University of Alberta

Analyzing Canadian Public Preferences for Plant Molecular Farming Research Priorities

by

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Abstract

This research is motivated by the development of plant molecular farming technology, an emerging area of applications of agricultural biotechnology. The study focuses on assessing public preferences for research funding allocations to different research areas of plant molecular farming, including health research applications, industrial areas of research, environmental research, consumer products, and social, economic, and public policy areas of research. This study also focuses on evaluating the influence of demographic and socio-economic characteristics on individual's choice behavior. The data for this study were collected from a representative sample of Canadians through a 2005 Internet-based survey. The sample is generally representative of the Canadian adult population. Respondents were asked to complete a stated choice experiment designed for the topic of the study. The results of conditional logit models indicate that members of the public possess positive attitudes to plant molecular farming technology and most accept that the Canadian government allocates research funding to this technology. Overall there was significant preference for allocating research funding into health and environmental areas of research. Respondents' age, gender, education level, and occupation have stronger influences on their preferences than respondents' income, area of residence, and any association with a health-focused group. Based on the results of the conditional logit estimations, research priorities and optimal funding allocations were indicated. The study gives government and decision makers information on public preferences related to this new area of agriculture biotechnology.

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Chapter 1 Introduction

1.1 The Development of Plant Molecular Farming

Modern biotechnology takes many forms, with the most widely discussed technique being recombinant DNA technology, often referred to as genetic engineering or genetic modification (Nevitt et al. 2003). Genetic engineering of plants may involve placing gene(s) copied from another variety or even another species into a plant but commonly refers to gene transfer across species (Nevitt et al. 2003). Plant Molecular Farming (PMF) is an emerging application of biotechnology, involving the use of the techniques of genetic engineering in the potential plant-based production of a variety of proteins and related products that have pharmaceutical, industrial and consumer uses (Einsiedel and Medlock 2005; Veeman 2006). The first pharmaceutical protein made in plants was human growth hormone (Barta et al. 1986). Since then other proteins from experimental vaccines to antibodies to industrial proteins have been produced experimentally in plant-based production systems (Ma, Drake, and Christou 2003; Breithaupt 2004; Fischer et al. 2004b).

Development bottlenecks in the pharmaceutical industry, agriculture and food manufacturing industry may be one reason that stimulates the development of PMF technology to facilitate growth in these sectors. A driving force of possible PMF-based pharmaceutical production is because the pharmaceutical industry faces increasing production costs using conventional bioreactors, a capacity shortage of conventional fermentation production systems, lengthy time periods of conventional production systems, and the need for affordable medicines in developing countries (Nevitt et al. 2003; Elbehri 2005). Current production vehicles for pharmaceutical products largely require mammalian cell culture methods (Nevitt et al. 2003). Commercial-scale mammalian cell culture systems are expensive to build and maintain and tend to be inflexible to market needs (Nevitt et al. 2003). The shortcomings of mammalian cell culture systems have provided incentives to pursue alternative methods for producing pharmaceutical products. Plants and plant systems are one of the choices (Nevitt et al. 2003). Nevitt et al. (2003) noted that research in both the public and private sectors has shown a potential for using transgenic plants as bio-reactors to produce therapeutic proteins. PMF technology has been argued to be a potential production system to enhance productivity to develop high-value therapeutic products and to mass-produce industrial bioproducts. Potential solutions for environmental problems are also envisaged.

The countries participating in the development of PMF technology include the United States, Canada, some western European countries (such as France), Japan, and Argentina (Arcand and Arnison 2004). The first PMF research field trial was in the United States, in 1992, using the alfalfa plants. Later, Canada's first field trial used canola (subsequently no longer used). Europe is behind North America in PMF innovations. In 1995, the first PMF field trial occurred in France. Argentina and Japan introduced their first field trials in 1998 and 2000 respectively. In 2002 Australia had its first field trial (GE^3LS)[1].

The major stakeholders in PMF industry are private companies. Other sectors, such as government and research institutions, are also participating in the development of this new biotechnology. Worldwide, few PMF products have actually been commercialized (Veeman 2006). In Canada no PMF products have been commercialized yet (Veeman 2006).

Veeman (2006) noted that PMF technology is still new and faces numbers of scientific and other challenges. The applications and products of PMF may have potential benefits, but may also be the source of appreciable risks and concerns (Einsiedel and Medlock 2005; Kirk and McIntosh 2005; Elbehri 2005; Veeman, Li, and Adamowicz 2006; Veeman 2006). Einsiedel and Medlock (2005) suggested that PMF technology raises possible health, environmental, social, ethical, and regulatory challenges that need to be considered. Since there is coexistence of benefits and risks associated with PMF, both scientific research and socio-economic research are needed to improve the technology and to assess how members of public view the introduction and development of the

[1] http://www.genomeprairie.ca/ge3ls/pharm, accessed on January 2006

technology. Both public and private sectors support research on PMF (Volinskiy et al. 2006). Till now, little is known about public attitudes to government investment of PMF research (Volinskiy et al. 2006). It is interesting to examine whether the general public is in favor of an extended investment compared to current PMF research funding, or if, on the contrary, the public would like to see a reduction in investments into PMF research. It is also of interest to understand preferences of the general public for allocations of PMF research funding in different research areas.

1.2 Research Objectives

The objective of this thesis study is to gain more information on public attitudes to plant molecular farming technology and gain a better understanding of public opinion of government investments in plant molecular farming research. This research contributes to the literature on assessing government research funding investment policy from the public aspect by demonstrating the application of a quantitative approach. This research also contributes to the literature on PMF related policy development studies by applying economic methodology. It is hoped that this study will be of interest to policy makers, as well as members of the public, since government needs to consider public opinion when making policies and regulations and there is a need for public participation in policy making processes.

The research objectives can be summarized as follows:

- To assess public respondents' general attitudes (positive or negative) to plant molecular farming technology;
- To gain knowledge of how Canadians would allocate government research funding into different PMF research applications and the views of Canadians relative to their preferences for research activities directed at different areas of PMF research and development
- To determine whether the demographic and socio-economic characteristics of public respondents have an influence on their preferences on research funding allocations;

- To derive public views of research priorities for different types of PMF applications and allocations of government funding on PMF research.

1.3 Thesis Outline

The thesis is organized in six chapters. Following this introduction given in Chapter 1, Chapter 2 presents an overview of issues regarding plant molecular farming technology. Thus Chapter 2 mainly focuses on introducing the assessment of the benefits and risks associated with PMF technology. Potential applications of PMF technology and the description of production processes of PMF products are described. Chapter 3 provides an overview of previous studies related to the research topic. This chapter begins with a description of previous studies of PMF, focusing on public acceptability assessments, followed by an overview of studies on research investments and funding allocations. A review of literature relating to choice experiment methods, which are applied in the study, is also discussed. Chapter 4 continues by describing the theoretical framework of the method for modeling research funding choice behavior, including an overview of discrete choice model, Lancastrian consumer theory, random utility model, and econometric modeling. A description of survey design and data collection and a summary of data description are also provided. Chapter 5 discusses the model development, model estimation, and analysis of results. Policy implications based on the results from the empirical model are discussed. In the final chapter, the findings and their implications of the study are summarized. This chapter also outlines some of the contributions of the study, as well as some limitations. The chapter concludes with recommendations about future research in this area.

Chapter 2 Plant Molecular Farming

2.1 Introduction

To provide background information for the study of plant molecular farming technology, this chapter begins with an introduction to PMF technology outlining its potential applications and production processes. This is followed by a discussion of potential benefits and potential risks associated with PMF technology.

2.2 Introduction to Plant Molecular Farming

2.2.1 What is Plant Molecular Farming?

According to the Canadian Food Inspection Agency, plant molecular farming (PMF) is "the growing of plants in agriculture to produce pharmaceutical or industrial compounds instead of food, feed, or fibre". The possible products of PMF technology range from the production of medical products, such as pharmaceuticals and vaccines, to the manufacture of industrial products like biodegradable plastics and industrial chemicals[2].

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[2] Plant Molecular Farming -- http://www.inspection.gc.ca/english/sci/biotech/reg/pmfamve.shtml, accessed on July 2 2006

2.2.2 Potential Applications of Plant Molecular Farming

Table 2-1 Potential Applications of PMF Technologies across Key Sectors

Health and Medicine	Agriculture and Food	Industrial Bioproducts
• Biopharmaceuticals • Vaccines • Antibodies • Enzymes • Diagnostic Kits • Gene therapies • Therapeutic proteins	• Disease and drought resistant crops • Functional foods • Nutraceuticals • Biopesticides	• Biofuels and bioenergy • Manufactured products • Biochemicals • Bioplastics • Biolubricants • Biocatalysts • Biosensors

Source: King (2004) "Plant and Animal Molecular Farming Technologies and the Potential Economic, Social and Environmental Benefits They Can Bring to Canada and Canadians, Overview and Perspective From Industry Canada". Industry Canada. Presentation at BMPS Workshop. April 2004.

2.2.3 The Production Processes for PMF Products

Plant molecular farming technology uses the techniques of genetic engineering, that is, recombinant DNA technology (GE^3LS)[3]. Scientists place into the host plant a gene from another organism that expresses desired new trait(s) (Nevitt et al. 2003). In this way, the new trait(s) will be transferred into the host plant. Then the plant grows with the trait(s) using its own biological machinery. Once the plant has matured, it would be harvested, and the new trait molecule would be extracted, purified, refined and used in pharmaceutical or industrial production. In this process, plants themselves may potentially become "factories" for producing new trait molecules (GE^3LS)[4].

[3] http://www.genomeprairie.ca/ge3ls/pharm, accessed on January 2006

[4] http://www.genomeprairie.ca/ge3ls/pharm, accessed on January 2006

2.3 The Potential Advantages and Benefits of Plant Molecular Farming

Potential benefits and advantages of PMF are outlined by scientists and by industry stakeholders. The potential benefits associated with PMF technology involve potential health benefits, industrial products and potential economic benefits. In the following section, these potential benefits are discussed.

2.3.1 Potential Health Benefits

The potential health benefits associated with PMF technology include the "prospects of new and safer pharmaceuticals or medicine with diagnostic, therapeutic and prophylactic uses" (Veeman 2006, p.2) and also include the possibility to develop nutritionally improved food.

New Methods of Pharmaceutical Production

Through genetic engineering techniques, plants could provide a wide range of types of proteins, including some not possible by traditional production technologies of microbial fermentation and mammalian cell cultures (Miller 2004; Byrne, Ward, and Harrington 2004; Elbehri 2005). During normal growth, genetically engineered plants may synthesize "recombinant" proteins and then the proteins are extracted from the plants to produce potential PMF pharmaceutical products, including blood components and products, hormones, antibodies, enzymes, vaccines and other medically proteins (Ma, Drake, and Christou 2003). There has been interest in the potential ability of PMF technology for new medicines and to target a group of new diseases that have not been addressed by traditional production (Elbehri 2005). Potential new PMF-based pharmaceuticals are proposed for diseases and illness such as cancer, cardiovascular diseases, infectious diseases, diabetes, measles, tuberculosis, HIV/AIDS, and SARS (Amos 2004; Elbehri 2005; Veeman 2006).

Product Safety

Molecular farming with transgenic plants is seen to have safety advantages over protein production using transgenic animals (Kostandini 2004; Kostandini 2005; Horn, Woodard, and Howard 2004; Fischer et al. 2004a). These advantages arise because the possibility that viruses or prions contaminate pharmaceutical products is expected to be lower for PMF production systems than for production systems that are based on mammalian cell cultures or transgenic animals (Ma, Drake, and Christou 2003). Plants do not serve as hosts for mammalian pathogens (Cramer et al. 1996). Unlike products isolated from blood or produced in animal cell cultures, pharmaceuticals derived from "plants will not carry potential harmful human diseases or animal viruses, reducing the risk of drugs being contaminated with animal pathogens, prions, or diseases-causing germs" (SABIC 2003, p.1-2). And plants are currently known not to transmit plant viruses to human (Miller 2004). People argue plants also have a number of unique practical advantages, such as the "high stability of proteins expressed in seeds and the ability to express pharmaceutical proteins in edible organs for oral administration with minimal processing" (Horn, Woodard, and Howard 2004, p.1). Another suggested safety advantage of PMF-based pharmaceuticals is that using GM/GE technique it is possible to target disease in a very specific manner by inserting the specific desired gene(s), therefore maximizing efficacy while minimizing side effects (Elbehri 2005).

To Develop Nutritionally Improved Food and Industrial Products

PMF technology also involves in the production of potential new plant-based consumer products. These kinds of products could include "food crops that would contain essential micro-nutrients (essential minerals, like iron or zinc, and enhanced vitamins that are required for human health but are lacking in diets of many of the poor in developing nations; golden rice is one of the examples), and oilseed crops modified to reduce current unhealthy components (like triglycerides) or to express desirable combinations of dietary fat profiles" (Veeman 2006, p.4). The prospective purpose of these plant-based consumer products is to provide consumer products with healthy components (like omega-3 fatty acids) or to provide consumer products that might help to reduce the probability of some illness and disease (tomatoes enriched with lycopene are an example) (Pew 2002; Veeman 2006).

Another area of PMF applications involve the production of potential new and cheaper plant-based industrial products, such as biofuels, bioplastics, and industrial enzymes (Veeman 2006). "Biofuels are renewable energy resources that can be produced from modified crops, providing substitutes for depleting stocks of oil and natural gas that hold the promise of reduced greenhouse gas emissions" (Veeman 2006, p. 4). Bioplastics are another potential PMF-based industrial products, which have the possible advantages of rapid biodegradability (Veeman 2006). Biodegradable molecules have been derived from modified corns to produce bioplastics in the experimental stage (Einsiedel and Medlock 2005). The enzyme trypsin, used in large volumes in the detergent and leather industries as a catalyst, has been produced in genetically modified corn (Einsiedel and Medlock 2005).

2.3.2 Potential Economic Benefits

It has been argued that PMF technology could have a significant economic impact on consumers and the economy because this technology may lower costs for some products (such as pharmaceuticals, industrial products, and food). Further it may be the source of new products (e.g. pharmaceuticals, industrial products) that have benefits to users and consumers and that are the basis of new industries.

Lower Cost

It has been argued by its proponents that PMF technology may provide relatively cost-effective means of producing pharmaceuticals, industrial products, and food products (Fischer et al. 2004a; Veeman 2006). It has been suggested that the utilization of plants to produce potential PMF products could lower production costs for current or new pharmaceuticals (see for example, Kusnadi, Nikolov, and Howard 1997; Mison and Curling 2000; Pew 2002; Ma, Drake, and Christou 2003; Arcand and Arnison 2004; Fischer et al. 2004a). Nevitt et al. (2003) pointed that the plants from which potential PMF-based pharmaceutical products may be extracted are highly efficient and cost effective to produce. It is suggested that using plants may require lower capital and operating costs compared to traditional production facilities (Miller 2004). In PMF-based pharmaceuticals production, the argument of lower cost is since potential products are argued to be produced using agricultural processes of plant cultivation rather than using the biological-reactor-based processes of mammalian cell culture (the current dominant pharmaceutical production) (Veeman 2006). The costs involved in establishing a field of plants are argued to be significantly smaller than those needed to build and maintain an indoor mammalian cell bioreactor (Nevitt et al. 2003). Moreover, another aspect of cost effective advantage of PMF technology, suggested by Nevitt et al. (2003), is that, because "plants do not host mammalian viruses or human pathogens", the expenditures to conduct "viral screening and processes that prevent contamination from human infectious agents" could be reduced to near-zero with PMF-system (Nevitt et al. 2003, p.4). Viral screening processes are significant expenses in mammalian-base bioreactors. Lower production costs provide the possibility that proteins that could not be produced cheaply enough at high volume through conventional methods might become "economically viable" (GE^3LS) [5]. Thus PMF technology may have the potential to benefit medical consumers by providing a more affordable source of pharmaceuticals.

However, it is worthwhile to notice that the prediction of potential cost benefits of PMF technology does not take PMF-related regulation costs into consideration. The omitted costs may include any allowance for return to investment, patent charges, licensing fees, and the costs of containment, testing and monitoring (Veeman 2006). These costs could be expected to have impacts on companies' costs and will also affect the costs to consumers of PMF products.

[5] www.genomeprairie.ca/ge3ls/pharm/general/whyplants.html, accessed on January 2006

Large-scale Production

Plants platforms for PMF production are suggested to have the ability to allow for large-scale production capacity (Elbehri 2005). Some people argue that using PMF plant-based production systems, some pharmaceuticals are expected to be produced in much larger volumes and in much shorter time periods than in current pharmaceutical production systems, which are normally based on microbial fermentation or mammalian cell culture (Veeman 2006). PMF technology is also argued to be more flexible enabling rapidly scaled up production to meet rapidly increasing demand (Nevitt et al. 2003; Elbehri 2005). To take PMF-based pharmaceuticals production as an example, plant-based production systems are argued to have the ability to increase production to respond to increased demand at low cost and at less time by planting more acres of genetically modified plants, rather than building new bioreactor facilities required by cell culture systems (Nevitt et al. 2003, Veeman 2006), which can take years to build and are expensive to build.

2.3.3 Economic Development Opportunities

The development of PMF technology is suggested to be a potential opportunity for Canadian farmers to improve their economic situation because some novel PMF plants may expand farmers' alternative crop production choices and markets opportunities (Swoboda 2002; Veeman 2006). However, some studies argue that, in reality, the size of the fields that will grow PMF plants is relatively small. Therefore, the potential economic benefits for farmers may be limited. PMF technology is also viewed as an opportunity for Canadian development of new industrial and pharmaceutical processing industries; the development of new industries provides benefits to employment and economic growth (BIOTECanada 2004; Veeman 2006).

2.4 Potential Risks of Plant Molecular Farming

In addition to the expected potential benefits, the innovation of plant molecular farming technology raises health, environmental, social, and regulatory risks and concerns which need to be addressed.

2.4.1 Potential Contamination of Food Supply

The dominant concern about PMF technology is the possibility that PMF products and waste might contaminate food crops and food supply chain (Elbehri 2005; Einsiedel and Medlock 2005; Veeman 2006). If plants used for PMF applications are also crops used to provide food for people and feed for livestock, some are concerned that the modified genes for PMF applications might get into the food supply chain through direct cross pollination, through commingling, through wind, through animals, insects and/or birds (Einsiedel and Medlock 2005). Pollen from plants modified to produce PMF products may fertilize nearby food or feed crops of the same species so that neighboring food/feed might contain the new trait modified protein, which might have negative effects on human or animal consumers (Byrne, Ward, and Harrington 2004). Commingling of PMF plants and normal agricultural plants might happen through improper labeling, mixing of seed in planting, harvesting, transportation, or processing equipments, or the presence of "volunteer" PMP plants in subsequent seasons in the same field (Byrne, Ward, and Harrington 2004). The other potential source of contamination of food crops is from humans either by accident (e.g. accidentally taking plant material from a greenhouse and dropping it onto a field) or on purpose (Einsiedel and Medlock 2005). It has been suggested that the consequence of potential contamination of the food supply chain by PMF-based products could be serious, since this would not only cause significant food safety risk but would also bring about costs and considerable market losses throughout both the national and the international food chains (Veeman 2006).

2.4.2 Potential Environmental Risks

Another major concern about PMF-based production systems is that the modified genes or PMF products may have potential short-term/long-term negative effects on wildlife and ecology as well as soil, water and other components of the natural environment. It is a concern that the transgenes would spread in the environment and have influence on non-target ecosystem components (Elbehri 2005). It has been argued that the potential environmental risks of any genetically engineered crop for PMF production may include gene flow to wild relatives, effects on biodiversity, or harm to other organisms (Freese 2004). For example, wildlife might be harmed because of the possibility of accidental ingestion of PMF materials by birds, animals, or other organisms (Veeman 2006). "Soil micro-organisms may be inhibited by decomposing crop residues or substances exuded from roots of PMF plant" (Byrne, Ward, and Harrington 2004). Cummins (2003) suggested that it is likely that the breakdown of PMF plants, leaves and root debris will pollute surface water and groundwater. There are also concerns about whether the disposal of waste and modified material will enter into soil and then contaminate the ecosystem (both plants and animals) (Einsiedel and Medlock 2005).

2.4.3 Potential Health Risks

Potential long-term effects on human health are another significant issue of concern (Einsiedel and Medlock 2005). The concerns about how PMF technology might impact health over time are raised. It also has been suggested that this novel technology might have negative effects that research cannot detect right now (Einsiedel and Medlock 2005). A concern related to health issues is that unexpected toxins or residues of pesticides used on a PMF crop may contaminate the final pharmaceutical products (Byrne, Ward, and Harrington 2004). Health risks for PMF plant growers could come from exposure to unhealthy levels of a biopharmaceutical by absorbing products from leaves through skin, inhalation and contact with potent drugs and chemicals, or breathing in dust at harvest (Byrne, Ward, and Harrington 2004).

2.5 Summary

In this chapter, features of PMF technology were introduced. This technology is an extension of biotechnology, focusing on using plants to produce new molecules instead of conventional uses. The development of PMF technology is proposed to meet demands in the medical sector, industry, and agricultural industries. PMF technology may have broad applications, mainly in health and pharmaceutical applications, agriculture and food sectors, and industrial sectors. The production processes and potential benefits and risks associated with PMF technology were noted. This is a promising technology that may provide new treatments for diseases at lower costs and in larger amounts. However, there are also risks from the possibility of contamination of food supply, and health and environmental risks. In the following chapters the preferences of members of the public for government investment in PMF related research are analyzed. Individuals' perceptions and preferences for allocation of government funding to different PMF research areas will be assessed.

Chapter 3 Literature Review

3.1 Introduction

This chapter provides a brief review of literature, citing studies that are related to this study. It begins with a description of research that has been conducted to assess the perceptions of members of the public relative to plant molecular farming technologies. This is followed by a discussion of various studies and methodologies that are related to research funding investments and allocations, including the methodology of choice experiment methods. The last section provides an introduction to stated preference techniques, choice experiment methods and relevant applications.

3.2 Public Perception Studies Relevant to Plant Molecular Farming

As a recent novel biotechnology, plant molecular farming is commencing to attract attention from both industry and academia. Most of the studies related to PMF focus on science-based technology (e.g. Johnson 1999; Gleba et al. 1999; Fischer et al. 2004a; Horn, Woodard, and Howard 2004) or the development of policy and regulations (e.g. Arcand and Arnison 2004; CFIA 2005b; CFIA 2005c; CFIA 2005d). However, little is known about public attitudes to and perceptions about PMF technology (Einsiedel and Medlock 2005). Veeman (2006) stated that any new technology needs social acceptability to be successful (Veeman 2006). "Gauging public attitudes toward any new technology becomes an important step in market assessment and justification of financial investment to conduct research and development" (Kirk and McIntosh 2005, p.1). The social acceptance of PMF technology will influence the commercial feasibility of this biotechnology (Kirk and McIntosh 2005). Some studies involving early assessments of public attitudes and perceptions of the prospect of PMF technologies have recently been reported in the United States and Canada.

In the study of Nevitt et al. (2003), the authors used qualitative data gathering methods (participatory appraisal formats and focus groups) in the United States to assess public attitudes and perceptions for the use of transgenic tobacco to produce pharmaceuticals. Data were obtained using several approaches: face-to face interviews, telephone interviews, email exchanges, small group discussions, and observation at a conference[6] with a range of stakeholders (tobacco producers, policy makers, NGOs, and agricultural biotechnology company representatives) from various regions. Nevitt et al. (2003) reported that most stakeholders (except for some NGOs) gave supportive opinions on this technology. However, stakeholders also expressed concerns about the potential environment impacts and regulatory capacity related to this application.

A study by Stewart and McLean (2005) conducted a telephone survey (with 680 respondents) in five mid-south states of the United States in 2004 to assess public opinion for PMF related applications. The authors concluded that the application of PMF to produce industrial or pharmaceutical products and to produce high quality food were viewed by respondents to be more potentially beneficial than the application of PMF to produce plants modified for chemical or pest resistance. The authors also found that almost two-thirds of the respondents expressed concerns about the contamination of food supplies when transgenic plants were used to produce industrial and pharmaceutical products and slightly more respondents expressed more anger if they were to consume industrial PMF products than pharmaceutical PMF products.

Kirk and McIntosh (2005) conducted a study to investigate the existing level of general social acceptance for a potential plant-made vaccine (PMV) technology, which represents one of the applications of PMF technology. The authors conducted a public opinion survey of 706 respondents in the greater Phoenix area (in Arizona, United States). The survey comprises three multiple choice questions, one of which is designed to gain an indication of the prospects for public acceptance of the PMV technology (the willingness to use vaccine produced from modified plants). The results of the survey demonstrated

[6] Pharming the Field: A Look at the Benefits and Risks of Bioengineering Plants to Produce Pharmaceuticals, sponsored by The Pew Initiative on Food and Biotechnology (http://pewagbiotech.org/)

that there appeared to be a positive public potential support for PMV and genetically engineered vaccines in general. Sixty-eight per cent of respondents expressed some level of acceptance for use of a PMF-based vaccine.

In Canada assessments of public attitudes and perceptions on PMF applications have also been undertaken (Veeman 2006). Einsiedel and Medlock (2005) reported on Canadian responses to two questions designed to examine public support for two PMF applications in a semiannual public survey conducted by the Canadian Biotechnology Secretariat. There was evidence of slightly higher support for PMF health products than industrial products.

Einsiedel and Medlock (2005) carried out modified focus group discussions with 48 participants (providing participants background information), designed as public consultation, in four regions in Canada in 2004 to assess early-stage consumer perceptions and policy preferences for PMF technology. The study focused on assessing public awareness of PMF, identifying key issues of PMF from the perspective of lay Canadians, and examining public acceptability of five specific PMF applications (different PMF products expressed in different types of plants). Participants' first impressions of PMF were reported as "mixed but leaned towards the positive" (Einsiedel and Medlock 2005, p.28). The key issues participants were concerned with included the potential for cross-pollination and contamination of food crops (the dominant issue), issues of safety, regulations, and policy, and the potential long-term side effects on human health or the environment. Regarding acceptability to participants of the five PMF applications, participants assessed the applications on a case-by-case basis. The authors suggested that health and medical applications are viewed by participants as being more acceptable than industrial applications. For industrial applications, the applications that could produce environmentally friendly products are preferred over the applications that could produce products at a lower cost. Participants tended to regard using food crops for PMF applications as more risky than using nonfood crops. Participants also preferred to use enclosed settings for PMF applications. The method of focus groups used in this study is argued to provide a way to uncover the reasons for participants' attitudes and preferences.

Veeman (2006) overviewed the preceding and related literature and concluded that with the exception of environment-focused NGOs, currently public perceptions of PMF technology tended to be positive. Positive attitudes were generally evident for potential PMF applications to medical products but these were "conditional on assurance of strict regulations that ensure food and environmental safety" (Veeman 2006, p.8). This author also suggested that, based on the past experience of situations where food safety has been threatened, the public positive attitudes and perceptions for PMF technology could "erode rapidly" (Veeman 2006, p.8) if PMF materials were to contaminate the food supply chain or damage the environment.

Based on the suggestion of Swallow and Mazzotta (2005) that research allocations can be used to measure perceptions, this thesis study will assess preferences for the allocations of public funding to PMF related research as an approach to measure public attitudes and perceptions for PMF technology. Kirk and McIntosh (2005) suggested that a "survey about technology can be designed to determine the true public perception of a specific technology, to understand the public perception of specific needs and risks, and/or to gauge general public acceptance of novel technologies" (Kirk and McIntosh 2005, p.228). This is an argument also that public opinion is best evaluated through direct surveys. The method of direct survey will also be adopted in this thesis study.

3.3 Public Funded Research and Research Funding Allocations

This study focuses on assessing people's perceptions and preferences regarding Canadian public research funding allocated to PMF related research. Numbers of researchers have been studied the benefits of public funded research and have attempted to estimate and predict the allocations of research funding.

Surveys, case studies, and sector-wide economic analysis have been employed to study the benefits of publicly funded scientific research (Salter and Martin 2001). Wolf and Salter (1997) conducted case studies to assess the social and economic benefits of publicly funded research. However, the application of case studies is limited by high administration cost and the requirements of time for data collection (Salter and Martin 2001). Hertford and Schmitz (1977) employed economic surplus concepts to estimate the benefits of agricultural research. Typically estimated annual benefits are compared with annual costs of research to find the internal rate of return as a measure of the efficiency of research activities. Some studies rely on econometric techniques to measure the economic and social rate of return to research (Mansfield et al. 1991; Mansfield 1998; Beise and Stahl 1999). Using other economic methods to measure research benefits, Cox, Mullen, and Hu (1997) applied nonparametric methods to measure the impact of public research expenditure on Australian crop-based agriculture; the internal rates of return to research expenditures were also estimated.

Allocations of research funding and research resources among different regions and among different research areas have also been studied. Survey methods, case study methods, economic methods, and econometrics methods have been applied (Luckert and Haley 1989; Lootsma and Bots 1999; Guttman 1978; Schultz 1971; Huffman and Miranowski 1981; Shumway 1977; Rose-Ackerman and Evenson 1985; White and Araji 1990; Abler and Musser 1995). Luckert and Haley (1989) developed a survey to assess people's perceptions on funding mechanisms for silviculture across Canada. Respondents were asked their opinions of factors that should be considered in allocating silvicultural budgets and were also asked their assessments of current allocations. Based on these responses, the efficiency of different types of funding allocation mechanisms was evaluated. A case study was conducted by Lootsma and Bots (1999) to assess how research funds could be allocated among faculties on the basis of the annual research output at the Delft University of Technology, in Netherland. Scores were assigned to each research output in the given year. On the basis of these scores, the total annual university budget for research was proportionally allocated to the faculties.

In a study by Guttman (1978), agriculture research was viewed as a public good and a demand model was applied to explain allocations of agriculture research to different sectors. Schultz (1971) assessed resource allocations in agricultural research considering both demand and supply aspects. A four-equation model was applied by Huffman and Miranowski (1981) to assess the resource allocations for state agricultural experiment station research, including both demand and supply equations for research, an equation for allocating state government revenues to station research, and an expenditure equilibrium equation. Criteria weights were used by Shumway (1977) to evaluate research priorities and this author also employed project ranking as an alternative method to optimize resource allocation. Rose-Ackerman and Evenson (1985) proposed a political-economic model to analyze the allocation of research funding among different states in the United States. A theoretical economic model was developed by White and Araji (1990) to analyze research allocation processes by exploring relationships between research funding and research benefits, and considering the factors contributing to the allocation of research funds. Abler and Musser (1995) applied a tobit model to examine political, economic, and environmental factors affecting the allocations of federal Low Input/Sustainable Agriculture (LISA) funds among states in the United States during the period 1988-1989.

Stated preference methods, developed to estimate non-market values (Mitchell and Carson 1989), have also been used by economists to assess the funding level and funding allocations and to estimate people's willingness to pay for research programs. Whitehead, Hoban, and Clifford (2001) employed contingent valuation methods to estimate willingness to pay (WTP) for agricultural research and extension programs among North Carolina households, including food production research and water quality research. A telephone-based survey containing contingent valuation questions that elicit WTP measures was designed and applied. The survey focused on a hypothetical reduction in federal agricultural research funding. Survey respondents were asked for their willingness to pay for state funding of the current level of agricultural research and extension, using single-bound referendum questions and multiple-bound questions. The WTP measures were estimated and compared. Willingness to pay and determinants of willingness to pay were also compared between food production programs and water quality programs. This study found that North Carolina households are willing to pay between $218 and $401 million for food production programs and between $251 and $698 million for water quality programs annually.

Subject complexity and research process uncertainties are seen as major difficulties in evaluating the value of research (Swallow and Mazzotta 2004). Swallow and Mazzotta (2004) attempted to overcome these by using choice experiment methods, based on the stated preference approach, which can "address a complex set of attributes capturing both use and non use values of research" (Swallow and Mazzotta 2004, p.976). A survey was developed to measure people's preferences for scientist efforts allocated across Rhode Island Agricultural Experiment Station's (AES) research programs. The survey presented four plans to respondents: "eliminate AES research", "decrease AES research effort", "increase AES research effort", and "maintain the current AES research effort". In each plan, efforts were allocated differently across five research fields, which are the attributes. A linear-in-parameters nested-logit model was employed to examine the influence of each attribute on respondent's choice behavior. Respondents' willingness to pay for specific AES plans was estimated. Marginal analysis was also conducted to identify the change of benefits that an additional scientist-month would provide in each research field. This study identified economic benefits provided by AES research program and assessed preferences for the allocation of scientist-months of effort among different research fields. The study provides a useful example to the use of choice experiment methods to conduct non-market valuation to assess research priorities.

3.4 Literature Review on Stated Preference and Choice Experiments

3.4.1 Stated Preference Techniques

Stated preference techniques are developed to measure non-market valuations (Mitchell and Carson 1989; Bennett 1999). This method uses people's responses to questions that are designed to reveal information about their preferences or values for hypothetical situations (Freeman 1993). Stated preference techniques have a number of advantages. This method can estimate both use and non-use values when related data are not available or actual market behavior is not observed (Freeman 1993). The method requires primary data sources that are originally designed and developed for the specific purpose of the study.

The objective of this study is to examine the public's preferences for allocation of public research funding to different types of PMF research. Allocation of public research funding to different types of PMF research is not a market good and at present there is no revealed information that shows the public's choice behavior for allocation of public research funding to different types of PMF research. In this circumstance it is necessary to apply stated preference techniques to establish hypothetical market situations and pose hypothetical questions (Adamowicz et al. 1998). Survey methods are an efficient way to collect information on respondents' preferences in hypothetical scenarios. The respondents are required to make hypothetical selections based on hypothetical situations and their responses will be recorded. However, the stated preference techniques rely on respondents' subjective choices. This can cause potential biases because respondents are likely take hypothetical situations less seriously than real life situations (Morrison et al. 1996).

3.4.2 Choice Experiment Methods

The most common methods of stated preference techniques are contingent valuation methods (CVM) and choice experiments (CE). CVM methods focus on a specific choice and collect information about respondents' preferences regarding specific choice alternatives (i.e. whether respondents support or oppose choice alternatives) (Boxall et al. 1996; Adamowicz et al. 1998).

In choice experiment methods, respondents are presented with a series of hypothetical choice sets comprised of multiple (two or more) alternatives, which are defined by descriptive attributes with varying levels (Bennett 1999). For each choice set, respondents are asked to choose their most preferred alternative from the alternatives essentially by trading off attributes (Bennett 1999). Compared to CVM, CE methods attempt to understand respondents' preferences over the attributes of the alternative rather than the specific alternative (Boxall et al. 1996). By analyzing choice responses, CE methods provide a way to measure respondent's values for the attributes (Adamowicz et al. 1998) and to estimate the "relative importance of the individual attributes" in determining respondents' choice behavior (Jaffry et al. p.2). It is also noted that CE methods provide a way to elicit the "trade-offs that respondents are willing to make between these attributes" (Jaffry et al. p.2) and to "produce specific estimates for the value of unit changes in attributes" (Morrison et al. 1996, p.9). The CE methods could also be used to estimate the total satisfaction (represented by utility scores) for different combination of attributes (Ryan 1996). Overall, CE methods rely on the accuracy and completeness of the attributes used to describe the choice situations (Boxall et al. 1996).

Choice experiment methods were first developed in the marketing and transportation literature. Early applications were by Louviere & Hensher (1982) and Louviere & Woodsworth (1983). CE methods can be used to construct hypothetical market situations which currently do not exist. This feature of CE methods is particularly useful in marketing studies to estimate preferences for new products. Therefore, CE methods are extensively employed in various areas of market research, such as agriculture and food commodities (examples are Jayne et al. 1996; Macpherson, Binney, and Kearns 2000; Lusk and Fox 2001; Lusk, Roosen, and Fox 2003; Jaffry et al.; Enneking 2004), industrial products (for example, Ewing and Sarigollu 2000), travel choices (Louviere 1988 is an example), mass communication choices (examples include Biehal, Stephens, and Curlo 1992; Danaher and Mawhinney 2001; Finn et al. 2001), and school choices (e.g. Walberg and Bast 1993). CE methods have been also used in demand analysis to estimate respondents' willingness to pay for particular attributes or new products (Lusk, Roosen, and Fox 2003; Jaffry et al.; Enneking 2004) and to measure the trade-offs among attributes (Johnson 2003).

Choice experiment methods have also been applied in relative to biotechnology products. Larue et al. (2004) conducted a survey that attempted to differentiate consumer valuations of functional health properties in conventional, organic, and genetically modified foods. Random parameters logit models were used to analyze the choices made by respondents for the three food products. Hu et al. (2004) conducted a survey directed at sliced, pre-packaged bread to elicit the trade-offs that consumer may make between possible risks associated with GM ingredients and potential health or environment benefits in the context of food products with GM ingredients. Considering heterogeneous consumer preferences, a latent class choice model is used to analyze consumers' preferences for GM food. Hu, Veeman, and Adamowicz (2005) also conducted a Canadian nation-wide Internet-based survey to assess consumers' choice behavior of pre-packaged sliced bread under different genetically modified (GM) food labeling policies. The survey included a repeated choice experiment that simulated different labeling scenarios for the selected bread products. A mixed logit model is applied to analyze consumers' choice behavior in different GM labeling polices and the heterogeneity in consumer preferences.

The ability to decompose values of environmental programs into implicit values associated with particular attribute of those programs has made choice experiment methods attractive in environmental studies (Champ, Boyle, and Brown 2003). Choice experiment methods have been used to estimate the impacts on economic welfare from changing the provision of environmental goods or conditions, which do not currently exist. Adamowicz, Louviere, and Williams (1994), Adamowicz et al. (1997), and Buchanan, Morey, and Waldman (1998) estimated recreational site choice models for fishing, moose hunting, and mountain biking attributes respectively. Another advantage to employ CE in environmental studies is that this method could measure both direct-use values and passive-use values, for example, estimating the total value of enhancing the population of a threatened species (Adamowicz et al. 1998), the value of mitigating forest loss resulting from global climate change (Layton and Brown 2000), and the value of reducing acid deposition injures to cultural resources (Morey et al. 2000).

Choice experiment methodologies have also been applied to evaluate choice behavior involving transportation (examples are Hensher 1992; Hensher 1994; Kroes and Sheldon 1988; Garrod, Scarpa, and Willis 2002), tourism (Morley 1994 is an example), and health economics (examples are Magat, Viscusi, and Huber 1988; Viscusi, Magat, and Huber 1991; Harris 2002, Strand 2004; Sculpher et al. 2004)

3.5 Summary

The purpose of this chapter was to provide background information for this study by discussing some studies related to the research topic. To our knowledge, no research has yet been done to study allocations of public research funding to different types of PMF research. From reviewing the methods used to measure research funding allocations, choice experiment methods seem to be a relatively new and popular method that have been applied in somewhat similar situations where market data are unavailable. Thus the literature review includes a description of stated preference technique and choice experiment methods and a summary of choice experiment applications. The next chapter will discuss the theoretical basis of choice experiments, the methodology and econometric model used to carry out this study, survey design, and data collection.

Chapter 4 Modeling, Survey Design, and Data Collection

4.1 Introduction

This chapter focuses on issues relating to choice modeling and on the data used in this study. Descriptions of the survey design, the application of the econometric model and the data are included. In section 4.2 an overview of consumer choice theory is presented. The conditional logit model is also outlined. Section 4.3 describes the survey questionnaire that provided data for the study. Applying consumer choice theory to assess funding allocations to plant molecular farming research is discussed in section 4.4. The last two sections of the chapter describe issues relating to the data collection and the data sample that is used in the analysis.

4.2 Theoretical Framework for Modeling Research Funding Choices

4.2.1 Random Utility Theory

The foundational theory underlying the analysis of choice experiment data is the concept of random utility theory, which is based on discrete choice theory and Lancastrian consumer theory.

4.2.1.1 Individual Choice Behavior

-- Discrete Choice Theory and Lancastrian Consumer Theory

Based on work by Ben-Akiva and Lerman (1985), the methodology of discrete choice theory applies to situations in which the decision maker's choices are discrete. In discrete choice theory it is assumed that decision maker's evaluation of available alternatives may be represented by a utility function and that the decision maker will follow the decision rule of utility maximization. In other words, the decision maker will select the choice alternative with the highest utility.

Following Ben-Akiva and Lerman (1985), a real-valued utility index associated with alternative i for decision maker n can be defined as:

$$U_{ni},\ i \in C \tag{4.1}$$

C is defined as the choice set, which is the set of all possible alternatives from which i is selected.

According to the decision rule of discrete choice theory, alternative i will be chosen by decision maker n over all the other available alternatives if and only if alternative i gives highest utility, that is $U_{ni} > \max U_{nj}$ for all $i \neq j,\ i, j \in C$.

Lancaster (1966) modified consumer theory to define utility in terms of the attributes of a product. Typically attributes are interpreted as the characteristics of choice alternatives. Thus, it is assumed that consumers (or decision makers) derive utility from consumption of the attributes of choice alternatives, rather than deriving utility from the alternatives themselves. The total utility obtained from a choice alternative is determined by the aggregation of the utility derived from each attribute. The total utility of the choice alternative may be decomposed into separate utilities for the different attributes (Lancaster 1996).

Applying the approach of Lancaster (1996), the utility function that relates to each alternative choice can by described by k attributes that may be evident in combinations of attributes at different levels. For example, the utility function of alternative i for decision maker n could be expressed as:

$$U_{ni} = U(X_{ni}) \tag{4.2}$$

where $X_{ni} = (X^1_{ni}, X^2_{ni}, \ldots, X^k_{ni})$ is a vector of k attributes associated with alternative i for decision maker n.

In empirical applications, researchers normally introduce into the utility function a vector of individual decision maker's socioeconomic characteristics, such as socio-economic and demographic factors. These characteristics may explain "the variability of tastes across the population" (Ben-Akiva and Lerman 1985, p.48). Thus the utility function can be expressed as:

$$U_{ni} = U(X_{ni}, A_n) \tag{4.3}$$

where A_n is a vector of socioeconomic characteristics of decision maker *n*.

4.2.1.2 Random Utility Theory

Probabilistic choice theory, which "specifies the probability with which an individual will select any feasible alternatives" (Ben-Akiva and Lerman 1985, p.58), provides a framework for analyzing discrete choice theory. The probabilistic choice mechanism is developed to explain the inconsistency and non-transitive preference of the choice behavior in the experimental observation (Ben-Akiva and Lerman 1985). The random utility approach is one of the applications of probabilistic choice mechanism (Ben-Akiva and Lerman 1985).

Following Ben-Akiva and Lerman (1985), decision makers are assumed to have perfect discrimination abilities and make their decision rationally to choose the alternative with the maximum utility. For any decision maker, the probability that an alternative is chosen is defined by the probability that the utility of that alternative is larger than the utilities of all other alternatives (Ben-Akiva and Lerman 1985). The probability of selecting an alternative increases as the utility associated with it increases. Therefore, between alternative *i* and alternative *j*, the probability that alternative *i* is chosen over alternative *j* by decision maker *n* is equal to the probability that the utility of alternative *i* (U_{ni}) is greater than the utility of alternative *j* (U_{nj}) in the choice set. This can be written as follows:

$$\Pr(i / C) = \Pr(U_{ni} > U_{nj}, \text{ for all } i \neq j,\ i, j \in C) \tag{4.4}$$

Ben-Akiva and Lerman (1985) argue that inconsistent choice behavior observations and non-transitive preferences could be explained to be probabilistic to the researchers because of a lack of precise knowledge about decision maker's decision processes. The decision makers are always assumed to be rational, to have complete awareness of their choice behavior, and to choose the alternative with maximum utility. However, the choice behavior and "the utilities obtained by decision makers are not known to the researchers with certainty and are viewed as random from the perspective of researchers due to their incomplete information and deficiencies of observation" (Ben-Akiva and Lerman 1985, p. 55; Champ, Boyle, and Brown 2003). Consequently, this component of the theory is called random utility theory.

Following Ben-Akiva and Lerman (1985), researchers express the random utility of each alternative as the sum of deterministic (also called systematic) component, *V*, which is observable, and the random component (the random error term), ε, which is unobservable. In addition, researchers appeal to Lancastrian consumer theory relative to the deterministic component of total utility. Therefore, the total indirect utility of alternative *i* for decision maker *n* can be expressed as:

$$U_{ni} = V(X_{ni}, A_n) + \varepsilon_{ni} \qquad (4.5)$$

Then the probability that alternative *i* in choice set *C* is chosen by decision maker *n* can be written as:

$$\begin{aligned} \Pr(i/C) &= \Pr(U_{ni} > U_{nj}, \text{ for all } i \neq j,\ i, j \in C) \\ &= \Pr(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}, \text{ for all } i \neq j,\ i, j \in C) \\ &= \Pr(V_{ni} - V_{nj} > \varepsilon_{nj} - \varepsilon_{ni}, \text{ for all } i \neq j,\ i, j \in C) \qquad (4.6) \end{aligned}$$

4.2.2 Multinomial Logit Model

As indicated above, in models based on random utility theory, it is assumed that choices are made based on utility differences across alternatives:

$$\Pr(i/C) = \Pr(U_{ni} > U_{nj}, \text{ for all } i \neq j,\ i, j \in C)$$

$$= \Pr(V_{ni} - V_{nj} > \varepsilon_{nj} - \varepsilon_{ni}, \text{ for all } i \neq j,\ i, j \in C) \qquad (4.6)$$

The probability that individual n chooses alternative i depends on the probability that the difference between the observed components of utility for alternative i and j is greater than the difference between the unobserved components of utility for alternative j and i. The difference between $V_{ni} - V_{nj}$ is observable, but the difference between $\varepsilon_{nj} - \varepsilon_{ni}$ is unobservable and is assumed to be a random variable.

Manski (1973) identified four potential sources of randomness (ε): (i) unobserved attributes, (ii) unobserved taste variations, (iii) measurement errors, and (iv) use of instrument/proxy variables. Each of these will affect the distribution of utility (Ben-Akiva and Lerman 1985, p.56). Different assumptions regarding the distribution of the random error term, ε, will result in different models. By assuming a particular distribution of the error terms, it is possible to derive the distribution of each difference $\varepsilon_{nj} - \varepsilon_{ni}$ for all i, $j \in C$, $i \neq j$ (McCann 2002).

The derivation of the econometric model outlined here follows McFadden (1974). McFadden (1974) assumed that the random error term, ε, "is a function that varies randomly in the population with the property that in each possible alternative set C, the values ε are independently identically distributed with the Gumbel distribution" (McFadden 1974, p.111) (this is also called a Type I extreme distribution). Following Ben-Akiva and Lerman (1985, p.104), if the random error term (ε) is Gumbel distributed, then

$$F(\varepsilon) = \exp[-e^{-\mu(\varepsilon-\eta)}],\ \mu > 0 \qquad (4.7)$$

and

$$f(\varepsilon) = \mu e^{-\mu(\varepsilon-\eta)} \exp[-e^{-\mu(\varepsilon-\eta)}], \qquad (4.8)$$

where η is a location parameter and μ is a positive scale parameter.

For convenience, η=0 is assumed for all the random error terms. Then ε will be Gumbel distributed with parameter (0, μ). Therefore, the probability that alternative *i* is chosen by decision maker *n* over the other available alternatives is expressed as:

$$\Pr_n (i) = \frac{e^{\mu V_{ni}}}{\sum_{j \in C} e^{\mu V_{nj}}} \tag{4.9}$$

Equation 4.9 describes the multinomial logit model (MNL). It assumes that the probability of choosing alternative *i* depends on the utility of alternative *i* relative to the utility of all of the other alternatives.

The scale parameter μ is not "identifiable" (Ben-Akiva and Lerman 1985). A common assumption is to set μ to a convenient value, such as 1. As μ approaches infinity, the model becomes deterministic (Hanley et al. 1998).

A further issue to be considered is the functional form of the observed component of the total indirect utility function V_{ni}. It is a convenient initial assumption to assume V_{ni} is a linear-in-parameters function of its attributes X_{ni} and additive in the variables (Ben-Akiva and Lerman 1985). That is, $V_{ni} = \sum_{k=1}^{K} \beta_k X_{ni}$, where β_k represents a vector of parameters or "taste weights" of attribute *k* for alternative *i*. Then, the total indirect utility function considering socioeconomic characteristics will be:

$$U_{ni} = \beta_0 + \beta_1 X^1_{ni} + \ldots + \beta_k X^k_{ni} + \beta_{k+1} A_1 + \ldots \beta_{k+n} A_n + \varepsilon_{ni} \tag{4.10}$$

The linear-in-parameters multinomial logit model version is expressed as:

$$\Pr_n (i) = \frac{e^{\beta X_{ni} + \beta_i A_n}}{\sum_{j \in C} e^{\beta X_{nj} + \beta_i A_n}} \tag{4.11}$$

Following Ben-Akiva and Lerman (1985), the estimation of parameter vector β s of the multinomial logit model could be accomplished by several methods. Maximum likelihood is a commonly applied estimation procedure. This method provides an estimator of β which results in the likelihood function being a maximum (Ben-Akiva and Lerman 1985). The likelihood of the whole sample of N observations is the product of the likelihoods of the individual observation (Ben-Akiva and Lerman 1985). Ben-Akiva and Lerman (1985) noted that if L* is defined as the likelihood function, the likelihood function to estimate the parameters for a general multinomial choice model is expressed as:

$$L^*(\beta_1 \dots \beta_n) = \prod_{n=1}^{N} \coprod_{i \in C} P_n(i)^{Y_{ni}} \tag{4.12}$$

where $P_n(i)$ is a function of $\beta_1 \dots \beta_n$, N represents the sample size, $Y_{ni}=1$ if decision maker *n* choose alternative *i*, or 0 otherwise. If the likelihood function is globally concave, a maximum will exist. "A maximum likelihood estimator is the value of the parameters for which the observed sample is most likely to have occurred" (Ben-Akiva and Lerman 1985, p.20). The maximum likelihood estimator of β is consistent, asymptotically normal, and asymptotically efficient (Ben-Akiva and Lerman 1985).

The multinomial logit model developed by McFadden (1974) combines Lancastrian consumer theory analysis of alternative choices and random utility maximization. The multinomial logit model could be applied to identify the attributes that affect decision maker's choice; it can also be applied to identify the trade-offs between the attributes.

4.2.3 The Difference between Multinomial Logit Models and Conditional Logit Models

The multinomial logit model and the conditional logit model are different. Specifically, the conditional logit model is an extension of the multinomial logit model that is particularly appropriate in models of choice behavior (Rodriguez 2001).

4.2.3.1 Multinomial Logit Model

In the multinomial logit model, the utilities are usually expressed by individual-specific factors, which describe the characteristics of decision makers, such as gender and age. The estimated coefficients, β_i, could be interpreted as reflecting the effects of these individual-specific factors on the possibility of making a given choice or on the underlying utilities of the different alternatives (Rodriguez 2001). The individual-specific factors are constant across alternatives for each decision maker. That means, for each individual, the same factors are used to model utilities of all alternatives, which is restrictive.

The multinomial logit model is:

$$\Pr_n(\text{i}) = \frac{e^{\mu\beta_i X_{ni}}}{\sum_{j\in C} e^{\mu\beta_i X_{nj}}} \text{ for } i=1, \ldots, \text{N} \quad (4.13)$$

The estimated coefficients are specific to each alternative. Alternative i will have a set of estimated coefficients β_i s; the alternative j will have its own set of estimated coefficients β_j s.

4.2.3.2 Conditional Logit Model

McFadden (1974) proposed modeling the utilities in terms of choice-specific factors rather than individual-specific factors[7]. The choice-specific factors describe the characteristics of alternative choices. The choice-specific factors vary across choices, and possibly across the decision makers as well.

The conditional logit model is:

$$\Pr_n(\text{i}) = \frac{e^{\mu\beta X_{ni}}}{\sum_{j\in C} e^{\mu\beta X_{nj}}} \text{ for i=1, \ldots, N} \quad (4.14)$$

[7] Rodriguez, G. 2001. Multinomial Response Models. --http://data.princeton.edu/wws509/notes/c6.pdf, accessed on July 2, 2006.

Unlike in the multinomial logit model, the estimated coefficients, β s, are not specific to the choice (Chung 2006). All the choices share the same estimated coefficients.

The reason why the multinomial logit and conditional logit models are different is because the multinomial logit model focuses on the influence of individual's characteristics on choice behaviors, while the conditional logit model assumes that decision makers make a given choice based on the characteristics of different choices, conditional on the choice. A more general model could combine the multinomial logit model with the conditional logit model (Rodriguez 2001). Utility would be expressed by both individual-specific factors and choice-specific attributes.

4.3 Survey Design

The survey questionnaire (refer to Appendix A) for this study was developed by Dr. Wuyang Hu, Dr. Michele Veeman and Dr. Wiktor Adamowicz in the Department of Rural Economy at the University of Alberta. The survey questionnaire includes five sections. The first section is an introduction and warm-up section which asks respondents to indicate their opinions about the funding level for numbers of public services, including education services, policy and securities services, health care services, maintaining natural and wildlife reserves, providing safer food, and highways and roads services. Respondents are then provided with glossary information on "terms in modern agricultural and food research" (see Appendix A for this). The information provided includes definitions and descriptions for terms that are used in the survey, including food, feed, non-food crops, agricultural biotechnology, genetic modification/genetic engineering, and plant molecular farming. Examples of possible benefits in the form of applications of PMF technology and examples of possible risks associated with PMF are also provided to respondents. Readers are referred to page 3 of the survey in Appendix A for this information. Respondents could revisit the information during the survey.

The second section of the questionnaire contains two sets of general attitudinal questions, relating to respondents' perceptions about risks associated with food safety issues and environmental safety issues. Following recommended procedures (Adamowicz 1995). These two sections identify the study topic in general and frame the problem for respondents to consider in the following parts of the questionnaire.

The third section of the questionnaire applies choice experiment methodology relative to respondents' opinions about the allocations of public funding to different types of research on plant molecular farming. The data from this experiment are the topic of this thesis study. Respondents are informed that the Canadian government currently invests about 10 million Canadian dollars a year on PMF-related research and that this is allocated in certain proportions across five different areas of PMF research which include health research, industrial research applications, research directed at environmental implications of PMF, and research on consumer focused applications and, finally, research on social economic, and public policy areas related to PMF. A brief description of these various research areas is provided to respondents as shown in Table 4-1.

Table 4-1 Description of Areas of PMF-related Research

Categories	Description
Health	To develop new and cheaper PMF-based medical drugs and vaccines directed to human problems of health and disease.
Industry	To develop new and cheaper industrial products like bio-plastics, bio-fuel and industrial enzymes.
Environment	To assess and limit impacts of PMF on wildlife and ecology as well as on soil, water and other components of the natural environment.
Consumer	To develop nutritionally improved food or food at lower prices.
Social, economic & public policy	To identify and address public, social and ethical concerns, and economic implications and to provide guidance on potential regulations (such as patents and labelling)

Source: Plant Molecular Farming Survey Questionnaire

In the design component of the choice experiments of the survey, the total funding allocated to PMF research was varied, specifically, as "decrease by 20%", "decrease by 10%", "maintain the current level", "increase by 10%", "increase by 20%", and "provide no funding". Also the proportion of funding currently allocated to each area of research was varied, specifically, as 0%, 10%, 20%, and 30% of the funding currently allocated. The attributes and corresponding levels are listed in Table 4-2.

Table 4-2 Attributes and Levels

Attributes	Levels
Total plant molecular farming research funding	0%, 80%, 90%, 100%, 110%, and 120% of current total research funding
Research funding allocated to health research area	0%, 10%, 20%, and 30% of total research funding
Research funding allocated to industry research area	0%, 10%, 20%, and 30% of total research funding
Research funding allocated to environment research area	0%, 10%, 20%, and 30% of total research funding
Research funding allocated to consumer research area	0%, 10%, 20%, and 30% of total research funding
Research funding allocated to social, economic and public policy research area	0%, 10%, 20%, and 30% of total research funding

Source: Plant Molecular Farming Survey Questionnaire

Using a fractional factorial design, the number of choice sets is specified as 96. However, to answer 96 choice sets by one respondent is not realistic. Therefore, the 96 choice sets are randomly blocked into 12 sets. Each set includes 8 choices and one set of these is presented to each respondent. These are randomly applied; 12 respondents are needed to provide the complete responses for all the alternatives.

Each choice set contains four alternative plans with different levels of total PMF research funding and different funding allocations across the five PMF-related research areas identified in Table 4-1. Among the four alternative plans, there are two alternatives that are identical across all the eight choice sets. One is "maintain the current level of research funding and maintain the current allocations"; the other is "provide no funding for PMF research". Respondents are informed that the current level of research funding allocated to PMF related research is 10 million Canadian dollars and the current funding allocation is that 30% of the total research funding is allocated to research in the health area, while

20% of the total research funding is allocated to industrial PMF research, and 10% of the total research funding is allocated to research on environmental issues relating to PMF. It is also indicated that 20% of the total research funding is allocated to consumer research, and 20% of the total research funding is allocated to social, economic, and public policy research. Respondents are asked to choose their preferred plan from each group of four alternative funding allocation plans provided in each choice set. Figure 4-1 gives an example of a choice set.

Figure 4-1 Example of Choice Set

Plan A		Plan B		Plan C		Plan D
Maintain the current levels of research funding allocated as:		**Decrease** current research funding by 10% with the remaining funding allocated as:		**Increase** current research funding by 20% with the new total funding allocated as:		Provide no funding for PMF research
Health	30%	Health	10%	Health	30%	
Industry	20%	Industry	30%	Industry	30%	
Environment	10%	Environment	10%	Environment	10%	
Consumer	20%	Consumer	20%	Consumer	10%	
Social, economic and public policy	20%	Social, economic and public policy	30%	Social, economic and public policy	20%	
I prefer (choose only one)						
o		o		o		o

The survey then proceeded, in the second part of this section, to provide an opportunity for respondents to construct their most favoured plan for PMF research funding allocations. In this component, respondents could choose to change the percentage of the government's annual agricultural and food research funding to be provided to PMF related research and also could choose change the allocations, in percentage form, to be provided to different PMF research areas. In this part of the survey, respondents could also choose the current funding plan, which has the same total funding level and allocation as in the first eight choice sets. They could also choose that the "government allocate no funds at all to PMF research".

Subsequent section of the questionnaire focused on respondents' familiarity with PMF, their likely information sources on this, their risk-benefit assessments of various PMF applications, and respondents' opinions on regulation of PMF activities. Respondents' demographic and socio-economic information are collected in the final section of the survey.

4.4 Application of Consumer Choice Theory for Research Funding Choices

In the survey on which this study is based, respondents are asked to make a choice among a series of sets of four alternatives, satisfying the criteria of random utility theory that the number of alternatives in the set is finite. The alternative research funding allocation plans are heterogeneous plans with particular attributes, satisfying the criteria that the alternatives are mutually exclusive. All possible alternatives are included because one of them is to "provide no funding for PMF research", satisfying the criteria that the set of alternatives is exhaustive.

It is assumed that for any respondent *n*, he/she will obtain utility from each research funding allocation plan, *i*. Respondents express their preferences for different research funding allocations plans, relating this to the utility they would receive from that plan. That is, if a respondent prefers research funding allocation plan A to research funding allocation plan B, then it is assumed that the utility associated with plan A is at least as large as the utility associated with plan B, that is $U(A) \geq U(B)$.

Following the theory of consumer behavior of Lancaster (1966), the utilities of different research funding allocation plans are influenced by their attributes X_i, and respondents select the alternative with preferred combination of attributes. Therefore, the conditional indirect utility function that describes the utility obtained by respondent *n* conditional on choosing alternative *i* can be expressed as:

$$V_{ni} = V(X_{ni}, S_n) = \beta X_{ni} + \gamma_i S_n \quad (4.15)$$

where X_{ni} defines the attributes of different research funding allocation plans, with alternative *i* for respondent *n*, representing specifically, total research funding, research funding to health areas of research, research funding to industrial applications, research funding to environmental areas, research funding to consumer products, and research funding to social, economic, and public policy areas of research. S_n defines a vector of demographic and socioeconomic characteristics of the respondent *n*.

Based on random utility theory, the conditional indirect utility function is stochastic. The utility obtained by respondent *n* from research funding allocation plan *i* consists of the observable component V and the random component ε_{ni}:

$$U_{ni} = V(X^k_{ni}, S_n) + \varepsilon_{ni} = \beta X^k_{ni} + \gamma_i S_n + \varepsilon_{ni} \quad (4.16)$$

The probability of respondent *n* choosing research funding allocation plan A rather than plan B is equal to the probability that the utility of plan A is greater than or equal to the utility of plan B:

$$\begin{aligned} \Pr(A) &= \Pr(U_{nA} > U_{nB}, \text{ for all } A \neq B, A, B \in C) \\ &= \Pr(V_{nA} + \varepsilon_{nA} > V_{nB} + \varepsilon_{nB}, \text{ for all } A \neq B, A, B \in C) \\ &= \Pr(V_{nA} - V_{nB} > \varepsilon_{nB} - \varepsilon_{nA}, \text{ for all } A \neq B, A, B \in C) \quad (4.17) \end{aligned}$$

Based on the assumption of Gumbel distribution of the random component and equation 4.15, the probability of respondent *n* choosing plan A, rather than other plans is:

$$\Pr_n(A) = \frac{e^{\beta X_{nA}+\gamma_i S_n}}{\sum_{j\in C} e^{\beta X_{nj}+\gamma_i S_n}} \quad \text{for j = PlanA, Plan B, Plan C, and Plan D} \qquad (4.18)$$

4.5 Data Collection

This study focuses on assessing perceptions of PMF expressed by members of the public, specifically relative to opinions about research funding allocations. Respondents are drawn from across Canada. Considering the complexity of the survey, time constraints, and survey administration costs, a computer-based, Internet-administered survey instrument is adopted, facilitated by a research company which drew the sample from a representative panel maintained by a market research company.

A total of 1574 public respondents completed the questionnaire. Respondents answered a total of 77 questions, which included sub-questions. In the choice experiments each respondent answered only one out of twelve versions, each with eight choice sets. Each version was randomly and fairly equally assigned across all respondents (as shown in Table 4-3).

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Table 4-3 The Distribution of Twelve Choice Experiment Versions Among 1574 Respondents

	Frequency		**Frequency**		**Frequency**
Version 1	7.2%	**Version 5**	8.5%	**Version 9**	7.9%
Version 2	8.8%	**Version 6**	9.0%	**Version 10**	7.8%
Version 3	9.1%	**Version 7**	8.0%	**Version 11**	8.1%
Version 4	9.0%	**Version 8**	8.5%	**Version 12**	7.9%

The last part of the questionnaire focused on collection of respondents' demographic and socio-economic information. Respondents are provided with the choice not to disclose this information. Where possible, missing values of the survey data were replaced by average data for the panel provided by the market research company. In instances where neither survey data nor panel data were available, non-responses were replaced by the median of the reported survey values.

4.6 Data Description

4.6.1 Data Description of Funding Allocation Choices

Although different respondents face different versions of the questionnaire and different choice sets have different alternatives, the first alternative plan presented (Plan A) is always the current research funding level and allocations, while the fourth alternative plan presented (Plan D) is always to provide no funding for PMF research. As shown in Table 4-4, about 50% of respondents chose the current research funding level and allocations. Less than 5% of respondents chose to provide no funding for PMF research. This suggests that respondents do not have strongly averse opinions about PMF technology.

Table 4-4 Choices of Research Funding Allocation Plans

	Current Funding Allocation Plan	Alternative Funding Allocation Plan	Alternative Funding Allocation Plan	Provide No Funding
Choice set 1	41.2%	36.3%	19.3%	3.2%
Choice set 2	48.6%	32.2%	15.1%	4.1%
Choice set 3	49.4%	29.4%	17.5%	3.8%
Choice set 4	51.0%	25.3%	19.4%	4.3%
Choice set 5	45.4%	26.7%	23.8%	4.1%
Choice set 6	49.4%	26.1%	20.3%	4.2%
Choice set 7	54.1%	21.3%	20.3%	4.3%
Choice set 8	52.7%	22.7%	19.4%	5.1%

From Table 4-4, it is observed that more respondents choose alternative funding allocation plan B than alternative funding allocation plan C. Based on the choice experiment design, these two alternative plans are balanced in attribute levels and therefore this should not be the observed pattern. The existence of the observed pattern may be explained by the fact that respondents initially do not have enough knowledge about PMF technology. They may be examining the choices from left to right. However, as the number of choice sets increase, the frequency differences between alternative funding allocation plan B and alternative funding allocation plan C decreases. This indicates that there may be a learning by respondents over the set of choices.

4.6.2 Demographic and Socio-Economic Characteristics

Among the 1574 public respondents, 80% of respondents answered the survey presented in English; the balance chose the French language version of the survey. The sample consists of 806 female respondents and 768 male respondents. The youngest respondent is 18 years old and the oldest respondent is 82 years old. Sixty per cent of the respondents are employed full-time or part-time and 41.8% of respondents report having a college diploma/degree or higher level of education. Thirty-two out of a hundred of the respondents report that they live in a rural area. A more detailed description of the demographic and socio-economic characteristics of the respondents to the survey is shown in Table 4-5.

Table 4-5 Summary of Demographic and Socio-Economic Characteristics of the Survey Data (Total 1574 respondents)

Demographic and Socio-economics Variables	Descriptions	Mean (S.D.)	Frequency
Language	English=1, French=2		80.1% English, 19.9% French
Gender	Male=1, Female=2		48.8% Male, 51.2% Female
Age	Min=18, Max=82	43.53 (14.73)	
Household Size		2.71 (1.33)	
Number of Children		0.73 (1.21)	
Education Level	Never attended school=1, ... , Some university or college=6, ... Post graduate university degree (Masters or PhD)=10	6.15 (1.87)	92.2% High school graduate
Employment Status	Working full- or part-time=1, Student=2, Not in the wage labour force=3, Retired=4, Not currently employed=5		60.3% Working full- or part-time, 17.5% Retired
Total Household Income Before Taxes	Less than $10,000=1, $10,000-$19,999=2, $20,000-$29,999=3, ..., $90,000-$99,999=10, More than $100,000=11	5.56 (2.63)	

Continued: Summary of Demographic and Socio-Economic Characteristics of the Survey Data (Total 1574 respondents)

Demographic and Socio-economics Variables	Descriptions	Mean (S.D.)	Frequency
Province	AB=1, BC=2, MB=3, NB=4, NL=5, NT=6, NS=7, NU=8, ON=9, PE=10, Quebec=11, SK=12		38.6% ON, 24.9% Quebec, 12.3% BC
Residence Region	Rural area=1, Not rural area=2		32% Live in rural area
Working Area	Hospital or health services=1, Government or non-government environment agencies=2, Food industry=3, Research Institution=4, Others=5		5.5%, 8.0%, 12%, 13.4%, and 61.1% separately
Associated with or donated to consumer group that focuses on Food safety issues	Yes=1, No=2		2.1% Yes
Associated with or donated to environmental group	Yes=1, No=2		7.6% Yes
Associated with group that seeks remedies for illness or medical problems	Yes=1, No=2		7.9% Yes

To assess the overall representativeness of the survey sample, the demographic and socio-economic characteristics collected from the survey sample are compared with those for the Canadian population, as indicated by the Statistics Canada 2001 Census (as seen in Table 4-6).

Table 4-6 Comparison of the Survey Sample with Canada's Demographic Characteristics (year 2001)

Socio-economic & Demographic Variable	Survey Sample	Statistics Canada 2001 Census
Language	80.1% English, 19.9% French	59.7% English, 22.7% French, 17.6% Others
Gender	48.8% Male	49.0% Male
Age	Mean=43.53	Median Age=37.6
Household Size	Mean=2.71	Average number of persons in private households=2.6
Number of Children	Mean=0.73	Average number of children at home per census family=1.1
Employment Status	60.3% Working full- or part-time, 17.5% Retired	61.48% employed
Total Household Income before Taxes	Mean= $55,600	Average= $58,360

Continued: Comparison of the Survey Sample with Canada's Demographic Characteristics (year 2001)

Socio-economic & Demographic Variable	Survey Sample	Statistics Canada 2001 Census
Education Level	Mean=Some university or college, Grade School (grade 1-8)=0.4%, Some high school (grade 9-13)=7.0%, High school graduate=16.3%, Some university or college=23.1%, College diploma/degree=18.0%, University degree=19.7%	Median=some postsecondary education, Grade School (grade1-8)= 9.83%, Some high school (grade9-13)=21.45%, High school graduation certificate=14.09%, Some postsecondary education=10.84%, College certificate or diploma=14.97%, University degree=15.43%
Province	38.6% ON, 24.9% Quebec, 12.3% BC	38.0% ON, 24.1% Quebec, 13.0% BC
Residence Region	32% rural area	20.3% rural area

Generally speaking, the survey sample is reasonably representative of the Canadian population as indicated by reference to data from Canada's previous census. The population of French-speaking respondents is slightly under-represented (-3.8%) in the survey sample. The percentage of English-speaking respondents in the survey sample is slightly higher than in the overall Canadian population. However, considering that many other language groups may choose English as the language with which to answer the survey, this feature of the survey sample appears to be acceptable.

The gender distribution and the average household size of the survey sample closely represent the gender distribution and household size in Canada. However, the average number of children in the households of the survey sample is somewhat lower than seen in the 2001 Census statistics. Similarly, the average age of the survey sample is approximately 6 years older than the average age of the total Canadian population in 2001. Although the mean education level of the survey sample is coincidentally identical to the median education level of Canadian population, compared to the distribution of education levels, the survey sample has less population with lower education levels and more population with higher education levels. The survey sample respondents generally obtained more education than the average Canadian.

The employment status and total household income before taxes of the survey sample are reasonably representative of the Canadian population overall, with the exception that the income of the survey sample is slightly lower than reported in the 2001 Census (-$2,760). The difference might be caused by some respondents refusing to report their income, which is common in stated preference surveys. The self-reported percentage of survey sample respondents living in rural areas is higher by 11 per cent than the rural percentage reported by Statistics Canada for the Canadian population[8]. In terms of geographical regional distribution, the overall distribution of the survey sample is fairly representative of Canadian's provincial distribution.

4.7 Descriptive Statistics

As mentioned in the survey design, the fourth section of the survey questionnaire contains rating scale questions focusing on assessing respondents' perceptions and

[8] According to Statistics Canada, Census 2001, the definition of an urban area is "area with a population of at least 1,000 and no fewer than 400 persons per square kilometer". The definition of "rural area" is "rural areas include all territory lying outside urban areas." The definition of "rural population" includes "all population living in the rural fringes of census metropolitan areas (CMAs) and census agglomerations (CAs), as well as population living in rural areas outside of CMAs and CAs".

attitudes about PMF technology. These rating scale questions provide another method to examine respondents' preference other than choice experiments method and to provide some explanation behind respondents' choice behavior. In the following section, respondents' self-reported level of familiarity with PMF, their risk-benefit assessments of PMF technology, and information sources on PMF will be discussed.

Table 4-7 Respondents' Self-reporting Level of Familiarity with PMF Technology (1574 Respondents)

Level of Familiarity	Number of Respondents	Percentage
Very familiar	14	0.9%
Moderately familiar	149	9.5%
Slightly familiar	586	37.2%
Unfamiliar	467	29.7%
Never heard of this before this survey	280	17.8%
Don't know/Unsure	50	3.2%
Skipped	28	1.8%
Total	1574	100%

The statistical results of respondents' self-reporting level of familiarity (Table 4-7) indicate that most of the respondents are not familiar with PMF technology. About 48% of respondents reported being not familiar with PMF and about 37% respondents report being slightly familiar with PMF technology. Only about 10% of respondents consider themselves familiar with it. Respondents' low level of familiarity and lack of knowledge with PMF technology may be one of the reasons why about 45% of responses for the choice experiments questions are to choose Plan A (refer to Table 4-4), which is the status quo plan. This endowment effect is a phenomenon of complex choice experiments questions.

Table 4-8 PMF Potential Risks (1574 respondents)

	High Risk	Moderate Risk	Slight Risk	Almost No Risk	Don't know /Unsure
PMF to produce better and cheaper medical drugs	8.5%	31.5%	34.7%	14.4%	10.9%
PMF to produce better and cheaper industrial products	9.2%	26.9%	34.2%	18.6%	11.2%
PMF to produce more nutritious and cheaper foods	16.9%	28.3%	31.0%	13.3%	10.5%
Contamination of food supplies	21.2%	32.1%	27.7%	9.6%	9.4%
Damage to the environment	24.3%	31.8%	25.2%	9.2%	9.5%

Table 4-9 PMF Potential Benefits (1574 Respondents)

	High benefit potential	Moderate benefit potential	Slight benefit potential	Almost no benefit potential	Don't know /Unsure
PMF to produce better and cheaper medical drugs	31.5%	37.7%	17.7%	3.4%	9.6%
PMF to produce better and cheaper industrial products	20.3%	38.6%	26.9%	4.5%	9.8%
PMF to produce more nutritious and cheaper foods	23.9%	34.6%	24.5%	7.3%	9.8%
Opportunity for Canada to lead and create job opportunities in a new industry	29.5%	37.3%	20.8%	3.7%	8.7%
Production of new drugs that may not be produced by conventional methods or increase in quantities of existing medical drugs at less cost	29.7%	37.5%	19.0%	4.7%	9.1%

In the rating scale questions, respondents were also asked about their perceptions of PMF related risks and benefits (Table 4-8 and 4-9). Among the three PMF applications, using PMF to produce more nutritious and cheaper foods is ranked as being the most risky applications and is ranked as having the least benefits. Although it is ranked as the second riskiest PMF application, using PMF to produce better and cheaper medical drugs is viewed by respondents as the most beneficial application. Using PMF to produce better and cheaper industrial products is ranked as the second beneficial PMF application and is considered to be the least risky one. The reason why industrial application is viewed by respondents as less risky may be that industrial products do not affect human health conditions as directly as the other two applications. Therefore, the results of risk-benefits assessment suggest that medical applications of PMF technology are preferred by respondents, following by industrial applications. Using PMF technology for food production is the least preferred application.

As for the potential risks posed by PMF technology, the potential damage to the environment is regarded as slightly more risky than the potential contamination of food supplies. Both of the two potential risk issues are viewed by respondents as highly risky. The two potential benefits posed by PMF technology, which are potential opportunities for Canada to lead and create job opportunities in a new industry and the potential production of new drugs that may not be produced by potential methods or increase in quantities of existing medical drugs as less cost are viewed as highly beneficial.

Table 4-10 Relationships between the Risks and Benefits associated with PMF (1574 respondents)

Relationships between Risks and Benefits	% of Respondents
Risks probably significantly outweigh benefits	10.7%
Risks probably moderately outweigh benefits	13.3%
Risks probably slightly outweigh benefits	12.5%
Risk probably roughly equivalent to benefits	11.4%
Benefits probably slightly outweigh risks	12.9%
Benefits probably moderately outweigh risks	18.9%
Benefits probably significantly outweigh risks	9.0%
Don't know/Unsure	11.3%

Respondents are asked to indicate the relationships between the risks and benefits associated with PMF technology (Table 4-10). 40.8% of respondents think benefits outweigh risks and 36.5% respondents think risks outweigh benefits. About 11% of respondents consider the risks and benefits are roughly equivalent. Overall, respondents view PMF as more beneficial than risky. It is noteworthy that about 10% respondents chose "don't know/unsure", which reflects respondents lack of familiarity with PMF technology.

Respondents were also asked about the sources that they would seek information on PMF and what would be their most trusted sources of information. These two questions are multiple choice questions. Table 4-11 shows the percentages of respondents who chose the information sources.

Table 4-11 Sources of Information on PMF (1574 respondents)

	Sources of information on PMF	Most trusted sources of information on PMF
Friends and family	11.7%	7.1%
Newspapers and magazines	33.1%	22.3%
Radio and TV	19.7%	14.0%
The Internet	78.3%	49.9%
Others	6.5%	3.0%
I would not seek any information	5.0%	N/A
Doctors and nurses	N/A	17.9%
University research scientists	N/A	52.5%
Federal or provincial government	N/A	20.2%
Don't know/Unsure	6.5%	N/A

Table 4-11 shows that the Internet is the most popular source for seeking information on PMF and also is highly trusted. This is probably because Internet is convenient and efficient for searching information. The reason why the Internet is highly trusted might be because Internet users could find both positive and negative information about the issues and they can make decisions based on their own judgment. Traditional media, such as newspapers and magazines, radio and TV, are still popular for respondents as main sources to seek information and are relatively trusted. Friends and family are not the major sources for seeking PMF information and also are not highly ranked for trust, as respondents may think friends and family are not knowledgeable on PMF issues. University research scientists are ranked as the highest trust sources.

4.8 Summary

This chapter provided an overview of the methods that were applied to carry out this study. In the first section, economic theory guiding this research study was outlined. A description of random utility theory was provided and a discussion was given of how this leads to the formulation of the multinomial logit model of choice behavior and maximum likelihood estimation. This was followed by a comparison of the multinomial logit and conditional logit models. The design of the survey questionnaire that was employed in this study was then described. The subsequent section discussed how to combine random utility theory and conditional logit model with the PMF research funding allocation choices, the focus of the study. The last two sections provided a discussion of data collection and a data description. The following chapter discusses model development, reports the results of model estimation, and discusses some implications of these.

Chapter 5 Model Development, Estimation and Results Analysis, and Policy Implication

5.1 Introduction

The processes of model development and estimation are discussed in this chapter. In Section 5.2, a description of the independent variables is provided and this section also outlines some issues in model development. In the following section, section 5.3, the results of the empirical model are discussed. The influence of respondents' demographic and socio-economic characteristics on their choice behavior for PMF research funding allocations is then discussed in this section. In section 5.4, the last section in this chapter, some observations on preferred PMF research investments based on the estimation results are presented.

5.2 Model Development

The main focus of this study is to gain an understanding of respondents' opinions and preferences for PMF research funding allocations. The theoretical framework of the conditional logit model employed to analyze respondents' choice behavior was discussed in Chapter 4. In this section, the empirical model development will be presented.

5.2.1 The Choice-Specific Attributes and the Individual-Specific Attributes

As discussed in Chapter 4 and shown in Appendix A, which gives the survey questionnaire, the choice-specific attributes, which are PMF funding allocations directed to five different focal areas of PMF research (i.e. to health, industrial, environmental, consumer applications, and to social, economic, and public policy issues) are expressed in terms of different percentages of total research funding allocations specified in various alternative plans. In some plans the percentages of the research funding allocations for specific research areas are varied. In others, percentage allocations may remain the same in the choice alternatives, but the total monetary value to be allocated to the various areas is varied, as the total funding levels in the alternative plans are varied. Based on the assessment, indicated to respondents, that the Canadian government currently funds about ten million Canadian dollars annually on PMF-related research, we find it convenient in the analysis of the data to convert the percentage allocations specified for different research areas into monetary values. Consequently the corresponding monetary values of the choice-specific attributes are employed in modeling[9].

Rescaling the choice-specific attributes of research funding allocations to the different research areas from percentages to dollar values gives relatively large numbers compared to the values of the individual-specific attributes. Therefore, the choice-specific attributes are further scaled to be expressed in terms of millions of dollars. Table 5-1 gives the summary statistics for the choice-specific attributes across all alternatives in all choice sets for all 1574 respondents.

[9] For example, in a specific alternative, total research funding is decreased by 20% and the allocations are 10%, 20%, 30%, 20%, and 20 % in health, industry, environmental, consumer, and social areas respectively. In this case, the total research funding is 8 million dollars and 0.8 million dollars will be allocated to the health area.

Table 5-1 Summary Statistics of Choice-Specific Attributes (in millions of dollars)

Choice-Specific Attributes	Minimum	Maximum	Mean	S.D.	Median
Total Research Funding	0	12	7.488	4.4395	10
Research Funding Allocated to Health Applications	0	3.6	1.744	1.2479	2
Research Funding Allocated to Industrial Applications	0	3.6	1.493	1.0520	2
Research Funding Allocated to Environmental Applications	0	3.6	1.216	0.9906	1
Research Funding Allocated to Consumer Applications	0	3.6	1.520	1.0764	2
Research Funding Allocated to Social, Economic and Public Policy Issues	0	3.6	1.516	1.0744	2

Note: The statistical results are based on the 50368 alternatives that are available for all 1574 respondents. Because each respondent has 8 choice sets, each with 4 alternatives, each respondent faced 32 alternatives.

Decision makers' demographic and socio-economic characteristics are expected to influence their choice behavior. The inclusion of demographic and socio-economic characteristics in the utility function can introduce respondents' heterogeneity into the model estimation process. Table 5-2 lists the definitions and codes for the postulated independent variables, including both choice-specific attributes and individual-specific attributes, in the model estimation.

Table 5-2 Variable Definitions and Codes

Independent Variables	Codes	Definitions
The Choice-Specific Attributes		
Total research funding	Total [1]	Continuous variable indicating the monetary values of total research funding
Research funding allocated to health applications	Health [1]	Continuous variable indicating the monetary values of research funding allocated to health applications
Research funding allocated to industrial applications	Industry [1]	Continuous variable indicating the monetary values of research funding allocated to industrial applications
Research funding allocated to environmental applications	Envt [1]	Continuous variable indicating the monetary values of research funding allocated to environmental applications
Research funding allocated to consumer applications	Consumer [1]	Continuous variable indicating the monetary values of research funding allocated to consumer applications
Research funding allocated to social, economic and public policy issues	Social [1]	Continuous variable indicating the monetary values of research funding allocated to social, economic, public policy issues
The Individual-Specific Attributes		
Gender	Gender	1=male, 0=female
Age	Age	Continuous variable representing respondent's age

Continued: Variable Definitions and Codes

Independent Variables	Codes	Definitions
Household size	Size	Continuous variable representing the number of people living in respondent's household
Number of children	Child	Continuous variable representing the number of children (under 18) living in respondent's household
Education level	Uni	1=university degree[2] or higher, 0=lower than university degree
Employment status	Employ	1=working full-/part-time, 0=unemployed
Income	Income	Less than $10,000=1, $10,000-$19,999=2, ..., $90,000-$99,999=10, More than $100,000=11
Live in British Columbia	BC	1=live in the Province of British Columbia, 0=not living in the Province of British Columbia
Live in the prairie area[3]	Prairie	1=live in the prairie area, 0=not living in the prairie area
Live in Quebec	QC	1=live in the Province of Quebec, 0=not living in the Province of Quebec
Live in Ontario	ON	1=live in the Province of Ontario, 0=not living in the Province of Ontario
Live in the rest of Canada[4] (self-stated)	Rest	1=live in the rest of Canada, 0=not living in the rest of Canada
Live in rural area	Rural	1=live in rural area, 0=not living in rural area

Continued: Variable Definitions and Codes

Independent Variables	**Codes**	**Definitions**
Work in hospital and health services	Work in Health Sector	1=Yes, 0=No
Work in government or non-government environmental agencies	Work in Environment Sector	1=Yes, 0=No
Work in the food industry	Work in Food Sector	1=Yes, 0=No
Work in a research institution	Work in Research Sector	1=Yes, 0=No
Associated with or donated to consumer group that focuses on food safety issues	Food Group	1=Yes, 0=No
Associated with or donated to environmental group	Environment Group	1=Yes, 0=No
Associated with group that seeks remedies for illness or medical problems	Health Group	1=Yes, 0=No

Notes:

1. These choice-specific attributes are in dollar values. The unit of each attribute is in millions of dollars.
2. University degree or higher includes university undergraduate degree, some post graduate university study, and post-graduate university degree (e.g., Master or Ph.D.).
3. Prairie area includes the Province of Alberta, the Province of Manitoba, and the Province of Saskatchewan.
4. "The rest of Canada" includes the Province of New Brunswick, the Province of Newfoundland and Labrador, Northwest Territories, the Province of Nova Scotia, and the Province of Prince Edward Island.

5.2.2 Issues in Model Development

Among the six choice-specific attributes, which are PMF research funding allocations respectively directed to health, industrial, environmental, and consumer research, as well as to social, economic, and public policy issues, there is a restriction that the values of research funding allocated in each area must sum to be equal to the value of total research funding. Econometric identification requires dropping one of these attributes in the model estimation to avoid collinearity (Swallow and Mazzotta 2004). The total value of PMF research funding is the attribute which is selected to be dropped in the analysis.

Preliminary significance tests for estimated coefficients on each demographic and socio-economic attribute suggest that some of the attributes do not influence or do not have a strong influence on respondents' choice behavior (indicated by insignificant and/or few significant estimated coefficients). These insignificant demographic and socio-economic attributes are dropped. Those dropped out of model estimation include respondent's household size, the number of children living in the respondent's household, respondent's employment status, whether or not respondents live in the prairie area, whether or not respondents live in the Province of Quebec, whether or not respondents live in the Province of Ontario, whether or not respondents live in the rest of Canada, whether or not respondents live in rural areas, whether or not respondents work in the food industry, whether or not respondents work in a research institution, whether the respondent has an association with a consumer group that focuses on food safety issues, and whether the respondent has an association with an environmental group.

The individual-specific attributes are interacted with alternative-specific attributes in order to capture the effects of demographic and socio-economic characteristics on respondents' perceptions and preferences for the alternative-specific attributes. All the individual-specific attributes are constant for each respondent; they do not vary across alternatives for the same respondent. If demographic and socio-economic attributes are introduced alone into the modeling, they will drop out of the differentiation of the utility function. This will cause "Hessian singularities" in the model estimation process (Bennett

1999). Therefore, a set of dummy variables, termed alternative specific constants (ASCs), are created such that a value of one is assigned to the ASC corresponding to a particular alternative and zero otherwise. Each ASC is related to a specific alternative. To establish variations of demographic and socio-economic variables, these are introduced into the model by being interacted with ASCs. An alternative specific constant itself can capture the mean effects of the unobserved factors in the choice behavior that cannot be explained either by alternative-specific attributes or individual-specific attributes (Ben-Akiva and Lerman 1985).

For the purpose of identification, at least one of the ASCs should be dropped from the model in estimation (Swallow and Mazzotta 2004). In this study, Plan A represents current total funding levels and allocations for PMF research and is the status-quo plan; Plan D represents the option of no research funding allocation to PMF research at all, which can be referred to as the "opt-out" alternative. We are particularly interested in respondents' opinions and assessments about the current research allocations to PMF research areas and the alternative of investing no research funding at all on PMF research. Therefore, the ASCs for Plan A and Plan D are included in the model estimations, while the ASCs for Plan B and Plan C, which are the two alternative research allocation plans, are excluded.

5.3 Estimation

Several versions of conditional logit models based on equation 4.11, with different model specifications, were estimated, using maximum likelihood procedures, by NLOGIT version 3.0 (Greene 2002). Models with attributes in linear functional form and models with attributes in non-linear functional form (quadratic and semi-logarithmic) are tested. It is concluded that a non-linear utility function is preferred to the linear utility function. The non-linear term in both the quadratic functional form and the semi-logarithmic functional form of the model are significant. Therefore, non-linear-in-parameters models are adopted to capture the observed and measurable part of indirect utility function.

Based on statistical fit, two conditional logit models are identified to be superior and reported here. The estimated coefficients for these non-linear models, Model I and Model II, are given in Table 5-3 and Table 5-4. The choice-specific attributes in Model I are in quadratic form; and the choice-specific attributes in Model II are in logarithmic linear (i.e., semilogarithmic) form. These two models are chosen to be reported based on the validity of model estimation. First, the logic of the relationships among the postulated variables is considered to be reasonable. Second, the estimated coefficients demonstrate high statistical significance. Moreover, these two models show superior goodness-of-fit and strong overall explanatory power. The results from log-likelihood statistics at convergence (-13544.06 for Model I and -13576.64 for Model II) indicate that these two models are statistically valid. The Chi-square statistics (1987.82 and 1922.66 separately) from the likelihood ratio test are significant at the 99% significance level. Hence, the null hypothesis that the coefficients are not significantly different from zero is rejected. Rho-square values, adjusted for degrees of freedom are 0.067 for Model I and 0.065 for Model II, which are considered acceptable[10]. The model with a quadratic indirect utility function seems to fit the data better than the model with semi-logarithmic utility function. First, both the value of log-likelihood at convergence and the value of adjusted Rho-square of the model with quadratic utility function are greater than in the model with semi-logarithmic utility function. Second, the quadratic indirect utility function model has a larger number of significant estimated coefficients than the semi-logarithmic indirect utility function model.

Both Model I and Model II include alternative specific constants for Plan A and Plan D, choice-specific attributes, interactions of choice-specific attributes with significant individual-specific attributes, and interactions between significant individual-specific attributes and alternative specific constants. The results from maximum likelihood estimation of Models I and II are shown in Table 5-3 and Table 5-4 respectively.

[10] Rho-squared (ρ^2) is a type of pseudo-R^2 measure of the goodness-of-fit of logit model (Uto 2005).

Table 5-3 Conditional Logit Estimates of the Parameters of Respondents' Indirect Utility Functions Derived from the Survey Data: Model I (Quadratic Utility Function)

Variables		Coeff.	t-ratio	Variables		Coeff.	t-ratio
ASC							
ASC for Plan A		0.3300	2.87***	ASC for Plan D		0.7176	1.30
Attributes							
Health		0.7749	6.14***	$Health^2$		-0.0667	-2.78***
Industry		0.2345	1.90*	$Industry^2$		-0.0984	-4.02***
Envt		1.1994	9.64***	$Envt^2$		-0.2035	-8.55***
Consumer		0.2465	1.92*	$Consumer^2$		-0.0780	-3.21***
Social		0.3553	2.80***	$Social^2$		-0.0825	-3.40***
Interaction between Attributes and Socio-economic factors							
Age	Health	0.0053	4.02***	Health Group	Health	0.0926	1.28
	Industry	0.0037	2.62***		Industry	0.1337	1.80*
	Envt	0.0037	2.67***		Envt	-0.0361	-0.48
	Consumer	0.0063	4.70***		Consumer	0.0670	0.92
	Social	0.0053	4.18***		Social	0.1290	1.91*
Gender	Health	-0.0826	-2.14**	BC	Health	0.0616	1.06
	Industry	0.0819	1.98**		Industry	-0.0370	-0.60
	Envt	-0.0677	-1.66*		Envt	0.1113	1.77*
	Consumer	0.0342	0.87		Consumer	0.0354	0.60
	Social	0.0211	0.56		Social	0.1207	2.11**
Uni	Health	0.0197	0.44	Work in Health Sector	Health	0.2081	2.39**
	Industry	-0.1101	-2.31**		Industry	0.3090	3.28***
	Envt	-0.0812	-1.69*		Envt	0.2300	2.48**
	Consumer	-0.1475	-3.21***		Consumer	0.1711	1.88*
	Social	-0.1162	-2.64***		Social	0.0447	0.54
Income	Health	0.0076	1.03	Work in Environment Sector	Health	0.3698	2.54**
	Industry	0.0115	1.48		Industry	0.2356	1.65*
	Envt	0.0025	0.32		Envt	0.3251	2.47**
	Consumer	0.0018	0.24		Consumer	-0.0063	-0.05
	Social	-0.0154	-2.14**		Social	0.0556	0.44

Continued: Conditional Logit Estimates of the Parameters of Respondents' Indirect Utility Functions Derived from the Survey Data: Model I (Quadratic Utility Function)

Variables		Coeff.	t-ratio	Variables		Coeff.	t-ratio
Interaction between ASC and Socio-economic factors							
Age	ASC for Plan A	0.0029	1.43	Health Group	ASC for Plan A	-0.1750	-1.62
	ASC for Plan D	0.0665	7.48***		ASC for Plan D	-0.0023	-0.005
Gender	ASC for Plan A	-0.0944	-1.55	BC	ASC for Plan A	0.1526	1.67*
	ASC for Plan D	0.4114	1.57		ASC for Plan D	0.5856	1.47
Uni	ASC for Plan A	-0.1195	-1.71*	Work in Health Sector	ASC for Plan A	0.2128	1.62
	ASC for Plan D	-0.7696	-2.56**		ASC for Plan D	2.0416	3.32***
Income	ASC for Plan A	0.0118	1.03	Work in Envrio-nment Sector	ASC for Plan A	0.1617	0.78
	ASC for Plan D	-0.0426	-0.85		ASC for Plan D	2.8239	3.11***
Adjusted p-square				0.06669			
Log Likelihood at convergence				-13544.06			
Chi-square				1987.82			

Note: *, **, and *** denote 0.1, 0.05, and 0.01 probability levels.

Table 5-4 Conditional Logit Estimates of the Parameters of Respondents' Indirect Utility Functions Derived from the Survey Data: Model II (Semilogarithmic Utility Function)

Variables		Coeff.	t-ratio	Variables		Coeff.	t-ratio
ASC							
ASC for Plan A		0.5766	5.02***	ASC for Plan D		-1.8045	-5.75***
Attributes							
Log(Health)		0.8697	6.22***	Log(Industry)		-0.3374	-2.54**
Log(Envt)		0.6639	4.94***	Log(Consumer)		-0.2181	-1.59
Log(Social)		0.0256	0.20				
Interaction between Attributes and Socio-economic factors							
Age	Log(Health)	0.0107	4.01***	Health Group	Log(Health)	0.1816	1.21
	Log(Industry)	0.0060	2.37**		Log(Industry)	0.2283	1.67*
	Log(Envt)	0.0064	2.53**		Log(Envt)	-0.0354	-0.26
	Log(Consumer)	0.0123	4.77***		Log(Consumer)	0.1581	1.12
	Log(Social)	0.0098	4.02***		Log(Social)	0.2664	2.04**
Gender	Log(Health)	-0.1849	-2.35**	BC	Log(Health)	0.1463	1.22
	Log(Industry)	0.1756	2.35**		Log(Industry)	-0.0340	-0.30
	Log(Envt)	-0.1453	-1.93*		Log(Envt)	0.2120	1.83*
	Log(Consumer)	0.0397	0.52		Log(Consumer)	0.0841	0.73
	Log(Social)	0.0141	0.19		Log(Social)	0.2270	2.05**
Uni	Log(Health)	0.0076	0.08	Work in Health Sector	Log(Health)	0.4643	2.54**
	Log(Industry)	-0.2177	-2.52**		Log(Industry)	0.5907	3.33***
	Log(Envt)	-0.1271	-1.45		Log(Envt)	0.4617	2.65***
	Log(Consumer)	-0.2896	-3.28***		Log(Consumer)	0.3856	2.20**
	Log(Social)	-0.1819	-2.16**		Log(Social)	0.0741	0.46
Income	Log(Health)	0.0143	0.95	Work in Environ-ment Sector	Log(Health)	0.7371	2.46**
	Log(Industry)	0.0228	1.61		Log(Industry)	0.3344	1.30
	Log(Envt)	0.0072	0.50		Log(Envt)	0.6072	2.43**
	Log(Consumer)	0.0018	0.12		Log(Consumer)	0.0047	0.02
	Log(Social)	-0.0316	-2.29**		Log(Social)	0.0829	0.35

Continued: Conditional Logit Estimates of the Parameters of Respondents' Indirect Utility Functions Derived from the Survey Data: Model II (Semilogarithmic Utility Function)

Variables		Coeff.	t-ratio	Variables		Coeff.	t-ratio
Interaction between ASC and Socio-economic factors							
Age	ASC for Plan A	6.40E-05	0.03	Health Group	ASC for Plan A	-0.2231	-1.94*
	ASC for Plan D	0.0449	7.64***		ASC for Plan D	-0.2996	-0.82
Gender	ASC for Plan A	-0.1343	-2.09**	BC	ASC for Plan A	0.1256	1.30
	ASC for Plan D	0.3686	2.10**		ASC for Plan D	0.3781	1.42
Uni	ASC for Plan A	-0.0294	-0.40	Work in Health Sector	ASC for Plan A	0.1314	0.93
	ASC for Plan D	-0.3803	-1.91*		ASC for Plan D	1.2937	3.07***
Income	ASC for Plan A	0.0153	1.25	Work in Environ-ment Sector	ASC for Plan A	0.1814	0.83
	ASC for Plan D	-0.0493	-1.47		ASC for Plan D	1.9397	3.38***
Adjusted p-square				0.06457			
Log Likelihood at convergence				-13576.64			
Chi-square				1922.6576			

Note: *, **, and *** denote 0.1, 0.05, and 0.01 probability levels.

5.3.1 Public Perceptions of Plant Molecular Research Areas

Based on the previous discussions, in the conditional logit model, the probability of choosing one alternative from all others is modeled as a function of choice-specific attributes and decision makers' socio-economic characteristics. The probability of a decision maker choosing an alternative increases as the levels of preferred attributes in that alternative increase and the level of un-preferred attributes in that alternative decrease (Bennett 1999). The estimated coefficients for attributes explain the relationship between the attributes and the probability that an alternative with that attribute will be chosen. A positive sign on the estimated coefficient of an attribute indicates that the decision maker will obtain more utility when he/she chooses the alternative containing a higher level of that attribute. Similarly, a negative sign on the estimated coefficient for an attribute indicates that as the level of that attribute increases, the decision maker will obtain less utility from the alternative containing that attribute, and the probability that he/she will choose that alternative decreases (Bennett 1999).

Comparing the two estimated conditional logit models, the results for Model I (quadratic indirect utility function) and the results for Model II (semi-logarithmic indirect utility function) are similar and so support each other. In both models, significant positive coefficients for the alternative-specific constant for Plan A indicate that, all else held constant, respondents obtain more utility from the current research plan for PMF than from the various other two alternative research plans. The estimated coefficient for the alternative-specific constant for Plan D is significant and negative in Model II (although this is not significant in Model I). This indicates that, holding everything else constant, respondents receive less utility from banning PMF research than from the other two alternative research plans. Overall, all else held constant, the most preferred funding plan for respondents is to maintain the current research funding levels and allocations. Overall, the various alternative plans, represented by Plan B and Plan C, with varying total research funding levels and/or different funding allocations across the five research areas (health, industry, environment, consumer, and social, economic, and public policy), are the second choice for most respondents. The least preferred choice for most respondents is that government does not allocate any funding for PMF research. It appears that the results may show an endowment effect, which is a common phenomenon (Shapansky 2001). It seems that most respondents preferred to stay with the current situation, perhaps because they prefer to avoid changes. However, between the new situations of Plans B and C, and no research on PMF at all, overall there is a preference for new funding allocations.

For Model I, the significant and positive coefficients for the linear-term of attributes indicate that respondents prefer more funding to be provided in each area. However, the significant but negative coefficients for the squared-term of attributes disclose that there is a turning-point for the research funding that is preferred to be allocated in each PMF focus area. In turn, this indicates the maximum amount of research funding respondents prefer to allocate to each of the five specific research areas. Beyond each of those points, respondents obtain less utility as the research funding for that area increases.

The results of Model II provide additional information relative to respondents' preferences to allocate funding toward each PMF research area. Insignificant coefficients for the logarithm of funding to consumer research and funding on social, economic, and public policy research indicates that in this formulation these two attributes do not have an impact on respondents' utility. In contrast, the estimated coefficients for the logarithm of funding on health research and environment research are significant and positive. This indicates that respondents will obtain more utility from more research funding allocated in these two areas. The estimated coefficient on health research is higher than the estimated coefficient on environmental research. This implies that, all else held constant, respondents prefer to allocate more funding to heath research than to environmental research. It is noteworthy that the estimated coefficient for the logarithm of funding allocating to industrial research is significantly negative, indicating that as the amount of funding allocated to industrial research increases, the utility received by respondents decreases. This is supported by the Model I finding of a relatively small value of coefficient on the linear term (0.235) and a relatively large value of coefficient for the squared term (-0.098) on industrial research. In turn this implies that initially, holding everything else constant, respondents receive some utility from allocating funding to industrial products research; however, the utility received decreases and becomes negative as the funding level to this research area increases.

Figures 5.1 and 5.2 demonstrate the relationships between the values of funding allocated to each research area and the utility respondents obtained from these investments. These depictions enable comparison of preferences for funding allocated to different areas.

These two figures are drawn using Microsoft Excel. Based on equation 4.15, the measurable part of the respondents' indirect utility functions for Model I and Model II respectively are:

$$V=ASCs+\beta_1*Attributes+\beta_2*Attributes^2+\gamma_1*Attributes*Demos+\gamma_2*Demo*ASCs \quad (5.1)$$

and

$$V=ASCs+\beta_3*\log(Attributes)+\gamma_3*\log(Attributes)*Demos+\gamma_4*Demo*ASCs \quad (5.2)$$

where $\beta_1, \beta_2, \gamma_1$, and γ_2 are the estimated coefficients for Model I (refer to Table 5-3) and β_3, γ_3, and γ_4 are the estimated coefficients for Model II (refer to Table 5-4).

It is impractical to indicate the relationship between utility and funding allocations for each individual respondent since each has different demographic and socio-economic characteristics. Thus a representative respondent for the sample is chosen. The representative respondent depicted has demographic and socio-economic characteristic representing the median of the sample. This representative respondent is a 41 years old female. She does not have a university degree. She lives in Canada, but she does not live in the province of British Columbia. Her household's income is $45,000. She does not work for a hospital or health service nor in an environmental agency and is not associated with any group that seeks remedies for illness or medical problems. Holding research funding in the other areas at the median level[11], the utility obtained by the representative respondent from the funding allocated in each area is shown as Figure 5.1 and Figure 5.2.[12]

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[11] The median level of research funding in health, industry, environmental, consumer, and social, economic and policy research are 2 million, 2 million, 1 million, 2 million, and 2 million respectively.

[12] In the choice experiment of the survey questionnaire, the maximum total research funding that can be chosen is 12 million Canadian dollars and the maximum amount of funding allocated to each research area is 3.6 million. Figure 5.1 and 5.2 extend the maximum amount of funding allocated to each research area to 6 million in order to identify and present the depicted trends.

Figure 5-1 Utility for Representative Respondent Obtained from Research Funding Allocated to Each Area (Model I: Quadratic Utility Function)

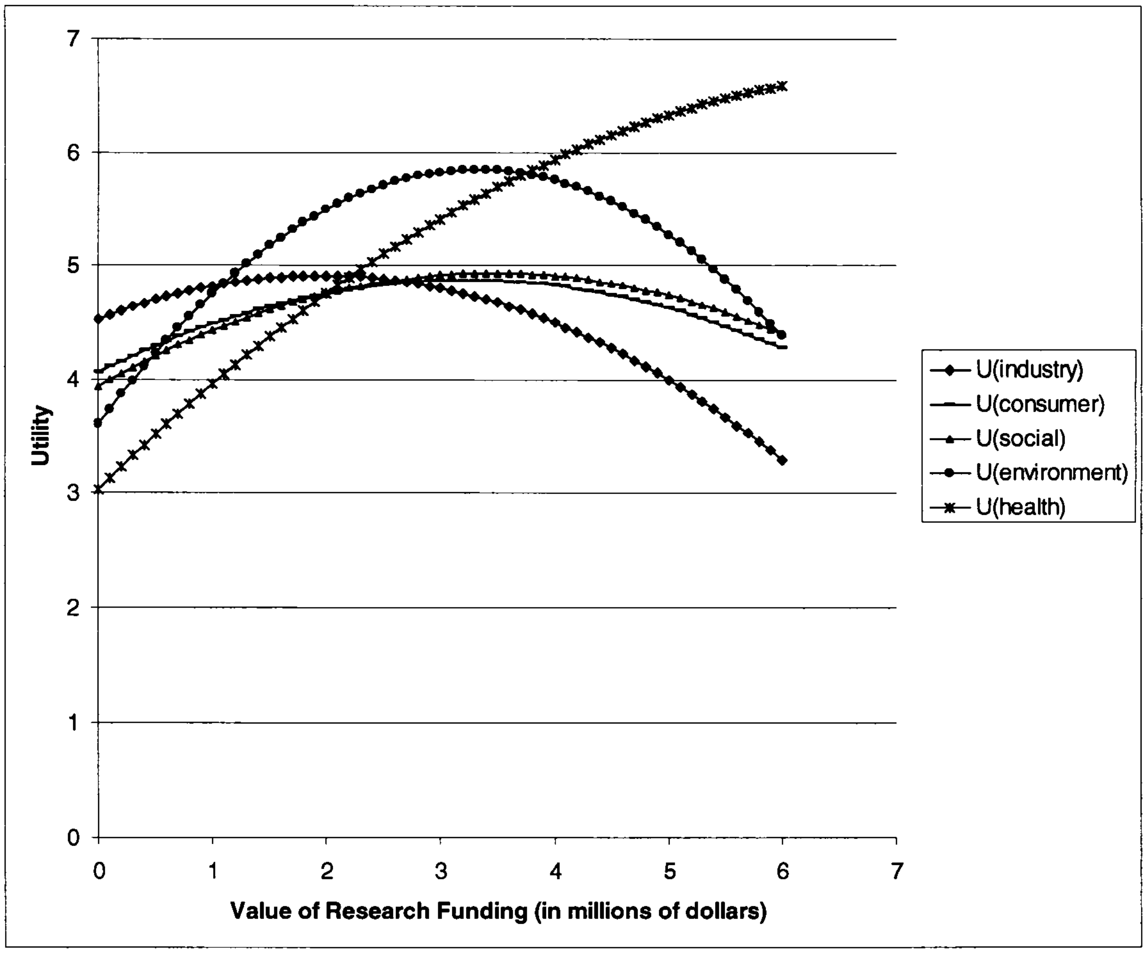
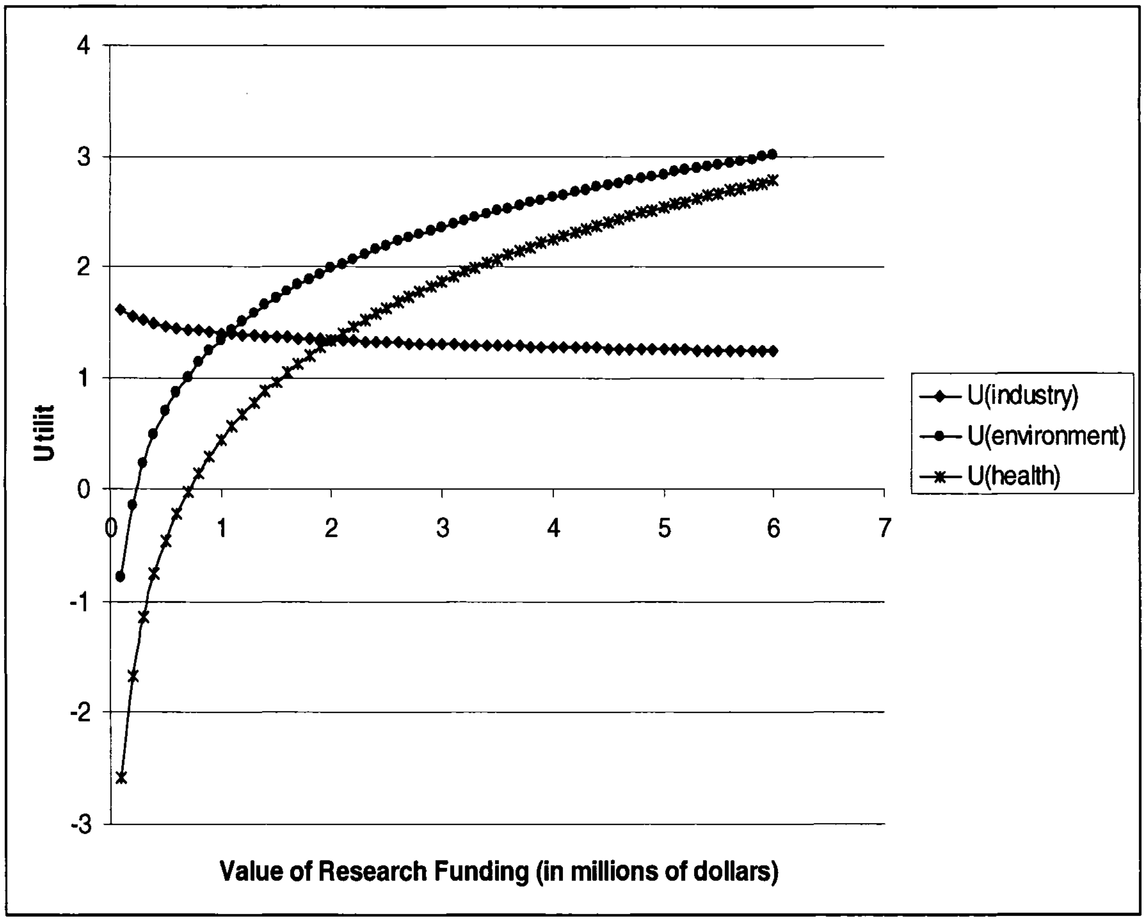


Figure 5-2 Utility for Representative Respondent Obtained from Research Funding Allocated to Each Area (Model II: Semilogarithmic Utility function)



Note: Since the estimated coefficients for the logarithm value of funding to consumer research and funding to social, economic, and public policy research are not significant, utilities for these are not included in the figure.

In Figure 5.1, the utility from funding invested in consumer focused PMF research and the utility from funding allocated to social, economic, and public policy research almost coincide. The slopes of both these utility functions are less than for the other research areas. As funding allocated to these two areas of research increases from zero to six million dollars, the utility obtained by respondents does not change as greatly as for the other research areas. This might explain why, in Model II, the estimated coefficients for these two attributes are not significant. According to the design of the choice experiments, the maximum amount of funding allocated to each research area is 3.6

million dollars (refer to Chapter 4, questionnaire description). Within this range, these two research areas (attributes) do not have a strong influence on respondents' utility. As shown in Figure 5.1, respondents' utility obtained from allocations of PMF funding in industrial research only increases slightly at first and then decreases dramatically. Therefore, it is not surprising to see a decreasing utility function for funding allocated to industrial research in Figure 5.2. In Figure 5.2, it is clear that allocating research funding to health and environmental issues is favored by respondents. Referring to Figure 5.1, one also observes a preference for these two attributes. The utility obtained from these two attributes increases dramatically initially, especially for funding allocated to environmental research. However, eventually utility decreases as the environmental investment increase. Even so, when respondents' utility obtained from funding allocated to the environment decreases, their utility obtained from funding allocated to health research is still increasing. Figure 5.1 indicates that the attribute of research funding allocated to health applications dominates respondents' utility. Allocating research funding to the health area is the most preferred attribute for respondents.

5.3.2 The Influence of Demographic and Socio-Economic Characteristics on the Preference for Attributes

The estimated coefficients for attribute variables simply represent the preferences for attributes overall for respondents. However, respondents with different demographic and socio-economic characteristics may have different preferences for research directed to different areas (i.e., to different research attributes). The interactions between choice-specific attributes and individual-specific attributes should reveal any diversity in tastes for attributes among different respondents.

5.3.2.1 Age

In both Model I and Model II, the estimated coefficients for the interaction terms between all the five choice-specific attributes and respondents' age are significant and positive.

This indicates that, holding everything else constant, the older the respondents are, the more they prefer to invest more research funding in all PMF research areas. It is noteworthy that in both models the magnitude of the coefficient for the variable interacted between respondents' age and the amount of funding allocated in the consumer area is the greatest, while the magnitude of the coefficient for the variable interacted between respondents' age and the amount of funding allocated to industry research and environmental area of research are the least. This suggests that older respondents prefer funding allocations in PMF consumer research to develop nutritionally improved food or to provide food at lower prices. Investing funding in industry research to develop new and cheaper industrial products and in environmental research to assess and limit impacts of PMF on the environment are relatively the least choices for older respondents.

5.3.2.2 Gender

Male and female respondents do show differences in preferences for research allocations. The interaction variables between choice attributes and respondents' gender disclose different preferences for PMF research funding allocations between these two genders. The results of both models show gender interacted with funding allocated to consumer research and funding allocated to social, economic, and public policy research to be insignificant. There are no differences in preferences between males and females for these two attributes. The significant and positive estimated coefficient for gender interacted with the industry attribute indicates that, all else held constant, male respondents would like to invest more funding in industry-focused research. However, as more funding is allocated to health and environmental research, the utility obtained by male respondents decreases and the probability that they choose that alternative decreases, as indicated by the significantly negative estimated coefficients for these two interaction variables. Moreover, male respondents prefer funding environmental research rather than health research, as indicated by the greater magnitude of the estimated coefficient for health variables interacted with respondents' gender. We can see that males are less inclined than females to prefer PMF health applications and PMF environmental applications. Perhaps this may reflect different perceptions of risks and/or less anticipation of benefits related to these two areas for men versus women.

5.3.2.3 Education Level

People with different education levels may assess issues differently. In this study, respondents with a bachelor degree or higher level of education tend to prefer less funding to be allocated to industry, environment, consumer, and social areas of PMF research according to the significantly negative estimated coefficients for these four interaction variables (although the coefficient for the environment interaction term is not significant in Model II). As for the preferences of investing research funding in health areas, there is no difference between respondents with different education levels. According to the findings noted above, respondents with more education, at least a university bachelor degree, tend to support PMF research slightly less than all other respondents. Table 5-5 shows that 4.09% of respondents with less education chose the "opt out" option, that is, chose the "no research funding on PMF" option; while slightly more respondents with more education (4.34%) preferred to ban PMF research.

Table 5-5 Frequency of Respondents with Different Education Levels Choosing Each Research Plan

Education Levels	Number of Respondents	Plan A	Plan B	Plan C	Plan D
Respondents with university bachelor degree or higher degree	376	48.56%	26.89%	20.23%	4.34%
Respondents with lower education than university bachelor degree	1198	49.09%	27.7%	19.14%	4.09%

The estimated coefficients for education levels interacted with funding also imply that respondents with a bachelor degree or higher level of education most dislike research allocations to develop nutritionally improved or cheaper food by genetically modified methods and funding directed to social, economic and policy research (Table 5-3 and Table 5-4).

5.3.2.4 Income Level

The significant and negative estimated coefficients for interaction variables between respondents' income levels and funding allocated to social, economic, public policy research implies that, holding everything else constant, respondents with higher incomes obtain more utility from less research funding being allocated to social, economic, and public policy research. Income levels do not influence preferences to allocate research funding to the other four areas since these estimated coefficients are not significant. The public nature of the source of the research funding, which is governmentally funded, might explain why income, generally regarded as an important demographic factor, is not a significant explanatory in this study. This may arise from respondents' expectations that individually they will not bear the burden of the research cost.

5.3.2.5 Living in British Columbia

Compared with respondents living elsewhere across Canada, those living in British Columbia prefer more funding to be allocated to environmental and social, economic and public policy research based on the significantly positive estimated coefficients on this variable.

5.3.2.6 Occupation

The occupation in which respondents work may also affect their assessments and opinions on the allocations of PMF research funding. Compared with respondents working in all other occupations, respondents working in hospitals and health services are in favor of more funding for health, industry, environment, and consumer research. Regarding funding allocations to social, economic, and public policy research, there is no difference between respondents working in hospitals and health services and respondents working elsewhere. A potential advantage of PMF technology relates to possible new treatments for disease and more affordable medicines, which may be attractive to respondents who work in hospitals and health areas. Similarly, respondents working in environmental agencies appear to receive more utility from choosing a research plan with more funding allocated to health, environmental, and/or industry (although the coefficients for the industry attribute are not significant in Model II). It may be that respondents who work in environmental agencies pay more attention to environmental protection issues and may view PMF technology as providing an environmentally friendly production process.

5.3.2.7 Association Membership

It is possible that membership in certain types of organizations/associations may reflect the attention the member pays to that issue and topic. However, we find that respondents who are associated with a group that seeks remedies for illness or medical problems do not show significant preferences for more funding to PMF-based health research; instead they prefer to allocate more funding to industrial and social, economic, and public policy research. This might suggest that respondents associated with groups that seek remedies for illness or medical problems do not regard PMF technology as a preferable method to improve people's health conditions. These respondents do prefer more research to be conducted to identify social and ethical concerns of PMF technology and to provide guidance on potential regulations and policies.

5.3.3 The Influence of Demographic and Socio-Economic Characteristics on Preferences for Alternatives

In the two model specifications, demographic and socio-economic variables are interacted with both the alternative specific constant for the current plan (Plan A) and the alternative specific constant for the opt-out plan (Plan D). These interaction terms express the effects of demographic and socio-economic characteristics on the probability of choosing the corresponding alternative, relative to the other available alternatives. The insignificant interaction term between respondents' age and the ASC for Plan A and the significantly positive interaction term between respondents' age and the ASC for Plan D imply that, all else held constant and assuming Plan B and Plan C equal, the older the respondents are, the more they prefer Plan D relative to Plan A, Plan B, and Plan C. However, from the discussion above, based on the significantly positive coefficients for the attributes interacted with age, the older are respondents, the more funding they prefer to allocate in each research area. These seemingly contradictory findings might be explained by segmentation of respondents. Among older respondents there may be two groups: one group strongly agreeing with PMF technology; the other group disagreeing with PMF technology.

From Model II, the estimated coefficient for gender interacted with the ASC for Plan A is significantly negative and the coefficient for gender interacted with ASC for Plan D is significantly positive. This implies that the most favored research plan for male respondents is Plan D, which is not to invest in PMF research. The least preferred choice for males is Plan A, the current plan. Significant and negative estimated coefficients for education levels interacted with both ASCs (although in Model II "university" interacted with the ASC for Plan A is not significant) indicate that, holding everything else constant and assuming Plan B and Plan C are equal, respondents with higher education levels prefer either Plan B or Plan C to Plan A and Plan D. They neither like the current plan nor choose to ban PMF research. Instead they prefer to choose a new research funding allocation plan.

Respondents living in British Columbia tend to prefer the current level and allocations of research funding compared to the two alternative plans, Plan B and Plan C, assuming these are equal and everything else is held constant, since the estimated coefficients for the interaction term in the quadratic model, Model I, are significantly positive. Holding everything else constant and assuming Plan B and Plan C are equal, respondents working in hospitals and health services and respondents working in environmental agencies prefer Plan D to Plan B and Plan C and are indifferent between Plan A and the two alternative plans (Plan B and Plan C). There might also exist group segments among respondents working in hospitals and health services and respondents working in environmental agencies. For respondents who are associated with a group that seeks remedies for illness or medical problems, the current plan is their least preferred choice as indicated by the significant but negative coefficient for the interaction term of health group association and ASC for Plan A in the model with semi-logarithm utility function.

5.4 Policy Implications

The estimation results from two conditional logit models present a picture of the general public's perceptions of PMF technology and respondents' preferences for PMF research investments. In general, the public appears to regard plant molecular farming technology favorably and there is a willingness for investments of public research funding to improve the technology and to develop related regulations. From policy analysis perspective, it is also interesting to examine research funding allocation priorities from the point of view of the Canadian public. Based on discrete choice theory, public respondents' satisfaction of research funding allocations are measured by the utilities that respondents obtained from that funding allocation plan. If the utility a respondent obtained from a specific funding allocation plan is maximized, this funding allocation plan is the most preferred plan and the allocations of funding will demonstrate this respondent's research priorities. Therefore, the following part of this study will attempt to find respondent research funding allocation priorities by maximizing the utilities.

Mathematical programming is a poplar method to analyze optimization problems. Following McCarl and Spreen (1997), the general mathematical programming problem is:

Optimize: F(X) (5.3)

Subject to: $G(X) \in S_1$ (5.4)

$X \in S_2$ (5.5)

F(X) is the objective function, which is expressed as a function of X. X is a vector of variables. The level of X will be chosen to optimize (maximize or minimize) the objective function. However, when a decision maker chooses the level of X, a set of constraints, S_1 and S_2 , must be obeyed. G(X) represents the algebraic relationships of X and G(X) must be a member of S_1. The variables, Xs, must be a member of the range S_2.

In this section of the study it is assumed that a policy maker wishes to optimize the utility of members of the public by allocating PMF research funding to the five applications, constrained by the maximum amount of research funding available. Then the optimization problem is:

Maximize: Utility

Subject to: the budget for PMF research funding

It is not realistic to examine preferences for funding allocations of each respondent, since each will have a different utility function. Therefore, the representative respondent is chosen to stand for all respondents. The representative respondent is a 41 years old female, living outside of the Province of British Columbia, without a university bachelor degree or higher education. Her annual household income is $45,000 dollars. She does not work in hospital and health services and does not work in an environmental agency. She is not associated with a group that seeks remedies for illness or medical problems.

Based on the estimated coefficients from conditional logit Model I[13], the representative respondent's utility is:

[13] Since estimated coefficients of two attributes in the semi-logarithmic model are not significant, only the results of the quadratic model, Model I, will be employed for optimization.

$$U=1.283+0.992X_H+0.385X_I+1.351X_E+0.504X_C+0.572X_S-0.067X_H^2-0.098X_I^2-0.204X_E^2-0.078X_C^2-0.083X_S^2 \quad (5.6)$$

where X_H, X_I, X_E, X_C, and X_S denote the amounts of funding allocated to health, industry, environment, consumer research, and social, economic, and public policy research issues, respectively.

Assuming that the total level of research funding that the federal government will invest on PMF research remains at the current level of some 10 million Canadian dollars, the constraints are: (1) The funding allocated to each research application area will be greater than or equal to zero but less than or equal to $10 million; (2) the sum of the funding allocated to the five applications in total should be greater than or equal to zero but less than or equal to $10 million.

Then the optimization problem for PMF research funding allocation is:

Maximize: $$U=1.283+0.992X_H+0.385X_I+1.351X_E+0.504X_C+0.572X_S-0.067X_H^2-0.098X_I^2-0.204X_E^2-0.078X_C^2-0.083X_S^2 \quad (5.7)$$

Subject to: $$0 \le X_H+X_I+X_E+X_C+X_S \le 10 \quad (5.8)$$

$$0 \le X_H \le 10 \quad (5.9)$$

$$0 \le X_I \le 10 \quad (5.10)$$

$$0 \le X_E \le 10 \quad (5.11)$$

$$0 \le X_C \le 10 \quad (5.12)$$

$$0 \le X_S \le 10 \quad (5.13)$$

This is a quadratic programming problem because the objective function is a non-linear quadratic function and the constraints are linear functions. Excel Solver software was applied to this quadratic programming problem to choose the value of the variables so that the quadratic objective function is optimized and simultaneously the linear constraints for the variables are satisfied. Table 5-6 shows the values of the different allocation variables at optimization.

Table 5-6 Results of Best Allocation for 10 Million PMF Research Funding (in millions of dollars)

Variables	Value
X_H	4.860
X_I	0.225
X_E	2.476
X_C	1.046
X_S	1.393

From Table 5-6, the best allocation of the given sum of $10 million funding for PMF research, from which the representative respondent receives the maximum amount of utility, is $4.86 million allocated to health applications research and $0.225 million allocated to industrial applications research. For research related to environmental applications, $2.476 million will be invested; $1.046 million will be allocated to research for consumer applications; and $1.393 million will be allocated to research on social, economic, and public policy issues.

As expected, PMF health research is most favored by respondents. This absolutely dominates the preferred allocation plan and accounts for almost 50% of total research funding. Following health research, the second preferred PMF research area is environmental applications, with close to one fourth of total research funding preferred. It may not be surprising that these two applications are preferred to others. The improvement of health conditions and protection of the environment appear to be two major issues engaging public interest. The third place for social, economic, and public policy research suggests that respondents regard the potential for PMF research related to regulatory, social, and policy issues as being important factors to evaluate PMF technology overall. The lower allocation for public research funding to industrial applications suggests that this is least preferred.

Table 5-7 Comparison between best funding allocation plan and current funding allocation plan (in millions of dollars)

Variables	Best Allocation Plan	Current Allocation Plan
X_H	4.860	3.0
X_I	0.225	2.0
X_E	2.476	1.0
X_C	1.046	2.0
X_S	1.393	2.0

Differences are observed between the current funding allocation plan and the best funding allocation plan, especially for the research funding allocated to industrial research. Comparing with the current allocation plan, more research funding is required by the representative respondent to allocate to health area of research and environmental area of research. The representative respondents prefer to invest less funding in consumer application research and research on social, economic, and public policy issue. There is a big difference between funding allocated to industrial areas of research and the desired level. This difference could be explained by the situation that the representative respondent is a female. Based on the results from Table 5-3 and 5-4, male respondents have significant positive preference for allocating research funding to industrial areas of research. It is noteworthy that each respondent has different demographic and socio-economic characteristics and therefore each of them will have their own best allocation plan. Theoretically, it is possible to calculate each respondent's best allocation plan and take an average to obtain the optimal funding allocation plan across all respondents.

5.5 Summary

This chapter provided a description of the model developed to analyze respondents' choices of PMF research funding allocations. The models are presented and discussed. The outline of model development started with an introduction to the independent variables, including choice-specific attributes and individual-specific attributes, and included the definitions and codes of the variables. The subsequent section discussed econometric identification issues, the selection of demographic and socio-economic attributes, and inclusion of alternative specific constants. The second section of the chapter provided results for two conditional logit models based on non-linear indirect utility functions. There are three major findings from the examination of respondents' preferences for PMF research funding allocations. Generally, respondents would like public funding to be allocated to PMF research. The most preferred area to allocate PMF research funding is health applications. Respondents with different demographic and socio-economic characteristic have different opinions and preferences for PMF research funding allocations. The last section of the chapter applied a methodology to optimize PMF research and presented the optimal solution for allocating 10 million dollars PMF total research funding. The next chapter provides an overview of this study, discusses its limitations, and gives suggestions for further study.

Chapter 6 Conclusion and Discussion

6.1 Introduction

This chapter gives a review and summary of the major findings of the study. Some limitations of the study are outlined and areas of further research are suggested. Some policy suggestions are provided based on the results of the study.

6.2 Overview of Findings

The purpose of this study was to assess attitudes and perceptions of members of the public to plant molecular farming technology and their preferences for allocations of government funding on PMF-related research. A nation-wide survey was undertaken in the fall of 2005. The survey contained a choice experiment designed to assess respondents' opinions about the allocations of funding to different types of research on PMF technology. Analysis of this data is the major focus of the study. Two conditional logit models, one with a quadratic utility functional form and the other with a semi-logarithmic utility functional form, were applied to estimate preferences based on the PMF choice data. Both models displayed similar results. The influence of respondents' demographics and socio-economic factors on their preferences for funding allocations is also examined using conditional logit models. The results of the conditional logit model were applied using mathematical programming to assess an optimal funding allocation based on the preferences of a representative respondent. No previous study has applied a quantitative approach to examine preferences for research funding allocations for this novel technology, to our knowledge. The findings of the study are summarized below.

We find that, in general, members of the public appear to view plant molecular farming technology favorably and there is a willingness for allocating public research funding on PMF-related research to improve the technology and to develop related regulations. Both the results of the choice experiments and the descriptive statistics of the rating scale questions related to risks/benefits assessment demonstrate the positive perceptions. Einsiedel and Medlock (2005) reported perceptions to be "mixed but leaned towards positive" first impression of PMF in their focus groups study. They also concluded that most of PMF stakeholders they interviewed gave PMF a favorable risk/benefit assessment and that stakeholders view PMF as acceptable as long as regulations are able to ensure the safety of humans and the environment. Another study by Veeman, Li, and Adamowicz (2006) also suggested a relatively optimistic view by Canadians of PMF products and applications. Veeman (2006) outlined that currently public perceptions of PMF technology tend to be positive.

The study presented respondents with a situation in which the Canadian government will allocate research funding to PMF related research. The PMF funding allocations are directed to five different focal areas of PMF research, including health applications, industrial applications, environmental applications, consumer applications, and social, economic, and public policy issues. Most of the respondents direct their support of investing funding into the five different PMF research areas. Model I further shows that, for each of the five PMF research areas, there is a maximum amount of public research funding that respondents would like to invest. Respondents do not agree to invest more research funding beyond the maximum amount they accept. Comparing respondents' preferences for the allocations of funding on the five different PMF research areas, respondents show preferences to allocating research funding in health applications and environmental areas of research, indicating a strong preference for the health area of research. Following health and environmental applications, the respondents' next choice is to allocate funding to consumer product applications and to research on social, economic, and public policy areas. Industrial applications of research are the least preferred choice by respondents. The descriptive statistics from rating scale questions also indicate respondents' preference for funding allocation in health area of research. Using PMF to produce better and cheaper medical drugs is ranked with the highest rank of benefits and relatively low rank of risks.

The finding of a preference for allocating research funding on PMF health areas of research in this study is supported by other studies. Gaskell et al. (2001) and Nielsen Jelsoe, and Ohman (2002) argued that publics have generally been more supportive of biotechnologies with medical applications than biotechnologies with agricultural applications. Nevitt et al. (2003) found that most stakeholders gave supportive opinions on the technology to use transgenic tobacco to produce pharmaceuticals. Kirk and McIntosh (2005) also noted a positive public potential support for plant-made vaccine technology using genetically modified plants. Einsiedel and Medlock (2005) concluded that health and medical applications of PMF technology were consistently preferred over industrial applications of PMF technology. For industrial applications, they found respondents to prefer producing environmentally friendly products than to produce products at a lower cost. Stewart and McLean (2005) reported that the applications of PMF to produce pharmaceutical products were viewed by respondents to be potentially more beneficial than others. Veeman (2006) also concluded that positive attitudes are evident for potential PMF applications to medical products. One of the reasons which could explain the strong preference of health applications of PMF technology and preference for allocating more funding on health research might be that people view GM/GE applications involving medical products as being more useful and therefore relatively lower risk than applications that are directed at only increasing crop production (Veeman, Li, and Adamowicz 2006)

The study also finds that respondents' demographic and socio-economic characteristics tend to influence their preferences for funding allocated to each PMF research area. For respondents in different age groups, the older are the respondents, the more they prefer to invest research funding in all the five PMF research areas. Older respondents especially prefer to allocate research funding in PMF consumer area of research to develop nutritionally improved food or to provide food at lower prices. Among the five research areas, allocating funding in industrial applications in order to develop new and cheaper industrial products is the least preferred choice for older respondents.

Compared to female respondents, male respondents prefer to allocate more funding in PMF industrial research, but not in health and environmental research. Between the health area of research and environmental area of research, male respondents would prefer to allocate funding in environment applications. However, Kirk and McIntosh (2005) concluded males to be slightly more accepting of genetically modified vaccines than females. The difference might come from that Kirk and McIntosh (2005) only focus on assessing one PMF health application, using genetically modified plants to make vaccines. PMF technology can have broad medical and health applications.

Respondents with a university bachelor degree or a higher level of education tend to support PMF technology slightly less than do respondents with lower levels of education. Both groups have the same opinions on allocating funding to health areas of research. However, respondents with a university bachelor degree or a higher level of education tend to prefer to allocate less research funding in industrial, environmental, consumer areas and social, economic, and public policy issues. Respondents with a bachelor degree or higher level of education most dislike allocating public research funds to develop nutritionally improved or cheaper food by genetically modified methods. This is consistent with the finding by Hu et al. (2004) that "having more education increases the probability of belonging to the Anti-GM consumer segment" (Hu et al. 2004, p. 402).

Respondents with higher income levels are less likely to prefer to allocate research funding on social, economic, and public policy research. Respondents' occupations also affect their opinions and preferences for the allocations of PMF research funding. Compared with respondents working in all other occupations, respondents working in hospitals and/or health services are more supportive to allocating research funding in health, industrial, environmental, and consumer areas of research. Respondents working in environmental agencies tend to be more supportive to allocating research funding in health, industrial, and environmental research. The places where respondents live can also affect their choices. Respondents living in BC prefer more funding to be allocated to environmental and social, economic and public policy research. It is found that respondents who are associated with a group that seeks remedies for illness or medical problems do not have strong preferences for more funding allocated to PMF health research. They prefer to allocate more funding in industrial and social, economic, and public policy research.

The demographic and socio-economic characteristics that do not influence or do not have a strong influence on respondents' choice behavior include respondent's household size, the number of children living in the respondent's household, respondent's employment status, whether or not respondents live in the prairie area, whether or not respondents live in the Province of Quebec, whether or not respondents live in the Province of Ontario, whether or not respondents live in the rest of Canada, whether or not respondents live in rural areas, whether or not respondents work in the food industry, whether or not respondents work in a research institution, whether the respondent has an association with a consumer group that focuses on food safety issues, and whether the respondent has an association with an environmental group.

Respondents faced three situations: maintaining the current PMF funding allocation plan, choosing two alternative funding allocation plans, and providing no funding for PMF technology. Most respondents preferred to maintain the current research funding levels and allocations given choices of these three situations. Providing no funding for PMF technology is the least preferred choice for most of the respondents. Some respondents also prefer to vary the total research funding levels and/or change the funding allocations across the five research areas based on their preferences. Similarly, respondents' demographic and socio-economic characteristics also influence their choice behavior of different funding plans. It is found that a group of older respondents prefer providing no funding for PMF technology, comparing to another group of older respondents who demonstrate strong interest in PMF technology. Relatively more male respondents tend to prefer providing no funding for PMF technology. Those that would like to invest research funding tend to prefer to choose new funding levels and allocations rather than maintain the current level and allocation. Respondents with a bachelor degree or high level of education tend to prefer to choose new funding levels and allocations based on their preferences. They tend to neither like to maintain the current funding plan nor to prohibit investment for PMF technology. Respondents who live in the Province of British Columbia tend to prefer the current funding level and allocations. It is also found that respondents who work in hospitals or health services or work in environmental agencies prefer not to provide research funding for PMF technology. There might exist group segments among these respondents. Some of them have positive attitudes to PMF; others possess negative attitudes. For respondents who are associated with a group that seeks remedies for illness or medical problems, maintaining current research funding levels and allocations is their least preferred choice.

Based on the results from conditional logit Model I and assuming the Canadian government invests a total of $10 million Canadian dollars on PMF related research, the funding allocations that are most preferred by representative respondents are: $4.86 million allocated to health applications research, $0.225 million allocated to industrial applications research, $2.476 million allocated to environmental applications, $1.046 allocated to research for consumer applications, and $1.393 million allocated to research on social, economic, and public policy issues. It is found that funding health areas of research related to PMF is the most preferred choice by most of the respondents.

6.3 Study Limitations and Further Research

Using a stated preference approach to assess allocations for research funding offers several advantages, for example, choice experiments approach can detect the trade-offs of attributes, which could not be accomplished by using rating scales technique. However, there are a number of limitations of the choice experiment method. From the researcher's perspective, the choice set is difficult to define since researchers normally do not have complete information on respondents' choice behavior. From the perspective of the respondents, choice experiments are complex to answer. In this study, about 45% of respondents chose the current funding allocation plan, which could be because of the complexity of questions. Respondents' responses for the rating scale questions (refer to section IV of questionnaire) indicate their lack of knowledge and uncertainty about PMF technology, since about 50% of respondents expressed unfamiliarity with PMF and about

10% of respondents chose "don't know" as the answers for risks-benefits assessment questions of PMF.

The disadvantage of the choice experiment method related to model estimation is that whenever respondents are asked to respond to a hypothetical situation, hypothetical biases and strategic biases are an issue (Bishop and Heberlein 1979). Hypothetical biases arise when respondents face a hypothetical situation with lack of realism and/or when respondents find the survey instrument is complex or lengthy. Respondents may not understand the questions they are being asked and/or they may not be committed to completing the survey. Respondents may not give an accurate response. Therefore, respondent's actual choice behavior may not be captured by responses to the survey questions. Strategic biases occur when respondents give their responses based on what policy they would like to implement, rather than based on their actual choice preferences. Strategic biases could be an issue in this study if people think that their choice may influence government policy for PMF research funding and funding allocations.

Another concern or limitation comes from the method used to collect the data. The study is conducted by an on-line survey. Although this was drawn from a representative panel the method may limit some aspects of the survey sample. It is likely that people with lower levels of education, with lower income, or living in a place where the Internet is not easy to access may have less access to the Internet and are not able to participate in the survey. Therefore, the study would not evaluate the opinions of PMF technology and preferences for research funding allocation of these groups of people.

Combining revealed preference data and stated preference data is viewed as an improvement for a survey approach because revealed preference data provides actual information about respondents' choice behavior. However, in this study no revealed preference data is available and because of the topic of the study, it will be difficult to obtain revealed data in the future.

Further research could focus on some modifications or extension of this study. This study applies quantitative analysis approaches and was preceded by focus group assessments of the survey. Nonetheless, the choice experiment approach did not include a qualitative analysis therefore reasons underlying respondents' choice behavior can not be identified. Further research could combine quantitative and qualitative approaches by asking some debriefing questions to elicit the reasons behind people's choice behavior.

Further research could also attempt to improve modeling. One option is to combine attributes of choice experiments with responses to rating scaling questions to observe the impact of respondents' attitude to PMF on their choice behavior. For example, if the interaction between respondents' familiarity with PMF and research funding allocated to health area of research is significantly positive, that means respondents with more knowledge of PMF technology prefer to allocate more research funding for health application research. Similarly, respondents' assessment of PMF related risks and benefits are important factors to explain their preferences.

Refering to the estimation results of the two conditional logit models (Table 5-3 and 5-4), the interactions of respondents' age and funding allocated to all the five different research areas are significantly positive. This implies that older respondents would like to allocate more research funding in all five research areas. However, the interaction of respondents' age and the ASC for plan D is significantly positive. This implies that older respondents prefer plan D, which is provide no funding for PMF research. The conflict between these two sets of variables discloses that there may be unobserved heterogeneity. There are some factors that have an impact on respondents' choice, which researchers are not able to observe and define. Take the age issues as an example, there might be different groups of older respondents with different preferences and perceptions of PMF research funding allocation. Further research could adopt random parameter logit models to explore whether there is variation among respondents' tastes with respect to attributes and latent class models to distinguish different groups of respondents who have different tastes.

6.4 Conclusion

This study provides a picture of opinions on PMF technology held by Canadian members of the public and their preferences for research funding levels and funding allocations related to this technology. It shows that most respondents would like to invest public research funding on PMF technology. It is noteworthy to mention that the positive attitudes by members of the public do not indicate that risks associated with PMF technology are not important to the general public. Kirk and McIntosh (2005) noted research studies (Siegrist 2000; Zechendorf 1994) showing that even though people perceive relatively high risks and unknown consequences with a technology, they still might not reject the technology, especially genetic technologies. The study also shows that most respondents most prefer to allocate funding to health areas of research. However, scientists and business people may have relatively more interest in the development of PMF industrial products than pharmaceutical products in Canada based on the numbers of confined PMF field trials conducted in Canada. The Canadian Food Inspection Agency (CFIA) reported that in 2005, seven out of eight confined research trials of plants with novel traits are for industrial products (CFIA 2005d).

Assessing members of the public's preferences among the research areas studied may help government, firms and institutions to better understand priorities and concerns of the general public. The challenge facing government is to design policies that will maximize the potential benefits of PMF technology to society while taking into account the concerns of the public. It is suggested from descriptive questions in the survey on which this study is based that the decisions about PMF techniques should be made based on scientific expertise but also include public involvement (Veeman, Li, and Adamowicz 2006). It is hoped that this research study will assist the government to develop policies and regulations related to PMF technology.

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Appendix A: Example of Survey Questionnaire

University of Alberta Survey on Public Opinions on Modern Agriculture and Food Research Questionnaire

Section I: Introduction

Introduction

Welcome and thank you for agreeing to take part in this research!

This is a part of a study conducted at the University of Alberta, Edmonton, Alberta. The study is funded by grants from the government funded research agencies Genome Canada, Genome Prairie and the Alberta Agricultural Research Institute. In this survey, we are interested in knowing the directions you would like to see for publicly funded research related to agriculture and food. You will have opportunities to provide your opinions on research areas such as food production, nutrition, the environment, policy, and consumers.

We ask that you complete all parts of the survey. If you have any questions, please feel free to contact us. Our contact information is given both on your consent sheet and at the end of this survey.

Thank you again for participating!

W1 . First, we would like to know your opinions about public service funding. In the following table we list some public services. Compared with their current funding levels, you may wish to either increase or decrease funding to a particular area. Please circle one funding option within each area that best describes your preferences.

Service Area	**Desired Change in Service Area Spending**					
	Reduced Substantially	Reduced Somewhat	Maintain Current Level	Increased Somewhat	Increased Substantially	Unsure
Education services in all levels of public schools	⬇	↓	—	↑	⬆	?
Police and security services	⬇	↓	—	↑	⬆	?
Health care services	⬇	↓	—	↑	⬆	?
Maintaining natural and wildlife reserves	⬇	↓	—	↑	⬆	?
Providing safer food	⬇	↓	—	↑	⬆	?
Highways and roads	⬇	↓	—	↑	⬆	?

Glossary:

Here we provide you with some terms in modern agriculture and food research that we will use in the survey. Please read this information before you continue the survey.

By "food" and "feed", we mean "plant crops used for human food, e.g., wheat or barley (food) and plant crops used for animal feed, e.g., hay, feed barley or feed wheat (feed)." By "non-food" crops we mean plants or parts of plants that are not used for human food (e.g., tobacco plants or tomato leaves are non-food crops).

By "Agricultural Biotechnology" and the application of "Genomic Technologies" we mean
"The scientific manipulation of living organisms, especially at the molecular genetic level, to produce useful products. Gene splicing and use of DNA are major techniques used."
By "genetic modification (GM)" or "genetic engineering (GE)", we mean
"The process that modifies the genetic makeup of an organism, usually by insertion of one or more genes. The genes may come from the same or another organism, even from an unrelated organism." These techniques may be used in plant molecular farming (PMF).

By "Plant Molecular Farming" (PMF) we mean
"The use of plants as a "factory" in agriculture to produce new materials in addition to food, feed and fibre; i.e., plants with new traits grown as crops are harvested for scientifically, medically or industrially useful products." Examples of possible applications of PMF include:

- Interleukin (an enzyme used in treating Crohn's disease) in tobacco: fast growth of tobacco may allow interleukin to be produced in high volumes.
- Edible vaccines in potatoes: these vaccines may substitute for some that require refrigeration and/or sterilization of needles.
- Bioplastics (biodegradable plastic products) in corn: bioplastics may substitute for synthetic plastics currently in use. Industrial enzymes produced in corn are another example.

Although there may be potential benefits from these types of PMF to make medicines, industrial products and new foods, there are also potential risks. Examples of possible risks are:

- Possible contamination of food supply from accidental mixing of PMF plants with food crops.
- Potential mixing of pollen or seeds from PMF plants with possible adverse effects on the environment; e.g., as weeds or by altering the natural ecology.
- Potential adverse effects on wildlife if animals, birds or insects eat PMF plants.

Section II: General Attitudinal Questions

Q1. For each of the issues listed below, please indicate the risk that you believe applies to each issue.

Statements	Your Opinion				
Bacteria contamination of food	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Pesticide residuals in food	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Use of hormones in food production	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Use of antibiotics in food production	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Genetically modified/engineered crops to increase crop production	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Drugs (i.e. medicines) made from plant molecular farming though genetic modification/engineering	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Genetically modified/engineered crops to increase nutritional qualities of food	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Genetically modified/engineered crops to produce industrial products like plastics, fuel or industrial enzymes	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
BSE (mad cow disease)	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Use of food additives	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Fat and cholesterol content	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure

Q2. We would also like to have your opinion on possible environmental safety issues that might result from modern agriculture. Please indicate the risk that you believe applies to each issue.

Statements	Your Opinion
Water pollution by chemical run-off from agriculture	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Use of genetically modified/engineered crops to increase crop production	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Use of genetically modified/engineered crops used for drug (i.e., medicine) production	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Use of genetically modified/engineered crops to increase nutritional qualities of food	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Use of genetically modified/engineered crops used for industrial products like plastics, fuel or industrial enzymes	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Agricultural waste disposal (e.g., animal manure disposal)	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Soil erosion from agricultural activity	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Use of herbicides and pesticides	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Adverse effects of agriculture on biodiversity	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure

Section III: Genomic Research Direction Public Choices

We would like to have your opinions on public-funded research projects in plant molecular farming (PMF). The following table describes these areas of research. The first column gives the general categories of projects and the second column provides brief descriptions of the objective of this research area.

Research Categories	**Description**
Health	To develop new and cheaper PMF-based medicinal drugs and vaccines directed to human problems of health and disease
Industry	To develop new and cheaper industrial products like bioplastics and enzymes.
Environment	To assess and limit impacts of PMF on wildlife and ecology as well as on soil, water and other components of the natural environment.
Consumer	To develop nutritionally improved food or food at lower prices.
Social, economic & public policy	To identify and address public, social and ethical concerns and economic implications and to provide guidance on potential regulations (such as patents and labelling).

C1. You are presented below with a series of 8 situations. Each situation contains alternative plans featuring different ways of allocating public research funds to the areas identified above (Health, Industry, Environment, Consumer, and Social & public policy). Each plan includes a description of the percentages of the total available funds that you can vote to be allocated to each research area. You are asked to indicate which plan you believe is the best.

For your information: Currently, the Canadian government funds about one billion dollars a year on agricultural and food research. Since research on PMF is in an early stage, the Canadian government invests roughly 1%, which is about ten million dollars, of its total agricultural and food funding on PMF-related research.

Please take time to carefully read the following instructions before proceeding:

- Suppose the research plans presented in each situation are the ONLY ones available.
- Each plan includes the total amount of research funds relative to the current level in Canada and how these funds are allocated across different research focus areas. Both the total and the focus allocation percentages may vary across plans.
- Each situation is different so please do not compare plans across different situations.

Your decisions are crucial for us to make suggestions to the Canadian government and relevant organizations for their future funding decisions on PMF research. Please make the choice of research plan that most closely reflects your true preference.

Plan A		Plan B		Plan C		Plan D
Maintain the current levels of research funding allocated as:		**Decrease** current research funding by 20% with the remaining funding allocated as:		**Decrease** current research funding by 20% with the remaining funding allocated as:		Provide no funding for PMF research
Health	30%	Health	10%	Health	30%	
Industry	20%	Industry	20%	Industry	30%	
Environment	10%	Environment	30%	Environment	10%	
Consumer	20%	Consumer	20%	Consumer	10%	
Social, economic and public policy	20%	Social, economic and public policy	20%	Social, economic and public policy	20%	
I prefer (choose only one)						
O		O		O		O

Plan A		Plan B		Plan C		Plan D
Maintain the current levels of research funding allocated as:		**Decrease** current research funding by 10% with the remaining funding allocated as:		**Increase** current research funding by 20% with the new total funding allocated as:		
Health	30%	Health	10%	Health	30%	
Industry	20%	Industry	30%	Industry	30%	Provide no funding for PMF research
Environment	10%	Environment	10%	Environment	10%	
Consumer	20%	Consumer	20%	Consumer	10%	
Social, economic and public policy	20%	Social, economic and public policy	30%	Social, economic and public policy	20%	
I prefer (choose only one)						
O		O		O		O

Plan A		Plan B		Plan C		Plan D
Maintain the current levels of research funding allocated as:		**Increase** current research funding by 20% with the new total funding allocated as:		**Decrease** current research funding by 10% with the remaining funding allocated as:		
Health	30%	Health	20%	Health	20%	
Industry	20%	Industry	30%	Industry	30%	Provide no funding for PMF research
Environment	10%	Environment	20%	Environment	30%	
Consumer	20%	Consumer	10%	Consumer	10%	
Social, economic and public policy	20%	Social, economic and public policy	20%	Social, economic and public policy	10%	
I prefer (choose only one)						
O		O		O		O

Plan A		Plan B		Plan C		Plan D
Maintain the current levels of research funding allocated as:		**Decrease** current research funding by 20% with the remaining funding allocated as:		**Maintain** the current levels of research funding allocated as:		
Health	30%	Health	30%	Health	20%	
Industry	20%	Industry	20%	Industry	20%	Provide no funding for PMF research
Environment	10%	Environment	20%	Environment	20%	
Consumer	20%	Consumer	10%	Consumer	20%	
Social, economic and public policy	20%	Social, economic and public policy	20%	Social, economic and public policy	20%	
I prefer (choose only one)						
O		O		O		O

Plan A		Plan B		Plan C		Plan D
Maintain the current levels of research funding allocated as:		**Decrease** current research funding by 20% with the remaining funding allocated as:		**Decrease** current research funding by 20% with the remaining funding allocated as:		
Health	30%	Health	20%	Health	10%	
Industry	20%	Industry	20%	Industry	20%	Provide no funding for PMF research
Environment	10%	Environment	20%	Environment	20%	
Consumer	20%	Consumer	20%	Consumer	30%	
Social, economic and public policy	20%	Social, economic and public policy	20%	Social, economic and public policy	20%	
I prefer (choose only one)						
O		O		O		O

Plan A		Plan B		Plan C		Plan D
Maintain the current levels of research funding allocated as:		**Increase** current research funding by 20% with the new total funding allocated as:		**Maintain** the current levels of research funding allocated as:		
Health	30%	Health	30%	Health	20%	
Industry	20%	Industry	30%	Industry	20%	Provide no funding for PMF research
Environment	10%	Environment	10%	Environment	30%	
Consumer	20%	Consumer	10%	Consumer	10%	
Social, economic and public policy	20%	Social, economic and public policy	20%	Social, economic and public policy	20%	

I prefer (choose only one)

O	O	O	O

Plan A		Plan B		Plan C		Plan D
Maintain the current levels of research funding allocated as:		**Decrease** current research funding by 10% with the remaining funding allocated as:		**Decrease** current research funding by 10% with the remaining funding allocated as:		
Health	30%	Health	30%	Health	30%	
Industry	20%	Industry	30%	Industry	10%	Provide no funding for PMF research
Environment	10%	Environment	10%	Environment	20%	
Consumer	20%	Consumer	20%	Consumer	20%	
Social, economic and public policy	20%	Social, economic and public policy	10%	Social, economic and public policy	20%	
I prefer (choose only one)						
O		O		O		O

Plan A		Plan B		Plan C		Plan D
Maintain the current levels of research funding allocated as:		**Decrease** current research funding by 20% with the remaining funding allocated as:		**Increase** current research funding by 20% with the new total funding allocated as:		
Health	30%	Health	20%	Health	30%	
Industry	20%	Industry	30%	Industry	10%	Provide no funding for PMF research
Environment	10%	Environment	20%	Environment	30%	
Consumer	20%	Consumer	20%	Consumer	10%	
Social, economic and public policy	20%	Social, economic and public policy	10%	Social, economic and public policy	20%	
I prefer (choose only one)						
O		O		O		O

C2. After seeing all the previous plans, you may feel that you have not seen a good research funding plan. Here is an opportunity for you to describe the plan you think is best, compared to current funding percentages. Remember that currently the total funding on PMF research is 1% of the Canadian Government's funding on agricultural and food research. If you like the current funding plan, you do not have to fill in the rest of the table. If you are not satisfied with the current plan, please "construct" your most favoured plan for PMF research funding in the second column of the table. You may choose to change the allocations to different PMF areas, choosing any percentages you want, including 0% for one or some research areas, as long as all the percentages add up to 100%. Alternatively you may vote for the government to allocate no funds at all to any PMF research by selecting the last column of the table below.

O I prefer the current plan		O I would like to see the following plan		O I would prefer the government allocate no funds at all to PMF research
1% of the government's annual research funding in PMF related research and allocated as:		I would like to see _____% on PMF related research from the government's annual funding and this should be allocated as:		
Health	30%	Health	______%	
Industry	20%	Industry	______%	
Environment	10%	Environment	______%	
Consumer	20%	Consumer	______%	
Social, economic and public policy	20%	Social, economic and public policy	______%	

Section IV: Plant Molecular Farming Questions

We now ask you several questions about the technology of "plant molecular farming". Your answers will help us to better understand how familiar the public is with this topic.

Q3. What is your level of familiarity with plant molecular farming?

O Very familiar
O Moderately familiar
O Slightly familiar
O Unfamiliar
O Never heard of this before this survey
O Don't know/Unsure

Q4. Where would you seek information on plant molecular farming? (check all that apply)

O Friends and family
O Newspapers and magazines
O Radio and TV
O The internet
O Other
O I would not seek any information
O Don't know/Unsure

Q5. What would be your most trusted sources of information on PMF? (check all that apply)

O Friends and family
O Newspapers and magazines
O Radio and TV
O The internet
O Doctors and nurses
O University research scientists
O Federal or provincial government

Q6. We would like to have your opinion about potential risks that might result from plant molecular farming. Please check the risk rating that you believe may come with each type of PMF.

PMF to produce better and cheaper **medical drugs**	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
PMF to produce better and cheaper **industrial products**	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
PMF to produce more nutritious and cheaper **foods**	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure

Do you believe that any of the following issues are major risks posed by PMF? Please check the level of risk that you believe applies.

Q6.1 Contamination of food supplies.

O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure

Q6.2 Damage to the environment.

O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure

Q7. We would like to have your opinion about potential benefits that might result from plant molecular farming. Please check the benefit rating that you believe each type of PMF may bring.

PMF to produce better and cheaper **medical drugs**	O High benefit potential O Moderate benefit potential O Slight benefit potential O Almost no benefit potential O Don't know/Unsure
PMF to produce better and cheaper **industrial products**	O High benefit potential O Moderate benefit potential O Slight benefit potential O Almost no benefit potential O Don't know/Unsure
PMF to produce more nutritious **and cheaper foods**	O High benefit potential O Moderate benefit potential O Slight benefit potential O Almost no benefit potential O Don't know/Unsure

Do you believe in any of the following benefits from PMF? Please check the rating you believe in.

Q7.1 Opportunity for Canada to lead and create job opportunities in a new industry.

O High benefit potential O Moderate benefit potential O Slight benefit potential
O Almost no benefit potential O Don't know/Unsure

Q7.2 Production of new drugs that may not be produced by conventional methods or increase in quantities of existing medical drugs at less cost.

O High benefit potential O Moderate benefit potential O Slight benefit potential
O Almost no benefit potential O Don't know/Unsure

Q8. What do you believe the general relationships are between the risks and benefits associated with plant molecular farming?

- O Risks probably **significantly** outweigh benefits
- O Risks probably **moderately** outweigh benefits
- O Risks probably **slightly** outweigh benefits
- O Risk probably roughly equivalent to benefits
- O Benefits probably **slightly** outweigh risks
- O Benefits probably **moderately** outweigh risks
- O Benefits probably **significantly** outweigh risks
- O Don't know/Unsure

Q9. The following statements are opinions on **the regulation** of plant molecular farming. Please choose your level of agreement or disagreement with each statement by checking the level that you believe.

Statements	**Your Opinion**
Regulators should work with industry in order to manage PMF technology	O Strongly agree O Somewhat agree O Somewhat disagree O Strongly disagree O Don't know/Unsure
Decisions about introduction of plant molecular farming should involve members of the public	O Strongly agree O Somewhat agree O Somewhat disagree O Strongly disagree O Don't know/Unsure
Decisions about introduction of plant molecular farming techniques should be made by scientific experts	O Strongly agree O Somewhat agree O Somewhat disagree O Strongly disagree O Don't know/Unsure
Industry alone should bear the liabilities and costs if there is a problem	O Strongly agree O Somewhat agree O Somewhat disagree O Strongly disagree O Don't know/Unsure
Industry and government should share the liabilities and costs if there is a problem	O Strongly agree O Somewhat agree O Somewhat disagree O Strongly disagree O Don't know/Unsure
The government should strictly regulate plant molecular farming research and monitor environmental and social issues associated with these practices	O Strongly agree O Somewhat agree O Somewhat disagree O Strongly disagree O Don't know/Unsure

Q10. In general, do you believe plant molecular farming should be pursued in Canada?

O Yes
O No
O Don't know/Unsure

Q10a. Assuming that plant molecular farming is pursued, what kind of restrictions do you believe should be put on PMF research before it should be allowed? Please circle the level of restriction under each PMF practice listed below.

Practices	Degree of restriction					
	Lowest restrictions →					Highest restrictions
	Allow to be grown in fields like conventional crops	Allow to be grown in fields **only** with specified isolation in physical distance **or** in time to other crops	Allow to be grown in fields **only** with specified isolation in distance **or** in time to other crops **AND** with no pollen flow (i.e. with plants modified not to flower)	Contained within a greenhouse	Contained within a greenhouse **AND** with plants modified for no pollen flow	**Only** in completely sealed facilities (e.g., underground)
*PMF using **food** crops to produce medicinal **drugs***			+		+	
*PMF using **non-food** crops to produce medicinal **drugs***			+		+	
*PMF using **food** crops to produce **industrial products***			+		+	
*PMF using **non-food** crops to produce **industrial products***			+		+	
*PMF using **food** crops to improve **nutritional quality of foods***			+		+	

Section V: Demographic Information

The following questions are designed to tell us a little about you. This information will only be used to report comparisons among groups of people. Your identity will not be linked to your responses in any way.

Q11. Are you…

O Male O Female

Q12. What is your age?

____

Q13. How many people, including yourself, live in your household?

____

Q14. How many children live in your household?

____

Q15. And how many children living in your household fall into each of the following age group?

a) 1 to 4 years

____

b) 5 to 11 years

____

c) 12 to 17 years

____

Q16. What is the highest level of education that you have completed? **CHECK ONE ONLY**

O Never attended school
O Grade school (grades 1 to 9)
O Some high school
O High school graduate
O Post secondary trade or technical school certificate/degree
O Some university or college

O College diploma/degree
O University undergraduate degree
O Some post graduate university study
O Post graduate university degree (e.g., Masters or Ph.D.)

Q17. Which of the following best describes your employment status? **PLEASE SELECT ONE ONLY**

O Working full- or part-time
O Full- or part-time student
O Not in the wage labour force
O Retired

Q18. For classification purpose, what is your total household income before taxes? **CHECK ONE ONLY**

O Less than $10,000 O $10,000-$19,999 O $20,000-$29,999
O $30,000-$39,999 O $40,000-$49,999 O $50,000-$59,999
O $60,000-$69,999 O $70,000-$79,999 O $80,000-$89,999
O $90,000-$99,999 O More than $100,000

Q19. What province or territory do you live in?
O Alberta O British Columbia O Manitoba
O New Brunswick O Newfoundland and Labrador O Northwest Territories O Nova Scotia O Nunavut O Ontario
O Prince Edward Island O Quebec O Saskatchewan
O Yukon

Q20. Do you live in a Rural Area?
O Yes
O No

Q21. Do you work in any of the following areas?

O Hospital or health services
O Government or non-government environment agencies
O Food industry (farming, processing, retailing, or food-related industry)
O Research institution
O None of the above

Q22. Are you associated with or donate to any consumer group that focuses on food safety issues?

- O Yes
- O No

Q23. Are you associated with or donate to any environmental group?

- O Yes
- O No

Q24. Are you associated with any group that seeks remedies for illness or medical problems?

- O Yes
- O No

Appendix B: The Terminology Used in the Thesis

Terms	Description
Bioreactor	An apparatus, such as a large fermentation chamber, for growing organisms such as bacteria or yeast that are used in the biotechnological production of substances such as pharmaceuticals, antibodies, or vaccines, or for the bioconversion of organic waste.
DNA	Deoxyribonucleic acid; the material of which genes are made. DNA consists of a linear sequence of subunits called bases. DNA is the carrier of genetic information, which is encoded in the sequence of bases. It is present in chromosomes in the cell nucleus, and also in chromosomal material of subcellular units such as mitochondria and chloroplasts.
Recombinant DNA	DNA that has been cut and respliced. "Recombinant DNA" and "recombinant techniques" generally refers to genetic engineering.
Transgene	The gene which has been introduced into a genetically engineered, or transformed organism.
Transgenic	Refers to the introduction of a gene into an organism by genetic engineering. A transgenic plant is one in which a gene ("transgene") has been inserted.
Transformation	The insertion of a gene into an organism by genetic engineering.
Isolation distance	"In order to prevent two types of crops (or two varieties of one type of crop) from cross-pollinating with each other, the two crops are planted in two different fields with a specified distance between them. This distance is called the isolation distance."
Temporal gap	"In order to prevent two types of crops (or two varieties of one type of crop) from cross-pollinating with each other, the two crops are planted at two different times of the year so that the pollination seasons of these two crops do not overlap. This difference in time is called the temporal gap."

Source: GE^3LS (http://www.genomeprairie.ca/ge3ls/pharm, accessed on January 2006)

Appendix C: The Application of Nested-logit Model for the Survey Data

Although the conditional logit model has been widely used due to its simply mathematical form and ease of estimation, it still undergoes model deficiency. According to McFadden (1974), conditional logit model was developed based on the assumption of independence of irrelevant alternative (IIA) property, which implies that the ratio of probabilities of choices between two alternatives is independent of any other alternative. This is a relatively severe restriction of preferences. One method of relaxing the IIA assumption is to construct a nested logit model in which the alternatives are grouped into similar classes and the probability of choosing a class is estimated as well as the probability of choosing an alternative from a specific class conditional on choosing the class (Grafton et al. 2004, pp 289).

Six nested logit models with different structures are tested for the PMF research funding data. The structures are shown as below.

Figure D-1 Nested-logit Model: Tree Structure 1

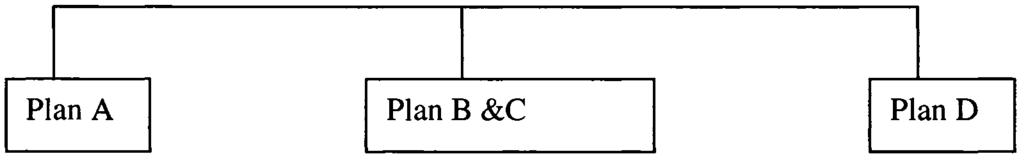


Figure D-2 Nested-logit Model: Tree Structure 2

Figure D-3 Nested-logit Model: Tree Structure 3

Figure D-4 Nested-logit Model: Tree Structure 4

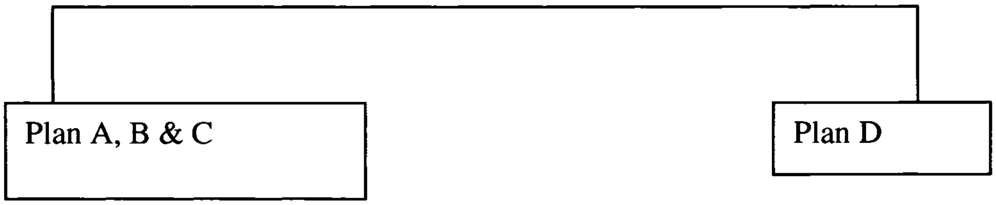


Figure D-5 Nested-logit Model: Tree Structure 5

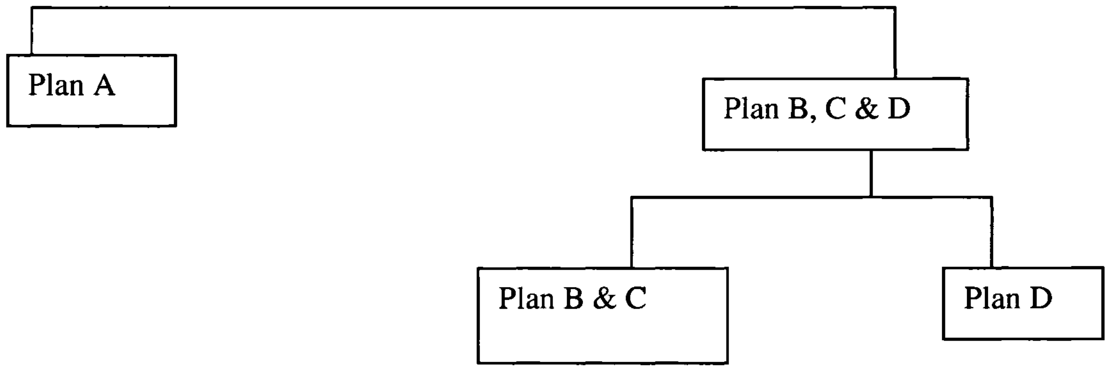
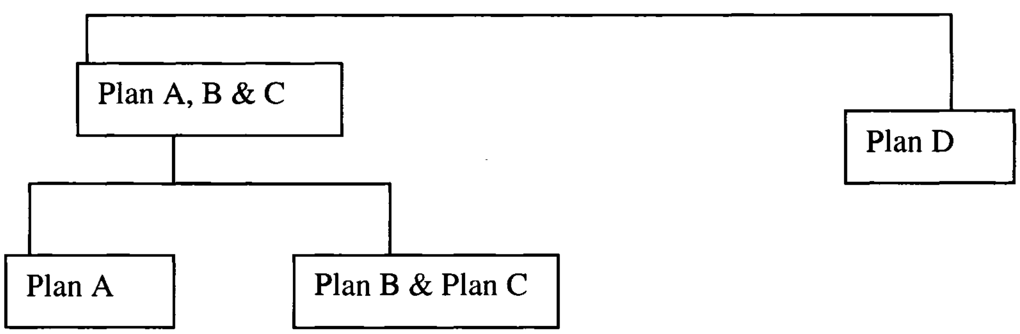


Figure D-6 Nested-logit Model: Tree Structure 6



Based on the non-nested test (Ben-Akiva and Lerman 1985), if there are more than 250 or more observations with two or more alternative and models having the same number of parameters, if the adjusted Rho-square of the two model differ by 0.01 or more, the model with the lower adjusted Rho-square is almost ce4rtainly incorrect. In our case, the differences of the adjusted Rho-square of conditional logit models and the adjusted Rho-square of nested logit models are all less then 0.01. This implies that the nested-logit models will not improve the model estimation.

Sources:

Ben-Akiva, M. and S. R. Lerman. 1985. *Discrete Choice Analysis: Theory and Application to Travel Demand.* Cambridge: MIT Press. 390 pp.

Grafton, R.Q., W.L. Adamowicz, D. Dupont, H. Nelson, R. Hill, and S. Renzetti. 2004. *The Economics of the Environment and Natural Resources.* Basil Blackwell Publishing.

McFadden, D. 1974. "Conditional Logit Analysis of Qualitative choice Behavior." In P. Zarembka, eds. *Frontiers in Econometrics.* New York: Academic Press, pp. 105-142.