" was assigned. Therefore, the A-1 version was represented as "0, 0", the A-2 version was "0, 1", the D-1 version was "1, 0", and the D-2 version was "1, 1". The impact of the sequencing was not known a priori.

Type of operation (Type)

This variable referred to the five different types of hog operations: farrowing, grower, finisher, farrow to finish, and others. Values of "1", "2", "3", "4", and "5" were given to those operations respectively. Farrowing and grower operations don't need large numbers of animals and thus were suitable for producers with small size farms, while finisher and farrow-to-finish operations require an economy of scale and need a large number of animals. Thus, it was hypothesized that producers with finisher and farrow-to-finish operations required a lower level of compensation for adopting a management practice change, compared with those with farrowing and grower operations.

Numbers of animals (Num1, Num2, Num3)

This variable included numbers of sows, weaners, and feeders, respectively referring to Num1, Num2, and Num3. It was hypothesized that the numbers of animals were negatively correlated with producers' WTA compensation.

Knowledge of BMPs (Kl)

This was a dummy variable that defines producers' knowledge of hog management practices that can reduce GHG emissions. It used a scale of 1 to 5, where "1" means a lot of knowledge, and "5" means no knowledge. Levels 1, 2, and 3 were given a value of "1", and levels 4 and 5 were given value of "0". The better knowledge of BMPs a producer has, a lower WTA compensation was expected.

Bid (Bd1... Bd6)

Bid value of carbon credits was hypothesized to negatively impact the dependent variable. That is, the higher the given carbon credit price, the higher carbon credit revenue generated by adopting the BMPs, and the smaller the probability that hog producers would reject that bid amount as their WTA compensation.

Protein level (Pl)

This variable referred to the crude protein level currently used by producers. It was hypothesized that producers already using lower protein content in their feeding would be more experienced and inclined to adopt the reduced protein feeding strategy, thus they would require lower WTA compensation.

Manure storage cover (Cover)

This variable reflected whether or not the producers already had a manure storage cover system. Those who had already adopted it received a value of "1" and were expected to ask for less compensation from the carbon offset revenue.

Attitude toward Reduced Protein Feeding (AtP)

In question 8 respondents were asked to express their attitude towards adopting reduced protein feeding from 17% to 14%. This variable was set as a dummy. Those who had a positive attitude toward it were given a value of "1" and expected to require less compensation from carbon offset revenue.

Attitude toward Manure Storage Cover System (AtC)

This was also a dummy variable similar to the previous one. It reflects a producer's attitude towards adopting a non-air-tight synthetic manure cover system. Those who were willing to adopt it were assigned a value of "1" and were expected to have a lower WTA compensation. Thus, AtP and AtC were both expected to be negatively correlated with WTA compensation.

Preference between 2 management practices (Pref)

In Question 15 producers were asked to choose between the two hypothetical management practices in Scenario 1 and 2. This variable was a dummy variable. Those who chose reduced protein feeding were assigned a value of "0" and those who chose the manure cover were given a value of "1". Those who preferred the manure cover system were expected to require less WTA compensation.

Education (Ed1, Ed2, Ed3, Ed4)

Four levels of education were listed: primary, secondary, some post-secondary, and university. Four dummies from Ed1 to Ed4 were constructed to represent each education level. Respondents with higher education such as Ed3 or Ed4 were expected to be more knowledgeable of the BMPs to reduce GHG emissions and would be more comfortable with adopting these management practices. Thus, a higher education level was hypothesized to result in a lower WTA value.

Income (In1, In2, In3, In4, In5)

Five dummies were generated for the five family income levels before tax: In1-\$0—20,000, In2-\$20,001—35,000, In3-\$35,001—50,000, In4- \$50,001—100,000, and In5-\$100,000 and above. Based on economic theory, individuals with higher income would be expected to have a lower marginal value of money. Likewise hog producers with higher income levels would require less compensation than producers with lower income. Thus, a negative correlation between income level and WTA value was hypothesized.

Gender and Age (Sex, Age)

Dummy variables were created to examine the influence of gender and age on a producer's WTA compensation. Some studies suggested that a younger producer would be more open-minded to environmental programs but the overall effect of these variables was unknown.

3.3.2 Models

Three regression models were constructed to estimate the mean WTA compensation for the three hypothetical scenarios that reduced GHG emissions. Model RPF is for the scenario of reduced protein feeding, Model MSC is for the manure storage cover system, and Model COST is for the cost scenario. The variables included in the various models are given below.

Model RPF:

WTA rpf = f (Bid, Ord1-2, Type, Num1-3, Kl, Pl, AtP, Pref, Sex, Age, Ed1-4, In1-5)

Model MSC:

WTA msc = f (Bid, Ord1-2, Type, Num1-3, Kl, Cover, AtC, Pref, Sex, Age, Ed1-4, In1-5)

Model COST:

WTA cost = f (Bid, Ord1-2, Type, Num1-3, Kl, Sex, Age, Ed1-4, In1-5)

3.4 Data analysis with the multiple bounded discrete choice method

Data analysis for the multiple bounded discrete choice model (MBDC) was introduced by Welsh and Poe (1998). The model uses the maximum likelihood estimation method, which estimates the vector of parameters to maximize the probability of obtaining the observed sample. It iteratively estimates the logit coefficients until the log likelihood of obtaining the observations is maximized.

MBDC analysis defines the dependent variable as the probability that a producer does not accept the bid amount as compensation to adopt the BMPs. In other words, it can be considered equivalent to the probability that the producers' WTA was higher than the given bid:

$$P(WTA > X) = 1 - F(X, \beta) = 1 - 1/(1+e)^{-(\alpha+\beta X)} \qquad (3.1)$$

Where X is the given bid value, □ is a vector of coefficients of independent variables that influent the producers' WTA value. F(X, □) is the probability function that producers accept the bid X when producers' WTA value is less than X. Welsh and Poe assumed that F(X, □) follows a logistic cumulative distribution (Welsh and Poe, 1998).

In regression with MBDC, the dependent variable is equal to the probability that the observation falls in a bid value interval. It can be illustrated with the cumulative density function:

$$P(X_{iL} < WTA < X_{iU}) = P(WTA < X_{iU}) - P(WTA < X_{iL}) = F(X_{iU}, \beta) - F(X_{iL}, \beta) \tag{3.2}$$

Where i represents individual observations, X_{iL} and X_{iU} are the lower and upper bounds of the bid interval where WTA compensation lies. Assuming each observation of WTA compensation was from the same probability distribution function, the likelihood function of the sample was the product of the probability of each observation. It can be illustrated as:

$$Likelihood = \prod_{i=1}^{n} \left[F(X_{iU}, \beta) - F(X_{iL}, \beta) \right] \tag{3.3}$$

A monotonic transformation using a natural logarithm function is usually applied to function (3.3) in favor of analytical simplification:

$$Ln(Likelihood) = \sum_{i=1}^{n} Ln\left[F(X_{iU}, \beta) - F(X_{iL}, \beta) \right] \tag{3.4}$$

The vector of parameters that maximize the likelihood function also maximize its logarithmic transformation. Based on the outputs of maximum likelihood estimation, Hanemann (1989) developed the method to calculate the mean WTA compensation:

$$MeanWTA = \frac{1}{\delta} \ln(1 + e^{\gamma\mu}) \tag{3.5}$$

Where □ is the coefficient of the bid, □ is the vector of coefficients of other explanatory variables, and µ is the vector of average values of the explanatory variables from the maximum likelihood estimation (MLE). Data analysis and regression was run using a GAUSS program developed by Welsh and Poe (1989).

3. 5 Hypothesis tests

3.5.1 Goodness of fit

In statistical theory, T-tests are a common statistic to examine the statistical significance of explanatory variables. However the logarithmic likelihood function in MLE is not defined, therefore other methods for testing the goodness of fit were proposed for MBDC models. These include the likelihood ratio test, the Lagrange multiplier test, and the Wald test. Among them the Wald test is argued to be the most advantageous. It can be specified as (Cuthbertson et al., 1992):

$$W = [R\beta - r]'[R(V)R']^{-1}[R\beta - r] \sim \chi_Q^2 \qquad (3.6)$$

Where R is a matrix of constraints with Q rows and K columns. Q is the number of constraints and K is the number of parameters. □ is a $K \times 1$ vector of estimated coefficients, r is a $Q \times 1$ vector of constants, and V is an estimated variance-covariance matrix of □. W has a χ^2 distribution with Q degrees of freedom.

When testing the joint significance with the Wald statistic, the coefficients on all the independent variables are hypothesized to be zero. The value of W can be calculated with this null hypothesis and the outputs from the regression of the MLE. The null hypothesis is rejected if the value of W is larger than the critical value of χ_Q^2, and vice versa.

3.5.2 Convolution approach

In order to test the differences among distributions of mean WTA compensation brought about by different bid orders and the sequencing of scenarios in the four questionnaire versions, a convolution approach was employed. It was first introduced by Poe et al. (1994) to examine the statistical difference in the distributions of mean WTP values. The mechanism for this approach is as follows. Assume two independent variables X and Y, with probability distribution functions of $f_x(x)$ and $f_y(y)$. Let V=X-Y, then the probability function of event V=v can be specified as:

$$f_v(v) = \int_{-\infty}^{+\infty} f_x(v+y) \cdot f_y(y) dy \qquad (3.7)$$

Then the cumulative distribution function of V=X-Y for discrete observations is:

$$F_V(v^0) = \sum_{\min(X-Y)}^{v^0} f_V(v) \Delta v \qquad (3.8)$$

The null hypothesis is: H_0: X - Y = 0. To test it, the Krinsky-Robb method can be used on equation (3.7) to estimate the confidence intervals for the convolution V. The 1-□ confidence intervals have the lower and upper boundaries as (Poe et al., 1994):

$$L_{1-\alpha}(V) = F_V^{-1}(\frac{\alpha}{2})$$

$$U_{1-\alpha}(V) = F_V^{-1}(1-\frac{\alpha}{2}) \tag{3.9}$$

The null hypothesis is accepted if the 1-□ confidence intervals of the convolution V includes zero at significance level of □, and vice versa. An accepted null hypothesis indicates that the two distributions mean WTP/WTA X and Y are not significantly different. The convolution is tested using a Gauss program.

Chapter 4: Results and Discussion

4.1 Survey response

4.1.1 Response rate

Of the 1,371 surveys sent out, 487 responses were received, accounting for 35.5% of the initial sample size. It is considered a good response rate, taking into account the geographical scope of the survey, the technical requirement to understand the survey questions, and the busy spring season for the producers when the survey was delivery. Among the survey received, 7 were mailed back because of wrong addresses (Table 4.1). 34 were received completely blank due to reasons such as the farm was still under construction, or producers were exiting or no longer in business because of tight profit margins or animal disease. A few producers didn't fill in the survey because they didn't understand it at all. Only one producer left it blank due to inability to understand French.

Incomplete answers of "Not Sure" for the full range of bids of Model 1 (Model RPF), Model 2 (Model MSC), and Model 3 (Model COST) were 22, 20, and 25 respectively. Non-responses to the WTA compensation question were 99, 114, and 112 for the three scenarios. Inconsistency in response was defined as individuals who switched from "yes" to "no" as the bid increased. For the three models there were 6, 5, and 86 responses that were inconsistent.

The greatest number of inconsistent answers appeared in the last scenario when respondents were asked for their WTA costs based on a certain carbon offset revenue level. There were 86 producers who didn't realize that it was a cost scenario and gave inconsistent answers. Among them, 85 were considered reversible and were reversed in an attempt to increase the response rate. A dummy variable "Rev" was created for this concern in the Model COST. A value of "1" was given to reversed responses, while a value of "0" was assigned to those who responded correctly.

Table 4.1 Response rate

	Model 1	Model 2	Model 3
Initial Sample	1,371	1,371	1,371
Wrong Address	7	7	7
Adjusted Sample	1,364	1,364	1,364
Received Surveys	487	487	487
Wrong Address	7	7	7
Blank	34	34	34
No WTA Answers	99	114	112
Inconsistent	6	5	86
Not Sure	22	20	25
Protest	14	14	14
Reversed	0	0	85
Usable for WTA analysis	305 62.63%	293 60.16%	294 60.37%

In the responses, 14 were considered as protests when "No" answers were given to the full range of bids of all three scenarios, and "No" answers were given to all the attitude questions. Protest responses also showed considerable negative attitude towards GHG mitigation programs and practices. This may have influenced their WTA compensation responses and generated bias. Therefore, they were not included in the data analysis.

As a result, the numbers of usable responses for the WTA compensation questions were 305, 293, and 294 surveys for Model 1, Model 2, and Model 3 respectively, accounting for 62.63%, 60.16%, and 60.37% of the received responses (Table 4.1).

4.1.2 Representativeness of respondents

The representativeness of the sample respondents determines the quality and credibility of the survey results. To exam this, a number of different comparisons were made between the responses received and published statistics. These comparisons included the geographic distribution of farms, the average number and type of animal, and the age and gender of the producer.

The address list provided by FPPQ, which contained 1,371 Quebec hog farms, was compiled according to their geographic distribution. Table 4.2 illustrates the compatibility between the geographic distribution of the received responses and the actual distribution of Quebec hog farms reported in the Statistics Canada's 2006 Agricultural Census.

Table 4.2 Comparison of the geographic distribution

Regions	Distribution of Quebec hog farms		Distribution of received responses		Additional responses needed	
Bas-Saint-Laurent	45	2.33%	11	2.35%	-0.02%	0
Saguenay—Lac-Saint-Jean—Côte-Nord	10	0.52%	4	0.85%	-0.34%	-2
Québec	36	1.86%	7	1.49%	0.37%	(2)
Mauricie	70	3.62%	11	2.35%	1.28%	(6)
Estrie	134	6.94%	37	7.89%	-0.95%	-4
Montréal—Laval	2	0.10%	1	0.21%	-0.11%	-1
Lanaudière	119	6.16%	31	6.61%	-0.45%	-2
Outaouais	5	0.26%	1	0.21%	0.05%	(0)
Laurentides	19	0.98%	3	0.64%	0.34%	(2)
Abitibi-Témiscamingue—Nord-du-Québec	6	0.31%	1	0.21%	0.10%	(0)
Gaspésie—Îles-de-la-Madeleine	1	0.05%	0	0.00%	0.05%	(0)
Chaudière-Appalaches	626	32.40%	235	50.11%	-17.70%	-83
Montérégie	604	31.26%	107	22.81%	8.45%	(40)
Centre-du-Québec	255	13.20%	20	4.26%	8.93%	(42)
TOTAL	**1,932**	100%	**469**	100%		

Source: Statistics Canada, 2007a. 2006 Agricultural Census
Note: the total number of 469 is the 487 received responses minus the wrong addresses and those who ripped off the code number on their questionnaires that was designed for tracking. Without the code number, it was impossible to allocate these responses to a region.

Table 4.2 indicates that received responses covered thirteen agricultural regions in Quebec. Only Gaspésie—Îles-de-la-Madeleine, which had only one hog farm reported in the 2006 Agricultural Census, didn't reply to the survey. Chaudière-Appalaches and Montérégie accounted for the largest numbers of hog farms: 32.40% and 31.26%. The Chaudière-Appalaches region had the largest portion of received responses (50.11%), and Montérégie had 22.81%. Centre-du-Québec had a smaller portion of survey responses than the actual regional distribution. The distributions of the responses in the other regions were similar to those in the Agricultural Census.

The average numbers of sows, weaners, and feeders of the received responses were 374, 861, and 1921 respectively (Table 4.5), accounting for 11.25%, 24.99%, and 63.77% of the animal distribution. This approximates the Statistics Canada's (2008) Quebec hog statistics of July 2007, the time when the survey was answered; 394 (9.58%), 1347 (32.74%), and 2373 (57.68%) for sows, weaners, and feeders respectively.

The average age of respondents was at the tail of the third age range, late 30s to early 40s, with a standard deviation of 20.54 (Table 4.3). This approximates the average age of Quebec farmers; 47.9 years. The proportions of male and female respondents were 85% and 15%, and were also similar to that of the Quebec farmers; 74% and 26% (Statistics Canada, 2007b).

These comparisons indicate there was no significant deviation between the received survey respondents and the target population. Therefore the responses can be considered representative of the population.

4.2 Survey statistics

4.2.1 Demographic and background statistics

Table 4.3 illustrates the statistics of producers' demographic, education level, and family income information. Female and male respondents accounted for 14.51% and 85.49% of the respondents respectively.

Table 4.3 Respondents' background information

		Numbers	Portions
Gender	Female	64	14.51%
	Male	377	85.49%
		441	100%
		Mean	Standard Deviation
Age	Female	2.891	7.889
	Male	2.984	20.904
	Total	2.970	22.356
Education	Primary	25	5.67%
	Secondary	214	48.53%
	Post-Secondary	152	34.47%
	University	50	11.34%
		441	100%
Family Income before tax in 2006	$0 - 20,000	73	17.02%
	$20,001 - 35,000	153	35.66%
	$35,001 - 50,000	113	26.34%
	$50,001 - 100,000	63	14.69%
	over $100,000	27	6.29%
		429	100%

The average education level of respondents was between secondary and post-secondary, which accounted for the largest portions of producers. Only 5.67% of the respondents had only primary education, while 11.34% had a university or equivalent degree.

Average family income before tax in 2006 lies between the ranges $20,001 - 35,000 and $35,001 - 50,000. 14.69% of respondents had an income level between $50,001 and $100,000. Only 6.29% of respondents had over $100,000 of family income in 2006.

4.2.2 Farm operation statistics

4.2.2.1 Operation type and animal numbers

Respondents were asked what type of hog operations they were managing. Over half of them, 55.06% had farrow-to-finish operations, only 4 producers had grower operations. The remaining 10.34% had farrowing operations and 18.88% had finisher operations. 14.83% of the producers had more than one operation, and six of these respondents had all four types of operations. However, most of the multiple operations can be categorized as farrow-to-finish based on the nature of hog operations (Table 4.4).

Respondents were asked for the numbers of animals on farm per year, in three categories, as an indicator of the type of operation and farm size (Table 4.5). The total hog inventory of the respondents was 1,144,645 animals, accounting for roughly 25% of the total pig inventory of Quebec in 2006 (Statistics Canada, 2007a). The average number of hogs per farm was 2,578.03

animals, which was higher than the average Quebec hog farm of 1,734.16 animals. The average number of sows, weaners, and feeders per farm was 374, 861, and 1,921 respectively. The smallest operation had only 20 feeders, while the largest one had 20,000 sows, zero weaners, and 100,000 feeders.

Table 4.4 Hog operation statistics

	# of farms	portions
Farrowing	46	10.34%
Grower	4	0.90%
Finisher	84	18.88%
Farrow to finish	245	55.06%
Multiple operations	66	14.83%
Total	445	

Table 4.5 Hog numbers statistics

	Sows	Weaners	Feeders	Total
Total hog numbers	128,740	285,994	729,911	1,144,645
Farm numbers	344	332	380	444
Average hogs / farm	374.24	861.43	1,920.82	2,578.03
Minimum hog numbers / farm (not zero)	5	6	20	20
Maximum hog numbers / farm	20,000	9,000	100,000	120,000

4.2.2.2 Current crude protein level in feed

In the Reduced Protein Feeding scenario, respondents were asked for their average feed crude protein content level. Among the 337 producers who answered this question, most of them had levels between 14% and 18% (Table 4.6). Crude protein levels between 16% and 17% were used by 41.84% of the respondents. Only 8 respondents had adopted a level lower than 14%, while 26 of the respondents had levels higher than 18%. The mean protein level adopted was 15.97%, with a standard deviation of 22.15 (Table 4.7).

Table 4.6 Respondents' average crude protein level in feed

Crude Protein Level	Responses	Proportion
p <14%	8	2.37%
14% <= p <15%	26	7.72%
15% <= p <16%	84	24.93%
16% <= p <17%	141	41.84%
17% <= p <18%	52	15.43%
p > = 18%	26	7.72%
Total	**337**	

Table 4.7 Statistics of average crude protein levels

Total Response	Minimum Protein Level	Mean	Maximum Protein Level	Standard Deviation
337	10%	15.97%	22%	22.15

4.2.2.3 Manure storage cover

In the Manure Storage Cover scenario, respondents were asked whether or not they currently had a manure cover and the type. Only 14.78% of the 433 respondents had adopted a cover system (Table 4.8). Most of the covers were unstructured and made of fiber such as "toile", which usually doesn't last for more than one year. This was similar to what was found in the interviews with producers in Saint-Hyacinthe and during the pretest. Only one respondent reported an installation of an anaerobic digestion system that generates on farm energy.

Table 4.8 Information of currently adopted manure covers

Manure Storage Cover	Responses	Portion
Have one	64	14.78%
Do NOT have one	369	85.22%
Total	433	

4.2.3 Attitudes and preferences

4.2.3.1 Knowledge of Best Management Practices

Producers were asked to scale their knowledge and awareness of management practices that would reduce GHG emissions in hog operations. Respondents used a scale of 1 to 5 to rank their knowledge, where 1 represented "know it very well" and 5 means "nothing at all". Table 4.9 shows that only 35% of the producers had previous knowledge or were aware of hog management practices that reduced GHG emissions.

Table 4.9 Producers' knowledge about BMPs

Knowledge	Responses	Portion
level 1 to3	156	35.14%
level 4, 5	288	64.86%
Total	444	

4.2.3.2 Preferences on government initiatives

Producers were asked to choose one or more of a list of five government initiatives that would influence their decisions to adopt a Best Management Practice. The responses are given in Table 4.10. It was not surprising to learn that most of the producers; i.e. 83%, indicated direct financial incentives, followed by technical advice and support. A quarter of the respondents chose the creation of a domestic emission trading market, since Canadian agricultural producers can currently only trade their carbon reductions on voluntary carbon exchange markets, such as the Chicago Climate Exchange (CCX). Over half of the respondents chose more than one initiative.

Table 4.10 Preferences on government initiatives

Government Initiatives	Responses	Portion
Technical Support	161	36.84%
Emissions Trading Market	109	24.94%
Research	92	21.05%
Voluntary Programs	50	11.44%
Financial Incentive	361	82.61%
Chose more than one	225	51.49%
chose 4 of the initiatives	12	2.75%
Chose all of the initiatives	9	2.06%

4.2.3.3 Attitudes toward reduced protein feeding and concerns

One of the objectives of this study was to identify the key factors that discouraged hog producers from adopting best management practices. In the reduced protein feeding scenario, producers were asked about their attitudes toward reducing their crude protein level from 17% to 14%. This was followed up with another question that asked their major concerns for not adopting it.

Table 4.11 illustrates the results. Approximately 40% of the respondents were willing to adopt this practice, leaving 60% not willing to adopt it. A comparison of the average protein levels was made for each group of respondents. It was found that there was no significant difference between them.

The biggest concern was the potential negative impact on animal performance as a result of reducing protein content in the feed. Approximately 64% of the respondents selected this concern. The second major obstacle was the lack of knowledge on efficient feeding strategies. Only 22% of the respondents identified carbon offset revenue as a major obstacle. Approximately 60% of the producers chose more than one concern, and 21% chose more than two concerns.

Table 4.11 Attitudes toward reduced protein feeding and concerns

Attitudes toward Reduced Protein Feeding	Responses	Portion	Average protein level
Willing to adopt it	162	40.5%	15.97%
Not Willing	238	59.5%	15.98%
Total	400		
Concerns for not adopting Reduced protein feeding			
Requires large investment (needs new silos)	47	15.16%	
Revenue is not large enough	68	21.94%	
Negative impact on animal performance	197	63.55%	
Not enough knowledge	191	61.61%	
Don't trust the government/GHG programs	74	23.87%	
Chose more than one	185	59.68%	
Chose 3 concerns	51	16.45%	
Chose 4 concerns	11	3.55%	
chose all of the concerns	3	0.97%	

It is important to note that 15% of the respondents did not have enough feed capacity for new protein feeding rations and thus would need to purchase and install extra silos (feed bins). This would result in a significant investment of both financial and labor resources. These producers can be defined as having a rotational operation. This is consistent with what was found in interviews with Quebec hog production experts, who estimated that 85% of Quebec hog producers had all-in-and-all-out operations and had enough feed capacity for a new feeding strategy. This finding indicates that a broad GHG mitigation program that aims at reducing crude protein in feed is financially viable across the majority of Quebec hog producers.

4.2.3.4 Attitudes toward manure storage cover and concerns

In the manure storage cover scenario, two questions were asked to detect producers' attitudes and concerns for adopting a non-air-tight synthetic cover system on their manure storage facility. Among the 400 producers who answered the attitude question, approximately half were willing to adopt it. It is interesting to compare the attitudes between those who currently have a cover system and those who do not. 87% of the producers with a cover system would adopt this practice, whereas only 46% of those who did not have a cover system would adopt it (Table 4.12).

Table 4.12 Attitudes toward manure storage cover and concerns

Attitudes toward Manure Storage Cover	Responses	Portion	Those who have a cover	Those who don't have a cover
Willing to adopt it	203	50.8%	46(86.8%)	157(45.9%)
Not Willing	193	48.3%	7(13.2%)	185(54.1%)
Total	400		53	342
Concerns for not adopting a manure storage cover				
Revenue is not large enough	55	20.00%		
Too large of an investment	202	73.45%		
Not enough knowledge	95	34.55%		
Don't trust this type of construction	66	24.00%		
Don't trust the governemt/GHG programs	70	25.45%		
Chose more than one	146	53.09%		
Chose 3 concerns	34	12.36%		
Chose 4 concerns	15	5.45%		
chose all of the concerns	1	0.36%		

The largest concern with this practice was the large investment required, as reported by 73% of respondents. Approximately 35% indicated that they did not have previous knowledge about this technology. Compared to the reduced protein feeding scenario (Table 4.11), hog producers were considerably more knowledgeable of manure cover technology. Almost a quarter of the respondents did not trust this type of construction, which was similar to the feedback from the pre-test, where some producers stated that neighbours had installed synthetic covers and they collapsed from wind, snow, or rain water. Another quarter of the respondents had negative attitudes towards government or other GHG mitigation initiators.

4.2.3.5 Preference between the two BMPs

At the end of the survey producers were asked their preference between the two BMPs presented. Among the 402 respondents who answered this question, 66% of them preferred the manure storage cover practice over the reduced protein feeding practice (Table 4.13).

Table 4.13 Preference between BMPs

Preference between the two BMPs	Responses	Portion
Reduced Protein Feeding	135	33.58%
Manure Storage Cover	266	66.17%
Total	402	

4.3 Willingness to accept compensation for adopting BMPs

4.3.1 Mean WTA compensation and confidence intervals

As reported in Table 4.14, the mean WTA compensation was estimated to be \$46.71 /tonne of CO_2e for the model Reduced Protein Feeding and \$40.40 /tonne of CO_2e for the model Manure Storage Cover. For the model COST, including the

85 reversed responses, the mean WTA cost was $11.88 for receiving carbon offset revenue of $20 per animal space per year. Excluding the reverse responses, a slightly lower mean WTA cost of $11.75 was estimated for the same amount of carbon offset revenue. Model RPF and Model MSC had standard deviations of $2.13 and $2.11. Model COST that excluded the reversals had a larger standard deviation than the one with the reversals, since the latter one had a larger sample size.

Table 4.14 Mean WTA and confidence intervals

	Mean WTA	SD	Lower Bound	Median	Upper Bound
	$	$	95% Confidence Intervals		
Model RPF	46.71	2.13	42.37	46.67	51.05
Model MSC	40.40	2.11	36.20	40.39	44.54
Model COST with reversals	11.88	0.42	11.06	11.86	12.70
Model COST without reversals	11.75	0.49	10.80	11.75	12.74

It was unexpected that the mean WTA compensation for adopting reduced protein feeding was higher than the mean WTA compensation for adopting a manure storage cover. A priori, it was hypothesized that producers would require more compensation for the manure storage cover because of its large investment and longer management time horizon. However, the lower number of carbon credits from the reduced protein feeding alternative seems to have required additional compensation. Reduced protein feeding generated 9 carbon offset credits for 500 animal spaces, while the manure storage cover generated 350 carbon offset credits per 500 animal spaces.

Confidence intervals were estimated for the three models using the approach developed by Park et al. (1991). The 95% confidence interval of Model RPF was slightly wider than that of the Model MSC. Model COST, without reversals, showed a wider confidence interval than the one with reversals. For all three models, the distributions of the mean WTA were located in the middle of the 95% confidence intervals.

4.3.2 Regression analysis

4.3.2.1 Regression analysis for Model RPF

The regression of Model RPF had 305 observations, which included variables ORD1, ORD2, PREF, SEX, AGE, ED2, ED3, ED4, IN2, IN3, IN4, IN5, TYPE, NUM1, NUM2, NUM3, KL, RES, BID, PL, and ATP. Variables ED1 and IN1 were removed because they were perfectly collinear with other education and income levels. The regression results obtained from Model RPF are given in Table 4.15.

Model RPF Wald statistics was significant ($W=320.85 \sim \chi^2(20)$); indicating that the null hypothesis that all of the coefficients simultaneously equaled to zero can be rejected at the 1% level of significance. Most variables had the expected signs; however, among the 20 variables included in the regression, only three achieved a significance level lower than 10%.

Table 4.15 Regression results of Model RPF

−2*Log Likelihood:	1063.063239			
Wald Statistic:	320.846502			
Observations:	305	Degrees of freedom:	285	

Var	Coef	Std. Error	T-Stat	P-Value
CONST	2.3052	1.9283	1.1955	0.233
ord1	0.5294	0.2127	2.4892	0.013
ord2	− 0.0249	0.2128	−0.1171	0.907
pref	0.2083	0.2252	0.9248	0.356
sex	0.1976	0.3436	0.5750	0.566
age	0.0934	0.1144	0.8161	0.415
ed2	0.4047	0.6086	0.6649	0.507
ed3	0.0970	0.6172	0.1572	0.875
ed4	0.0841	0.6796	0.1237	0.902
in2	0.1342	0.3441	0.3901	0.697
in3	− 0.2070	0.3422	−0.6049	0.546
in4	− 0.4582	0.3889	−1.1782	0.240
in5	− 0.1962	0.5425	−0.3616	0.718
type	0.0595	0.1159	0.5130	0.608
num1	0.0001	0.0002	0.5654	0.572
num2	− 0.0001	0.0001	−0.8660	0.387
num3	− 0.0000	0.0000	−0.5565	0.578
kl	− 0.0126	0.2282	−0.0553	0.956
pl	− 0.0329	0.1078	−0.3053	0.760
atp	− 1.2980	0.2234	−5.8111	0.000
BID	− 0.0493	0.0028	−17.8520	0.000

The variable BID was significant at the 1% level with a negative sign. This means that as the bid value increases the probability of the producer to reject the carbon offset revenue decreases. This was the expected sign a priori.

Variable ORD1 represents whether the bid values were presented in an ascending or a descending order. It was not surprising to have the bid order achieve a significance level of 5%, along with a large coefficient 0.5294, which suggest significant starting point or anchoring effects. Its positive sign indicates that the respondents who received the descending ordered bids tended to have higher WTA compensation, while those facing ascending bid values had lower WTA compensation. Order 1 was significant and positive in all three models. This supports previous studies that identified starting point or anchoring bias; i.e., that presenting bids in descending order resulted in a significantly higher mean WTP estimate than presenting them in ascending order (Boyle et al, 1985; Whitehead, 2002; Alberini et al., 2003; Vossler et al., 2004).

In contrast to ORD1, variable ORD2 represents the sequencing of scenario 1 and scenario 2 in the questionnaire. This variable was not significant in any of the three models. This differs from other empirical findings concerning sequencing effects (Halvorsen, 1996, Dupont, 2003). In these other studies, when an item was presented second it results in a significantly lower mean WTP estimate than when it is presented first.

The variable ATP, attitude toward Reduced Protein Feeding, was significant at the 1% level and had a negative coefficient equal to −1.298. This means that respondents who have a positive attitude toward this management practice tended to be less likely to reject a given bid value. This finding confirms that hog producers' attitude towards the BMP influences their WTA carbon offset revenue. Variable PREF, which represents producers' preference between these two BMPs, was not significant in Model RPF.

4.3.2.2 Regression analysis for Model MSC

Model MSC contained 293 observations. 21 variables were included in the regression; ORD1, ORD2, PREF, SEX, AGE, ED2, ED3, ED4, IN2, IN3, IN4, IN5, TYPE, NUM1, NUM2, NUM3, KL, RES, BID, COVER, and ATM. The overall regression performs well. The Wald statistic (W=293.35~χ^2(20)) indicates that the null hypothesis that all the coefficients were simultaneously equal to zero can be rejected at the 1% significance level. Seven variables were found to be significant at the 10% level or better: ORD1, ED4, NUM1, NUM3, COVER, ATM, and BID (Table 4.16).

Table 4.16 Regression results of Model MSC

-2*Log Likelihood: 1046.691355
Wald Statistic: 293.353599
Observations: 293 Degrees of freedom: 273

Var	Coef	Std. Error	T-Stat	P-Value
CONST	0.4733	1.0121	0.4676	0.640
ord1	0.5526	0.2163	2.5545	0.011
ord2	− 0.1207	0.2216	− 0.5445	0.587
pref	− 0.3854	0.2693	− 1.4310	0.154
sex	0.3296	0.3449	0.9555	0.340
age	0.1541	0.1102	1.3984	0.163
ed2	1.0734	0.7142	1.5029	0.134
ed3	1.0703	0.7151	1.4967	0.136
ed4	1.3181	0.7759	1.6989	0.090
in2	0.3686	0.3488	1.0569	0.291
in3	0.5334	0.3571	1.4936	0.136
in4	− 0.0986	0.4039	− 0.2442	0.807
in5	− 0.0663	0.5507	− 0.1203	0.904
type	0.0299	0.1194	0.2501	0.803
num1	0.0006	0.0003	2.1102	0.036
num2	0.0001	0.0001	0.7639	0.446
num3	− 0.0001	0.0001	− 2.5581	0.011
kl	0.1911	0.2342	0.8161	0.415
cover	− 0.7647	0.3240	− 2.3600	0.019
atm	−0.9919	0.2694	− 3.6812	0.000
BID	− 0.0500	0.0029	−17.0216	0.000

ORD1 and BID had similar signs and significance as in Model RPF. The BID variable had a similar coefficient in the two models. Variable PREF had a higher significance level than in Model RPF.

Variable Education Level 4 (ED4); university or equivalent level, was significant at the 10% level with a positive coefficient. This result was unexpected in that respondents with university education tended to demand significantly higher WTA carbon offset revenue for adopting a manure storage cover. The other two education levels (ED2, ED3) had the same positive coefficients but with a lower level of significance.

None of the Income Level Variables (IN2, IN3, IN4, and IN5) were significant at the 10% level. IN3, income between $35,001 and 50,000, had a significance level of 13.6%. This is slightly above the 10% level, which would indicate a weak positive relationship between this income level and the dependent variable.

Variable NUM1 and NUM3, which are the numbers of sows and feeders, were significant at the 5% level. NUM1 had a positive coefficient while NUM3 had a negative one. This indicates that the more sows a producer has, the more carbon offset revenue for adopting a manure cover system, whereas the more feeders, the less carbon offset revenue they would require. This implies hog producers with finisher and farrow-to-finish operations would be more likely to demand less compensation than those with only a farrowing operation.

Another significant variable was COVER; at the 5% level, with a negative coefficient. This confirms the hypothesis that if producers were currently using a manure storage cover they tended to demand less compensation for adopting this practice. The variable Attitudes toward Manure Cover (ATM) was also significant at the 1% level. Its negative coefficient further supports the hypothesis that those who exhibited positive attitudes toward this BMP would demand less carbon offset revenue to adopt it.

4.3.2.3 Regression analysis for Model COST

Model COST was designed to examine respondents' consistency through different scenarios. A total of 209 respondents answered this scenario consistently. Another 85 inconsistent answers were considered reversible and the reversals increased the responses to 294. The model regression was first conducted with reversals included and then excluded. Both regressions performed well, with a Wald statistic of ($W=360.64 \sim \chi^2(19)$) and ($W=249.99 \sim \chi^2(18)$) respectively. Both were significant at the 1% level and rejected the null hypothesis. Variables ORD1, ORD2, PREF, SEX, AGE, ED2, ED3, ED4, IN2, IN3, IN4, IN5, TYPE, NUM1, NUM2, NUM3, KL, RES, BID were included in both models. Another dummy variable REV, which indicates that the responses were reversed, was included in the regression with reversals. The results are presented in Tables 4.17 and 4.18.

The BID variable was significant at the 1% level, which was similar to the two other models. However it had a larger negative coefficient in Model COST. This may have occurred because in this model, respondents only needed to consider the given bid values, without considering other factors related to the change in management practice that were needed in the previous scenarios.

Table 4.17 Regression results of Model COST including reversals

-2*Log Likelihood:	1035.620164			
Wald Statistic:	360.643653			
Observations:	294	Degrees of freedom:	275	

Var	Coef	Std. Error	T-Stat	P-Value
CONST	0.7325	1.0455	0.7007	0.484
ord1	0.4272	0.2168	1.9700	0.050
ord2	− 0.3572	0.2243	− 1.5927	0.112
Pref	0.4158	0.2325	1.7887	0.075
Sex	0.6089	0.3679	1.6549	0.099
age	− 0.0612	0.1137	− 0.5385	0.591
ed2	0.3387	0.6857	0.4940	0.622
ed3	0.1591	0.6902	0.2305	0.818
ed4	− 0.0358	0.7580	− 0.0472	0.962
in2	0.2775	0.3471	0.7994	0.425
in3	0.7431	0.3564	2.0850	0.038
in4	1.2086	0.3941	3.0666	0.002
in5	1.7283	0.5307	3.2565	0.001
type	0.2071	0.1146	1.8070	0.072
num1	0.0001	0.0003	0.3671	0.714
num2	− 0.0001	0.0001	− 0.9236	0.356
num3	− 0.0000	0.0001	− 0.5936	0.553
kl	0.2560	0.2283	1.1213	0.263
rev	− 0.1046	0.2477	− 0.4223	0.673
BID	− 0.2528	0.0133	− 18.9504	0.000

ORD1 and ORD2 were consistent in Model COST. ORD1 was significant at the 5% level when reversals were included and at the 10% level when reversals were excluded. It is interesting to note that producers' preferences between the two BMPs, variable PREF, was significant at the 10% level with a positive coefficient when the reversals were included in the model. This means that those who preferred adopting a manure storage cover to reduce protein levels would be more willing to absorb a given cost. This confirms the hypothesis that those who prefer the manure storage cover practice would demand lower compensation.

Table 4.18 Regression results of Model COST excluding reversals

-2*Log Likelihood: 719.589337
Wald Statistic: 249.986466
Observations: 209 Degrees of freedom: 191

Var	Coef	Std. Error	T-Stat	P-Value
CONST	1.6327	1.0949	1.4912	0.138
ord1	0.4692	0.2540	1.8469	0.066
ord2	− 0.2272	0.2674	− 0.8499	0.396
pref	0.3740	0.2715	1.3772	0.170
sex	0.4735	0.4114	1.1509	0.251
age	− 0.1245	0.1320	− 0.9430	0.347
ed2	0.0913	0.7515	0.1214	0.903
ed3	− 0.0578	0.7464	− 0.0775	0.938
ed4	− 0.3669	0.8218	− 0.4465	0.656
in2	0.1722	0.4008	0.4297	0.668
in3	0.3311	0.4228	0.7830	0.435
in4	1.0804	0.4383	2.4650	0.015
in5	1.3006	0.6423	2.0248	0.044
type	0.1055	0.1351	0.7808	0.436
num1	− 0.0000	0.0003	− 0.1038	0.917
num2	0.0000	0.0001	0.2430	0.808
num3	0.0000	0.0001	0.0013	0.999
kl	0.2960	0.2678	1.1051	0.271
BID	− 0.2556	0.0162	− 15.7583	0.000

Producer's gender, variable SEX, was significant at the 10% level in Model COST when reversals were included. The positive sign of this coefficient indicates that male producers would absorb more costs for a given carbon offset revenue than female producers. PREF and SEX were not significant in the regression where the reversals were excluded.

In the regression with reversals included, income levels variable IN3 was significant at the 5% level and IN4 and IN5 were significant at the 1% level. All of them had positive coefficients, which indicates a positive correlation between income and producers' WTA cost. This was consistent with the hypothesis. For the regression with reversals excluded, only IN4 was significant at the 1% level.

Operation type, variable TYPE, was significant at the 10% level in the regression with reversals. Its positive coefficient indicates that as the operations change from farrowing, grower, to finisher, and farrow-to-finish, producers tend to accept a given cost level. Operation type was not significant in the regression when reversals were excluded.

4.3.3 Convolution analysis

In order to investigate the impact of bid order and the sequencing of scenarios on the mean WTA compensation distributions, a convolution analysis, as proposed by Poe et al. (1994), was conducted (Appendix 2). The cumulative distribution functions of the mean WTA were generated with a Krinsky-Robb simulation that draws 5000 samples from the covariance matrix to the mean WTA equation (Krinsky and Robb, 1986), and were used to estimate the confidence intervals for the convolution. The results are given in Table 4.19.

M1, M2, and M3 represent Model RPF, Model MSC, and Model COST with reversals included respectively, while M4 is Model COST with reversals excluded, and M5 is solely the 85 reversed answers in Model COST. The 95% confidence interval of the convolution between M1 and M2 did not contain zero, which means that the null hypothesis, that their mean WTA distributions were similar, can be rejected at the 5% significance level. Both of the convolutions, M3-M4 and M4-M5, did not fall in the rejection region of the null hypothesis. This implies that reversing the 85 inconsistent answers in Model COST and including them in the regression model did not make any statistical difference in the WTA estimate.

Table 4.19 Convolution analysis results

	95% Confidence Interval		
Distributions	**Lower Bound $**	**Upper Bound $**	**Alpha Significance Value**
M1-M2 *	0.29	11.12	0.03862
M3-M4	-1.34	1.06	0.82877
M4-M5	-1.29	1.89	0.71168
M1A1-M1D1 *	7.8	25.7	0.00039
M1A2-M1D2	-11.85	10.72	0.90727
M1A1-M1A2 *	1.63	22.18	0.02291
M1D1-M1D2	-5.79	14.41	0.3861
M2A1-M2D1 *	4.4	27.32	0.00913
M2A2-M2D2	-8.42	10.68	0.78804
M2A1-M2A2	-20.13	2.92	0.13289
M2D1-M2D2	-3.42	15.56	0.20533
M3A1-M3D1 *	28.79	43.93	0.20534
M3A2-M3D2 *	1	5	0.00371
M3A1-M3A2 *	0.74	5.03	0.00861
M3D1-M3D2	-2.21	2	0.91512

*: Those distributions with significant difference in mean WTA

Furthermore, within each model, sample responses were divided into four sub-samples according to the four versions of the survey (A1, A2, D1, and D2). The convolutions were thereafter employed in two steps. First, versions A1, A2 were compared with versions D1 and D2 with a particular focus upon discovering the starting point effects. Second, versions A1, D1 were compared with versions A2 and D2 to discover the sequencing effects of the scenarios.

For Model RPF, the 95% confidence interval of the convolution between M1A1 and M1D1 did not contain zero, which rejected the null hypothesis that they had similar mean WTA, whereas the convolution between M1A2 and M1D2 failed to reject the null hypothesis; i.e., did not reject that their mean values were similar. Regarding the sequencing effects, M1A1 and M1A2 fell in the rejection area of the null hypothesis while M1D1 and M1D2 failed to reject it, though the lower bound of the confidence interval, $1.63, was very close to zero.

In Model MSC, the 95% confidence interval of the convolution between M2A1 and M2D1 did not include zero, which rejected the hypothesis. The other three confidence intervals of the convolution included zero and thus did not reject the hypothesis.

Bid and sequencing effects had a larger impact on model COST. The 95% confidence interval of A1 and D1 versions extended from $28.79 to $43.93, which indicated a significant difference in the mean WTA distributions. The confidence interval of A2 and D2 extended from $1 to $5, and also fell in the rejection region of the null hypothesis. Compared to the other two models, Model COST suffered stronger starting point effects. The reason behind this seems to be that the cost scenario only gave carbon offset revenue and a bid list that represented different cost levels. The lack of other information makes respondents more sensitive to ascending-descending bid order and thus more subject to starting point or anchoring effects. This was different from the other two scenarios that gave specific information concerning the management practices.

In Model COST, A1, D1 were compared with A2 and D2 versions in order to investigate the effects of sequencing of the above two scenarios upon the WTA valuation. The convolution demonstrates sequencing effects with A1 and A2 but the effects are relatively weak, i.e. the lower bound of the 95% confidence interval was \$0.74. The 98% confidence interval had a lower bound of \$0.34. Comparing D1 and D2 versions did not indicate any sequencing effects with the above two scenarios upon the cost scenario.

4.4 Policy implications

In response to Canada's commitment to the Kyoto Protocol, the agricultural industry is capable of delivering more than 15% of the national reduction goal. The hog industry emits one fifth of the total agricultural GHG inventory and has the potential to generate a significant amount of carbon offsets.

In spite of efforts of the various stakeholders, neither a federally regulated emission trading system nor any voluntary carbon credit market has yet to be established in Canada. The previous federal Liberal administration had proposed a carbon trading system that included agricultural offsets. Their defeat in the last election stopped this development. The role of GHG emission reduction in the new "Clean Air Plan" advocated by the current federal Conservative government is still not clear. However, in the absence of a federal institutional framework, provincial governments are making policy decisions. The Quebec government has initiated the design of a provincial GHG reduction mechanism and Alberta has established a local carbon offset market through new legislation concerning large energy plants.

There is no doubt that Quebec's hog industry, the largest national pork supplier, could play an important role in either provincial or national carbon trading initiatives in the future. However, the institutional framework and working rules of the trading mechanisms have to be designed properly to minimize transaction costs. Similarly, they will impact the bargaining transaction on both the supply and demand sides. Specifically, the working rules will impact carbon trading efficiency and the allocation of benefits and costs within the market, and will also impact the economic viability of various carbon credits generated from different BMPs. In other words, the design of the institution and working rules will influence the incentives generated by the bargaining transactions and thus influence the potential offset credit supply (Thomassin, 2005).

This study explores incentive factors and the variables that will influence the supply side of the carbon market. The mean WTA carbon offset revenue for adopting a reduced crude protein feeding strategy was estimated to be \$46.71 per tonne of CO_2e, which is higher than that of adopting a manure storage cover; \$40.40 per tonne of CO_2e. There are several potential explanations for this result. First, producers could be looking at maximizing carbon offset revenue. The manure storage cover generates a greater number of offset credits; 350 carbon offset credits per 500 animal spaces. The reduction of crude protein in the feed only generates 9 carbon offset credits per 500 animal spaces. Despite the significant investment of installing a cover system, it doesn't require much maintenance.

Second, even though with reduced protein feeding, producers will have feed cost saving in their operation, there is an increase in management needed. With this BMP producers have to invest their management time and other resources throughout the period of an offset project.

Third, a reduced protein feed ration has the potential of having negative impacts on animal performance. This could be a major barrier to its adoption. Over 63% of the producers identified this concern. Using a phased feeding approach could overcome this barrier and reduce protein overfeeding in each weight level, and therefore would have less of an impact on animal performance.

The qualitative statistics indicate the potential of adopting a reduced protein feeding schedule in Quebec. First, the mean protein level in feed currently adopted by hog producers is 16%. Only 7.7% of the producers have a level lower than 15%, and 42% of the producers are feeding between 16% and 17% protein. This suggests there is the potential to decrease the protein content in feed. Second, in the sample, only 15% of the producers did not have enough storage capacity for this feeding strategy and would need to install new silos. The other 85% of the producers had all-in-and-all-out operations and could adopt a reduced crude protein feeding ration without a significant investment in farm facilities.

Regarding the manure storage cover scenario, only 15% of Quebec hog producers currently have a cover system. This would suggest there is a potential supply of offset credits from adopting this management practice in Quebec. The regression analysis indicates that the numbers of sows and feeders are significant factors affecting producers' mean WTA carbon offset revenue. This implies that under this scenario, the incentives for producers to supply carbon offset credits depends on the type of operation, the size of the farm, and the offset credit price. The regression coefficients indicate that producers with finisher and farrow-to-finish operations, or those with a large number of feeders, would be likely to demand less compensation than those with only farrowing operation and limited feeders, and therefore would be able to deliver more offset credits in a future operating carbon market.

Producers seem to be more familiar with the manure cover technology than with the reduced protein feeding strategy. Only 35% of the producers were concerned about their lack of knowledge in installing a cover, while the proportion for reduced protein feeding was 62%. However, a quarter of the producers did not trust the durability of a structured synthetic cover system presented in the scenario. In addition, over 73% of them thought the investment in the cover system was a major obstacle. This suggests that future government initiatives need to focus on three awareness issues. First, industrial standards for synthetic manure cover systems that strengthen their durability against wind, sunlight, and snowfall pressure should be implemented. Demonstration sites of the standardized products could be built in regions that have a high concentration of hog producers to improve the credibility of this technology. Second, once a durable technology is in place, the financial investment can be allocated throughout its life span, for example ten years. Third, producers should be informed of the increased nitrogen value of the manure as a fertilizer from a cover system. This would decrease their cost of crop production by reducing fertilizer costs. Although two thirds (66%) of the respondents preferred the manure storage cover over the reduced protein feeding, in order to increase the future carbon offset supply, public policy should make sure that producers understand the benefits coming from carbon offset revenue, increased manure nutrient value, and a durable manure cover system.

Producers' mean WTA cost was estimated to be $11.88 for a carbon offset revenue of $20 per animal space per year, indicating that they were willing to use 59% of the carbon offset revenue to implement the management practice. Regression analysis reveals the incentives for producers to absorb costs were affected by their gender, family income level, and operation type. Those with annual income over $50,000, who account for over one fifth (20.98%) of the sample were willing to absorb more costs.

The mean WTA cost estimate has an important implication for public policy. Aside from the implementation cost of changing practices or adopting the technology, there are administrative or transaction costs associated with generating carbon offset credits in the market. These include: submitting a change in management plan, approval costs, monitoring costs, verification, and certification costs. The policy framework and working rules of a carbon trading system will influence the size and distribution of these transaction costs. For example, if a protocol was developed for reduced protein feeding to include feed delivery records as the monitoring and verification process, this could decrease transaction costs. Other elements of the carbon trading system, such as the initial allocative design, will have significant distributional impacts upon both the supply and demand for credits (Thomassin, 2005). The results of the mean WTA cost estimate and regression analysis indicates that the transaction costs associated with carbon offset credits should be kept to a minimum.

Another policy option to increase the supply of carbon offset credits is through a cost-sharing program. Because of the nature of agricultural production, each individual farm can only deliver relatively small packages of carbon offsets. Aggregating carbon offset credits can reduce the administrative costs for producers and thus increase the incentives for them to supply offset credits. An example of an aggregator for offset credits is AgCert in western Canada. Many hog producers have joined the AgCert system, gaining credits by emptying manure storage before summer temperatures. However, aggregating carbon credits brings risks and complexity challenges to the agricultural sector with regards to the sale of credits (Macleod, 2005b).

Regarding preferred government initiatives, most of the producers (83%) suggested direct financial incentives. This was followed by a request for technical supports (37%). The lack of knowledge of the reduced crude protein feeding strategy and the durability concern of the manure storage cover technology are information barriers that should be overcome. This implies that the public awareness of carbon offset credits and the best management practices that can generate them should be improved.

4.5 Methodology implications

In the regression analysis, variable Ord1, which represents ascending-descending bid order, was statistically significant and had positive coefficients in all three models. This indicates that there are significant starting point effects. Thus, the estimated WTA was biased upward if the starting bid was set above the true WTA and biased downward if the starting bid was set below the true WTA (Boyle et al., 1985, Whitehead, 2002). The convolution analysis also demonstrates that the ascending-descending bid order does affect the magnitude of the WTA estimate. Model MSC suffers stronger bias with a higher significance level and a larger coefficient for Ord1 than Model RPF. This is because bids from Model MSC had a range of \$7 to \$70, while bids in Model RPF were from \$0.009 to \$1.8. It suggests that larger bid differences magnify the starting point bias introduced by iterative bidding and implies that smaller bid differences may mitigate the bias (Whitehead, 2002).

Compared to Ord1, variable Ord2, which was the sequence of the two BMPs presented in the questionnaire, was not significant in any of the three models in the regression analysis. It did have some significance for the Model RPF in the convolution. This indicates a weak sequencing effect and is inconsistent with some previous empirical literature that suggested that when an environmental good scenario comes second it will have a significantly lower welfare valuation than when it comes first (Halvorsen, 1996, Dupont, 2003).

The reason for less significant sequencing effects than starting point effects in this study might be because these two best management practices don't substitute for each other. In Dupont's study (2003), the significant sequencing effects may be largely from the substitute nature of swimming, fishing, and recreational boating, which also causes significant embedding effects. Moreover, the well described scenario design in this study also mitigates the sequencing effects explained by imperfect information as concluded by Halvorsen (1996).

One alternative to improve the robustness of CVM against sequencing effects, as suggested by Halvorsen, is by giving all of the information about the valuation items up front, followed by a WTP/WTA elicitation of all items at the end. That is, "a one-short, holistic valuation of all goods may be preferable to sequential valuation" (Halvorsen, 1996, p.497).

The convolution of Model COST reveals that it suffers from even stronger starting point bias and somewhat significant sequencing effects from the sequence of the above two scenarios. The reason seems to be the lack of information about the BMP, other than the bid values, which makes respondents more sensitive to ascending-descending bid orders and the sequence of the scenarios. Thus, the respondents are subject to greater starting point effects and sequencing effects. A possible way to improve it might be to put this scenario at the start of the questionnaire instead of asking it at the end.

Both the regression and the convolution analyses do not show any statistical difference between including and excluding the reversed responses in Model COST. However, it does not mean this kind of data manipulation is always correct. Strict statistical and hypothesis tests should be employed to ensure that serious possible bias does not occur.

Despite these possible effects and bias brought about by the valuation design, the MBDC approach achieves higher efficiency by using multiple bidding. A more precise estimate of WTP/WTA is found with this technique because more bids are used to bound the response range. An alternative to this tradeoff of efficiency and bias has been suggested by Boyle et al. (1985), to use simulated market research instead of hypothetical markets employed by CVM studies.

Chapter 5: Conclusions

5.1 Summary of findings

The Canadian agricultural sector has been identified as a potential supplier of carbon offset credits by adopting management practices that reduce GHG emissions; such as reduced protein feeding or manure storage covers, and enhanced carbon sequestration though tillage practices. This provides Canadian livestock producers with opportunities to generate carbon offset revenue by changing their management practices. The motivation to change management practices are increased with a revenue incentive, where the revenue is generated in the carbon market.

Since a federally regulated carbon trading market is not yet in place, this study employed the contingent valuation method to elicit the carbon offset credit price that Quebec hog producers would require to adopt different BMPs. A survey questionnaire was developed, which contained two hypothetical scenarios for specific BMPs; reduced protein feeding and a manure storage cover. Each scenario contained a willingness to accept elicitation matrix presenting carbon offset credit prices as bid values and respondents' level of certainty.

The survey was sent to 1,371 Quebec hog farms. 487 surveys were filled out and returned. Among them, approximately 60% were usable for the WTA elicitation. The representativeness of the responses was compared to published information on the geographical distribution of hog farms, the average and type of animal on the farm, and the age and gender of the producer. The survey respondents were similar to the published information, which suggests that the survey provides a good representation of the hog producers' responses. In Model COST, there were 85 inconsistent answers that were reversed in order to increase the response size. The empirical evidence in the analysis supported the statistical validity of this kind of data manipulation.

The producers' mean WTA carbon offset revenue to change to a reduced protein feeding ration was estimated to be \$46.71 per tonne CO_2e. This hypothetical scenario included changing the protein content of the feed from 17 to 14% with a feed cost saving of \$1.15 per ton of feed. The current mean feed protein level of the sample was calculated to be 16%.

The producers' mean WTA carbon offset revenue to adopt a manure storage cover system was estimated to be \$40.40 per tonne CO_2e, lower than the mean WTA for the reduced protein feeding practice. This can be explained by the larger number of carbon offset credits generated when installing a manure storage cover system. This BMP also required less management input as compared to the feeding strategy. This scenario provided producers with information on the investment required for a synthetic non-air-tight cover system, its life span, and the added benefits in the nitrogen value of the manure as a fertilizer.

The third scenario suggests that the mean WTA cost for adopting a BMP to be \$11.88, which was 59% of the carbon offset revenue of \$20. The cost scenario didn't give any specific details about the management practices that would have to be undertaken.

The regression analysis indicated that the producers' decision to adopt the new feeding strategy was influenced by their attitudes. Only 15% of Quebec hog producers have a rotation operation that would need more feed storage capacity for this practice, however most of respondents were concerned about the potential negative impact upon animal performance. As for installing a manure storage cover, producers' decisions were largely influenced by the type of operation, size of the farm, whether they currently have a cover system or not, and their attitude towards this BMP. The regression coefficients indicate that producers with finisher and farrow-to-finish operations, or with a large number of feeders, would likely demand less carbon offset revenue than those with only a farrowing operation and limited number of feeders. Finally, producers' willingness to absorb cost was affected by their gender, income level, and operation type.

Through the regression and convolution analysis, this study detected significant starting point effects generated by ascending-descending bid order in all three models. The model COST suffered stronger starting point bias because of the lack of information provided in the hypothetic scenario. However, the sequencing effect, the order of the scenarios, was not significant.

5.2 Limitations and future study

The main limitation of this study was the bid design in the manure storage cover scenario. The starting net carbon offset revenue bid was \$7.00 per animal-space per year, which exceeded the allocated cost of installing a cover system of \$4.00 per animal-space per year. The reason for a high starting bid design was because during the pre-test most of the respondents expressed concern about the significant financial investment to initiate the adoption of a cover system. In addition, they questioned the durability of the technology. Therefore, the starting bid was deliberately raised above the breakeven level in order to bound the WTA valuation. However, this might generate starting point bias, as the respondents may have placed a higher value because of the higher starting bid. In addition, some respondents might have misunderstood that they would gain more carbon offset revenue from this practice since the starting bid exceeded the cost. Future studies could test another bid design, including a breakeven bid that approximates the cost, to investigate whether this influences the WTA estimate.

The geographical scope of the project could be extended. For example, a survey could include Ontario, the second largest pork producing province. Since the industrial structure of hog production in Ontario is believed to be similar to that of Quebec, the survey could be implemented quite easily. The survey results of Ontario plus Quebec would provide a better estimate of the hog sector's potential carbon offset credit supply to a national emission trading system.

Additionally, it would be interesting to position the cost scenario at the start of the questionnaire instead of at the end. This could be used to test for the strong bid design effects found in this study. Other methodological explorations might include using bid designs with smaller bid increments, and a one-shot valuation of all BMPs at the end instead of presenting them in a sequence.

Finally, other best management practices, such as nitrogen efficient cropland manure applications, could be introduced to hog producers in future studies. This would provide producers with a carbon offset credit portfolio of BMPs that would reduce the administration and transaction costs of generating carbon offset credits. Future studies can explore producers' welfare valuation of a carbon offset credit portfolio.

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Appendix 1: Survey Questionnaire (English)

● A **Carbon Offset Credit** is a credit for a management decision that removes or reduces an amount of greenhouse gas emission from your operation. The common measure of removal or reduction is 1 tonne of Carbon Dioxide Equivalent (CO_2e).
● The major **greenhouse gases (GHG)** emitted from the livestock sectors are: Carbon Dioxide, Methane, and Nitrous Oxide. The largest component of GHG emissions from the hog industry are from manure management systems, both during manure storage and manure nutrient application to cropland.
● By implementing specific management practices on the farm, that are known to reduce GHG emissions, a producer may become eligible to create carbon offset credits that could be traded in a carbon market. Trading carbon credits can increase the producers' revenue.

---

1. After you return this survey, one dollar will be donated to a charity in appreciation of your completion of this survey. Which charity would you like to choose?

☐ Canadian Cancer Society

☐ Heart and Stroke Foundation

☐ Canadian Red Cross

☐ Fondation Tirelire (Les producteurs de porcs du Québec aident les organismes à soulager la faim)

2. What type of operation do you have?

☐ Farrowing

☐ Grower

☐ Finisher

☐ Farrow to finish

☐ Other (specify)________________

3. How many hogs do you have on your farm per year?

Sows______

Weaners______

Feeders______

4. Are you familiar with hog farming practices that can reduce GHG emissions?
(*1: know it very well; 5: not at all*)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

5. Which one of the listed government initiatives would be more likely to influence your decision to adopt farming practices to reduce GHG emissions on your farm?
(Choose one or more)

☐ Technical advice and support in adopting farming practices

☐ Creating an emissions trading market in Canada

☐ Investing more in research on agriculture and greenhouse gases

☐ Voluntary Programs

☐ Direct financial incentive for adopting a farming practice that reduces GHG emissions

Scenario 1: Reduced Protein Feeding

Changes to hog feeding strategies provide an opportunity to reduce the carbon and nitrogen content of the manure produced on the farm, which can result in decreased GHG emissions. By reducing the dietary crude protein content of a hog ration by 1%, manure nitrogen excretion will be reduced by roughly 10%. Reducing nitrogen output from a hog barn will reduce the quantity of nitrous oxide (N2O) produced when manure is applied to cropland.

- Assume for an all-in-and-all-out operation, the animals come into the barn at 27 kg and leave at 109 kg.
- If you decrease your crude protein content in feeds by 3% --- from 17% to 14%. This will result in a saving in feed cost of $1.15 per ton because of the lower cost of ingredients (after considering the milling costs).
- This change in management practice would generate carbon credits.
- There are administrative costs associated with accessing these credits. These include: submitting a change in management plan, approval costs, monitoring and verification costs.
- At the end of the year, the carbon credits would be granted to you. Each of the credits can be sold in the carbon market to generate carbon credit revenue.
- NET CARBON REVENUE = Carbon Credit Revenue – Administrative Costs

6. At what net carbon revenue would you be willing to adopt this change in management practice?

You must also consider **the feed cost saving of** $1.15/ton.

(*Please check on each category for each* ***net*** *carbon revenue* ***level – Note: this is a revenue question.***)

Net Carbon Revenue (*Per animal space**)	**Definitely Yes**	**Maybe Yes**	**Neutral**	**Maybe No**	**Definitely No**	**Not Sure**
$ 0.009						
$ 0.18						
$ 0.27						
$ 0.45						
$ 0.90						
$ 1.80						

* *Animal space is equal to your barn capacity. For example, if you have a 100-sow barn, you have 100-animal spaces, and for a 2000-head finisher barn; you have 2000-animal spaces.*

7. What is the crude protein level in the feeds of your farm? ______________

8. Are you willing to adopt this practice?

☐ Yes → Go to scenario 2 ☐No

9. What is/are your major concern/s for not adopting a reduced crude protein feeding program?

- ☐ This change requires too large investment (ex: needs new silos)
- ☐ The revenue from carbon credits is not large enough
- ☐ It will have a negative impact on animal performance
- ☐ Do not have enough knowledge to change my practice
- ☐ Do not trust the government or GHG program organizations
- ☐ Other (specify):

Scenario 2: Manure Storage Cover System

Conventional storage systems for liquid or solid manures are one of the major GHG emission sources on hog farms. It is estimated, however, that the installation of a manure storage cover system can reduce methane emissions by 92%. Manure storage covers can: keep methane from escaping to the atmosphere, reduce odor, conserve manure nitrogen for crop production, and keep rainwater from entering the manure storage.

- Assume that you will install a non-air-tight synthetic cover system on your manure storage facility and it costs **$40,000 per 1,000 animal spaces** and will last for **10 years**. Allocating the cost over the 10 years period is **$4 per animal space per year**.
- The nitrogen fertilizer value of your manure storage will almost double by installing a cover system.
- This project would generate carbon credits.
- There are administrative costs associated with accessing these credits. These include: submitting a change in management plan, approval costs, monitoring and verification costs.
- At the end of the year, the carbon credits would be granted to you. Each of the credits can be sold in the carbon market to generate carbon credit revenue.
- NET CARBON REVENUE = Carbon Credit Revenue – Administrative Costs

10. At what net carbon revenue would you be willing to install a non-air-tight synthetic cover system?

You must consider the added benefit of the increase in nitrogen value of your manure storage as a fertilizer, and the increased costs of $4 per animal space per year **for the cover.** ***(Please check on each category for each net carbon revenue level – Note: this is a revenue question.)***

Net Carbon Revenue *(Per animal space)*	**Definitely Yes**	**Maybe Yes**	**Neutral**	**Maybe No**	**Definitely No**	**Not Sure**
$ 7.0						
$ 17.5						
$ 35.0						
$ 42.0						
$ 52.5						
$ 70.0						

11. Do you currently have a manure storage cover? _______________ If yes, what type?

____

12. Are you willing to adopt this practice?

☐ Yes → Go to scenario 3

☐ No

13. What is/are your concern/s for not adopting the manure storage cover system?

☐ The revenue from carbon credits is not large enough

☐ It requires too much investment

☐ Do not believe that the manure cover system lasts for 10 years

☐ Do not have enough knowledge to change my practice

☐ Do not trust the government or GHG program organizations

☐ Other (specify):

Scenario 3:

This is different from the other scenario because it gives you a revenue number and then asks you about costs!

● Consider you are a grower to finishing operator that currently uses conventional practices.

● Assume that the greenhouse gas credits generated from a change in your management practice would bring you CARBON REVENUE of **$20 per animal space per year** with a carbon price trading at $20 per carbon credit.

● In order to access these credits, you would have to submit a change in management plan to the registrar, have it approved, and verify that the carbon emissions were reduced. At the end of the year, the Registrar would grant you credits. Each credit can be sold on the carbon market.

14. What COSTS (both the cost of the management change and the administrative cost) would to be willing to bear in order to receive carbon revenue of $20/animal space /year?

(*Check only one level for each level of cost – Note: unlike the other questions we are asking what costs you are willing to accept.*)

Total Cost per year *(per animal space)*	**Definitely Yes**	**Maybe Yes**	**Neutral**	**Maybe No**	**Definitely No**	**Not Sure**
$ 1						
$ 5						
$ 10						
$ 15						
$ 20						
$ 22						
$ 25						

Other information

15. If you have a choice among those 2 practices above, which one would you prefer and why?

☐ Reduced crude protein content

☐ Synthetic manure storage cover

Reason/s (specify):

16. Gender

☐ Female ☐ Male

17. Age

☐ 18-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 61-70 ☐ above 70

18. Highest level of education

☐ Primary

☐ Secondary

☐ Some post-secondary

☐ University

☐ Other (specify):

19. Family income before tax in 2006

☐ $0 --- 20,000

☐ $20,001 --- 35,000

☐ $35,001 --- 50,000

☐ $50,001 --- 100,000

☐ $100,000 and over

20. If you have any comments that you would like to bring up:

Thank you for your time.

Your assistance for completing this survey is greatly appreciated.

Survey Questionnaire (French)

● Un crédit compensatoire est un crédit pour la gestion des gaz à effet de serre (GES) qui réduit les quantités totales d'émissions des opérations agricoles. La mesure qui est utilisée pour comptabiliser ces réductions sont les tonnes de dioxyde de carbone équivalent (CO_2e).
● Les principaux gaz considérés avoir un effet sur le réchauffement climatique sont le dioxyde de carbone, le méthane, et l'oxyde d'azote. En ce qui concerne la production porcine, la majeure partie des émissions sont produites lors de la manutention des effluents d'élevage, pendant l'entreposage et l'application au champ.
● Par l'application de certaines pratiques étant reconnues pour diminuer les émissions de GES, un producteur pourrait devenir éligible à l'obtention de crédits compensatoires. Ces crédits compensatoires pourraient être vendus sur le marché du carbone et ainsi procurer une nouvelle source de revenus pour les entreprises participantes.

---

1. Si vous retournez ce questionnaire dûment rempli, un dollar sera donné à un organisme de charité en appréciation de votre collaboration. Quel organisme préférez -vous supporter ?

☐ Fondation Tirelire (Les producteurs de porc du Québec aident les organismes à soulager la faim)

☐ Fondation des Maladies du Coeur

☐ Croix Rouge Canadienne

☐ Société Canadienne du Cancer

2. Quel type d'élevage opérez-vous ?

☐ Maternité

☐ Pouponnière

☐ Finisseur

☐ Naisseur-finisseur

☐ Autre *(Spécifiez)* : ________________

3. Combien de porcs avez-vous en inventaire en moyenne ?

Truies_______

Porcelets_______

Porcs d'engraissement_______

4. Êtes-vous informés au sujet des pratiques agricoles pouvant diminuer l'émission de gaz à effet de serre ? *(1 : très informé, 5 : aucune connaissance)*

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

5. Parmi les initiatives gouvernementales suivantes, lesquelles pourraient influencer vos décisions quant à l'adoption de pratiques agricoles pouvant diminuer les émissions de GES sur votre entreprise ? *(Choisir une initiative ou plus.)*

☐ Conseil et support technique pour adopter ces pratiques agricoles.

☐ Créer un marché permettant la transaction des crédits compensatoires de GES.

☐ Investir davantage en recherche concernant l'agriculture et les GES.

☐ Programmes volontaires.

☐ Avantages financiers pour l'adoption de pratiques agricoles visant la réduction de GES.

Scénario 1: Diminution des protéines dans les aliments.

La modification de l'alimentation permet la diminution du carbone et de l'azote dans les déjections réduisant ainsi les émissions de GES. En diminuant de 1% les protéines brutes de la ration alimentaire, il est possible de réduire d'environ 10% le contenu en azote des déjections. La diminution de la charge d'azote permet la diminution de l'oxyde d'azote (N2O) lors de l'application au champ. L'application de cette pratique pourrait rendre le producteur éligible à l'obtention de crédits compensatoires.

● Faites l'hypothèse que vous avez un engraissement fonctionnant par tout plein-tout vide dont les porcs sont engraissés de 27 à 109 kg.

● Faites l'hypothèse additionnelle que vous procédez à une diminution du contenu en protéine de la moulée de **3%, c'est-à-dire de 17% à 14%.** Cette modification diminuerait le coût des aliments de **1,15$ la tonne** (et ceci après avoir considéré les coûts de moulange) et ne requiert aucun investissement supplémentaire pour l'entreposage.

● Suite à ce changement de pratique, vous pourriez obtenir **des crédits compensatoires**.

● Certains **coûts administratifs** sont prévus tels que: coût d'adhésion, coûts de vérification et d'acceptation.

● Le revenu net généré est calculé comme suit :

REVENU NET GÉNÉRÉ=Revenu Provenant des Crédits Carbone – Coûts Administratifs

● Pour obtenir ces crédits, vous auriez à soumettre votre changement de pratique aux autorités compétentes qui valideraient le changement et l'approuveraient. À la fin de l'année, les crédits carbones vous seraient émis, ceux-ci pouvant être vendus sur le marché du carbone créant ainsi une source de revenu.

6. À quel revenu net seriez-vous prêt à adopter ce changement de pratique ?

Veuillez considérer les économies de l'alimentation de **1,15$ par tonne**. *(Veuillez cocher un niveau de certitude pour chaque revenu présenté.)*

Revenus nets générés *(Par espace animal*)*	**Définitivement oui**	**Peut-être oui**	**Neutre**	**Peut-être non**	**Définitivement Non**	**Indécis**
0,009$						
0,18$						
0,27$						
0,45$						
0,90$						
1,80$						

** Un **espace-animal** est équivalent à la capacité de vos bâtiments d'élevage. Par exemple, si vous avez une porcherie pouvant contenir 100 truies, vous avez 100 espaces-animal et pour un engraissement de 2000 porcs, 2000 espaces-animal.*

7. Quel est actuellement le pourcentage de protéines brutes de vos aliments ?____________

8. Êtes-vous intéressés à adopter cette pratique ?

☐ Oui – Allez au Scénario 2 ☐ Non

9. Quels sont les principaux obstacles à la diminution de protéines dans votre programme alimentaire ? *(Choisissez un facteur ou plus.)*

☐ Ce changement représente des investissements importants (ex: achat de nouveaux silos).
☐ Les revenus de crédit-carbone ne sont pas assez importants.
☐ Ce type de pratique aurait un impact négatif sur la performance.
☐ Vous auriez besoin de plus d'information avant d'adopter de telles pratiques.
☐ Vous ne faites pas confiance au gouvernement ou aux programmes de GES.
☐ Autre *(spécifiez)* : ________________________________

Scénario 2: Recouvrement des ouvrages d'entreposage

Les ouvrages d'entreposage conventionnels pour déjection solide ou liquide sont une source majeure d'émission de GES sur les entreprises en production porcine. Il est estimé que le recouvrement des ouvrages d'entreposage réduit les émissions de méthane de 92%. En plus de garder le méthane à l'intérieur des ouvrages d'entreposage, il permet de diminuer les pertes d'azote, réduit les odeurs et empêche l'accumulation de l'eau de pluie dans l'ouvrage d'entreposage.

● Faites l'hypothèse que vous planifiez installer un recouvrement non-hermétique pour diminuer les émissions de GES estimé à **40 000$ par 1000 espaces-animal**. Le paiement des coûts relié à l'investissement est étalé sur 10 ans et représente donc un investissement de **4$ par espace-animal par année**. Le recouvrement non-hermétique a une **durée de vie estimée de 10 ans**.
● Il est estimé que par le recouvrement des ouvrages d'entreposage, le contenu en azote des déjections **double**, diminuant ainsi l'achat d'engrais azoté.
● Suite au recouvrement de l'ouvrage d'entreposage, vous pourriez obtenir **des crédits compensatoires**.
● Certains **coûts administratifs** sont prévus tels que: coût d'adhésion, coûts de vérification et d'acceptation.
● Le revenu net généré est calculé comme suit :
REVENU NET GÉNÉRÉ=Revenu Provenant des Crédits Carbone – Coûts Administratifs
● Pour obtenir ces crédits, vous auriez à soumettre votre changement de pratique aux autorités compétentes qui valideraient le changement et l'approuveraient. À la fin de l'année, ces crédits carbones vous seraient émis, ceux-ci pouvant être vendus sur le marché du carbone créant ainsi une source de revenu.

10. A quel revenu net seriez-vous prêt à ajouter un recouvrement non-hermétique à votre ouvrage d'entreposage ?

Veuillez considérer les bénéfices de l'augmentation d'azote des déjections et l'investissement de **4$ par espace-animal par année**. (*Veuillez cocher un niveau de certitude pour chaque revenus présentés.*)

Revenus nets générés *(Par espace- animal)*	**Définitivement oui**	**Peut-être oui**	**Neutre**	**Peut-être non**	**Définitivement non**	**Indécis**
7,0$						
17,5$						
35,0$						
42,0$						
52,5$						
70,0$						

11. Avez-vous présentement un recouvrement sur votre ouvrage d'entreposage ? Si oui, de quel type est-il ?

☐ Oui ☐ Non

Type : ______________________________

12. Êtes-vous intéressé à adopter cette pratique ?

☐ Oui – Allez au Scénario 3 ☐ Non

13. Quel sont les principaux obstacles pour ne pas recouvrir votre structure d'entreposage ?

☐ Les revenus de crédit-carbone ne sont pas assez importants.
☐ L'investissement requis est trop important.
☐ Vous auriez besoin de plus d'information avant d'adopter de telles pratiques.
☐ Vous ne faîtes pas confiance à ce type de construction.
☐ Vous ne faites pas confiance au gouvernement ou aux programmes de GES.
☐ Autre (spécifiez) : ______________________________

Scénario 3

Cette question est différente des scénarios précédents puisqu'elle présente des revenus provenant des crédits carbones et vous soumet une question reliée au coût du programme pour votre entreprise.

● Faites l'hypothèse que vous êtes un producteur naisseur-finisseur ayant des pratiques agricoles conventionnelles.

● Dans l'hypothèse que le marché du carbone est mis en place au Canada et de par le changement de vos pratiques, vous pourriez vendre des crédits générant des REVENUS de 20$ par espace- animal par année (20$ par crédit carbone).

● Pour obtenir ces crédits, vous auriez à soumettre votre changement de pratique aux autorités compétentes qui valideraient le changement et l'approuveraient. À la fin de l'année, les crédits carbones vous seraient émis, ceux-ci pouvant être vendus sur le marché du carbone.

14. Quel COÛT (ce montant comprend le changement de pratiques agricoles, de vérification et d'acceptation) seriez-vous prêt à accepter pour recevoir des revenus de 20$ par espace- animal par année provenant du marché du carbone ?

Veuillez remarquer que cette question est par rapport aux coûts contrairement aux deux scénarios précédents. *(Veuillez cocher un niveau de certitude pour chaque niveau de coûts.)*

Coûts totaux par année *(par espace- animal)*	**Définitivement oui**	**Peut-être oui**	**Neutre**	**Peut-être non**	**Définitivement non**	**Indécis**
1$						
5$						
10$						
15$						
20$						
22$						
25$						

Informations additionnelles

15. Si vous aviez le choix d'adopter l'une des deux pratiques suivante, laquelle préfériez-vous adopter et pourquoi ?

☐ Diminution des protéines dans les aliments

☐ Recouvrement des bâtiments d'entreposage

Raison *(spécifiez)* : ____

____

____

16. Sexe

☐ Femme ☐ Homme

17. Âge

☐ 18-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 61-70 ☐ plus de 70

18. Niveau d'éducation complété

☐ Primaire
☐ Secondaire
☐ Post-secondaire
☐ Universitaire
☐ Autre *(spécifiez)* : ______________

19. Revenu familial avant impôt en 2006

☐ 0 – 20 000$
☐ 20 001 – 35 000$
☐ 35 001 – 50 000$
☐ 50 001 – 100 000$
☐ Plus de 100 000$

20. Avez-vous des commentaires à formuler au sujet de ce sondage :

____

____

____

____

____

____

Merci pour votre temps

Votre participation est grandement appréciée.

Appendix 2: Convolution Results

M1 – M2:

Minimum Value of Distribution 1	41.5100
Minimum Value of Distribution 2	35.4600
Maximum Value of Distribution 1	56.4600
Maximum Value of Distribution 2	49.7900

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-8.2800
Highest Possible Convoluted Value	21.0000
Difference	29.2800

alpha (significance) 0.03862648

lower bound 0.95000000 percent CI 0.29000000
upper bound 0.95000000 percent CI 11.12000000

M3 – M4:

Minimum Value of Distribution 1	10.0600
Minimum Value of Distribution 2	10.6600
Maximum Value of Distribution 1	13.6800
Maximum Value of Distribution 2	13.5900

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-3.5300
Highest Possible Convoluted Value	3.0200
Difference	6.5500

alpha (significance) 0.82876936

lower bound 0.95000000 percent CI -1.34000000
upper bound 0.95000000 percent CI 1.06000000

M4 – M5:

Minimum Value of Distribution 1	9.7700
Minimum Value of Distribution 2	10.0600

Maximum Value of Distribution 1	14.6800
Maximum Value of Distribution 2	13.6800

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-3.9100
Highest Possible Convoluted Value	4.6200
Difference	8.5300

alpha (significance) 0.71167848
lower bound 0.95000000 percent CI -1.29000000
upper bound 0.95000000 percent CI 1.89000000

M1A1 – M1D1:

Minimum Value of Distribution 1	42.7000
Minimum Value of Distribution 2	26.6000
Maximum Value of Distribution 1	70.4000
Maximum Value of Distribution 2	49.9000

Level of precision of the convolution	0.1000
Lowest Possible Convoluted Value	-7.2000
Highest Possible Convoluted Value	43.8000
Difference	51.0000

alpha (significance) 0.00038816

lower bound 0.95000000 percent CI 7.80000000
upper bound 0.95000000 percent CI 25.70000000

M1A2 – M1D2:

Minimum Value of Distribution 1	35.3100
Minimum Value of Distribution 2	36.4700
Maximum Value of Distribution 1	70.7300
Maximum Value of Distribution 2	66.6800

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-31.3700
Highest Possible Convoluted Value	34.2600
Difference	65.6300

alpha (significance) 0.90727432
lower bound 0.95000000 percent CI -11.85000000
upper bound 0.95000000 percent CI 10.72000000

M1A1 – M1A2:

Minimum Value of Distribution 1	35.3100
Minimum Value of Distribution 2	26.6000
Maximum Value of Distribution 1	70.7300
Maximum Value of Distribution 2	49.8500

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-14.5400
Highest Possible Convoluted Value	44.1300
Difference	58.6700

alpha (significance) 0.02290832
lower bound 0.95000000 percent CI 1.63000000
upper bound 0.95000000 percent CI 22.18000000

M1D1 – M1D2:

Minimum Value of Distribution 1	42.6800
Minimum Value of Distribution 2	36.4700
Maximum Value of Distribution 1	70.3900
Maximum Value of Distribution 2	66.6800

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-24.0000
Highest Possible Convoluted Value	33.9200
Difference	57.9200

alpha (significance) 0.38609584
lower bound 0.95000000 percent CI -5.79000000
upper bound 0.95000000 percent CI 14.41000000

M2A1 – M2D1:

Minimum Value of Distribution 1 34.2300

Minimum Value of Distribution 2	19.7500
Maximum Value of Distribution 1	64.9300
Maximum Value of Distribution 2	62.7000

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-28.4700
Highest Possible Convoluted Value	45.1800
Difference	73.6500

alpha (significance) 0.00912696

lower bound 0.95000000 percent CI 4.40000000
upper bound 0.95000000 percent CI 27.32000000

M2A2 – M2D2:

Minimum Value of Distribution 1	32.4800
Minimum Value of Distribution 2	27.5800
Maximum Value of Distribution 1	57.9100
Maximum Value of Distribution 2	56.2400

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-23.7600
Highest Possible Convoluted Value	30.3300
Difference	54.0900

alpha (significance) 0.78804216

lower bound 0.95000000 percent CI -8.42000000
upper bound 0.95000000 percent CI 10.68000000

M2A1 – M2A2:

Minimum Value of Distribution 1	19.7500
Minimum Value of Distribution 2	27.5800
Maximum Value of Distribution 1	62.7000
Maximum Value of Distribution 2	56.2400

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-36.4900
Highest Possible Convoluted Value	35.1200

Difference	71.6100

alpha (significance) 0.13288776

lower bound 0.95000000 percent CI-20.13000000
upper bound 0.95000000 percent CI 2.92000000

M2D1 – M2D2:

Minimum Value of Distribution 1	34.2300
Minimum Value of Distribution 2	32.4800
Maximum Value of Distribution 1	64.9300
Maximum Value of Distribution 2	57.9100

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-23.6800
Highest Possible Convoluted Value	32.4500
Difference	56.1300

alpha (significance) 0.20533808

lower bound 0.95000000 percent CI -3.42000000
upper bound 0.95000000 percent CI 15.56000000

M3A1 – M3D1:

Minimum Value of Distribution 1	34.2300
Minimum Value of Distribution 2	9.2300
Maximum Value of Distribution 1	64.9300
Maximum Value of Distribution 2	16.7400

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	17.4900
Highest Possible Convoluted Value	55.7000
Difference	38.2100

alpha (significance) 0.20533808

lower bound 0.95000000 percent CI 28.79000000 upper bound 0.95000000 percent CI 43.93000000

M3A2 – M3D2:

Minimum Value of Distribution 1	10.3900
Minimum Value of Distribution 2	7.6300
Maximum Value of Distribution 1	16.3800
Maximum Value of Distribution 2	12.9000

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-2.5100
Highest Possible Convoluted Value	8.7500
Difference	11.2600

alpha (significance) 0.00370720

lower bound 0.95000000 percent CI 1.00000000
upper bound 0.95000000 percent CI 5.00000000

M3A1 – M3A2:

Minimum Value of Distribution 1	9.2300
Minimum Value of Distribution 2	7.6300
Maximum Value of Distribution 1	16.7400
Maximum Value of Distribution 2	12.9000

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-3.6700
Highest Possible Convoluted Value	9.1100
Difference	12.7800

alpha (significance) 0.00860600

lower bound 0.95000000 percent CI 0.74000000
upper bound 0.95000000 percent CI 5.03000000

M3D1 – M3D2:

Minimum Value of Distribution 1	10.3900
Minimum Value of Distribution 2	10.5000
Maximum Value of Distribution 1	16.3800
Maximum Value of Distribution 2	15.9100

Level of precision of the convolution	0.0100
Lowest Possible Convoluted Value	-5.5200
Highest Possible Convoluted Value	5.8800
Difference	11.4000

alpha (significance) 0.91512280

lower bound 0.95000000 percent CI -2.21000000
upper bound 0.95000000 percent CI 2.00000000