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Plant biotechnology in Ireland: Understanding the factors that shape plant biotechnology risk management policy in Ireland

by Shane Morris

Supervisor: Prof. Charles Spillane

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy,

School of Natural Sciences, Science Faculty,
National University of Ireland, Galway

December 2011
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Declaration

I hereby declare that this thesis is my own work and that it has not been submitted by me for any other degree or professional qualification.

Signed: Shane Morris

Date: 22\textsuperscript{th} December, 2011
Abstract

Plant science is critical for humankind as plants form the fundamental basis of society (i.e. food and fibre). Plant biotechnology has been identified as a key research area by the Irish Government, but this research also raises concerns regarding possible risks. As a result, understanding the factors that shape plant biotechnology risk management policy in Ireland is essential to the development of associated policy and regulatory frameworks.

The project first explores the background to plant biotechnology and genetic modification (GM). Subsequently, GM policy in Ireland (from 1974 to date) and the European Union (from 1973 to date) is examined and mapped. Key policy periods are identified and investigated. A longitudinal analysis of Irish public attitudes to modern biotechnology from 1996 to 2010 follows. Using both quantitative and qualitative tools, key groups (i.e. university based life scientists and the feed industry) in the innovation value chain are surveyed as to their attitudes regarding modern plant biotechnology. In addition, a content analysis of Irish daily newsprint media articles from 2007 to 2010 is carried out to identify coverage intensity, actors, framing and tone of GM articles. The project also compares the potential *ex-ante* environmental and agronomic impacts of GM glyphosate tolerant maize cultivation with current Irish maize production as maize provides an important source of animal feed to Irish farmers.

The various elements of this project are used to test the hypothesis that the development of Irish plant biotechnology policy corresponds with the punctuated equilibrium theory of policy change. It is indeed demonstrated that in the case of Ireland, punctuated equilibrium is at play, expressed by long periods of stability, punctuated by sudden shifts that are characterized by radical change (mainly driven by political considerations). Based on lessons learned and characteristics that apply when punctuated-type dynamics exist within a policy arena, recommendations are made regarding the future development of policy. These include a more appropriate policy approach that focuses on a comparative analysis of the risks and benefits of a plant trait, rather than on the process by which this trait was obtained, and that assesses risks and benefits in the context of current products and practices.
Acknowledgements

“The Daddy, Daddy, Daddy, where are you? Ima, where is my Abba?”

Lyanne Erin Morris, aged 3,
May 17, 2010

The above words were heard often during the writing of this thesis and on many occasions they were accompanied by tears of sadness. No matter how painful these words were for me locked inside the room writing, I knew in my heart, they were vastly more painful for the child uttering them. As a result, this thesis is dedicated to my beautiful and brilliant wife, Vardit and our fantastic children Lyanne, Michael, Ellan and Liad who have sacrificed the most during the writing of this thesis. I have willfully stolen irreplaceable time from them all during their most precious years. For this, I hope they will forgive me.

I am forever indebted for the help, guidance and support of all those who stood beside me during this project. Special thanks go to Dr. Catherine O’Mahony, Kristina Rehmet, Michael Griffin, Liz Gomes, Dr. Elaine Byrne (thanks for the music), Dr. Eoin Brazil, Dr. Yann Devos, Dr. Matty Demont, Dr. Stuart Smyth, Dr. Aishling Doyle, Dr. Sofie Vergucht, Tim O’Donovan, Deirdre Webb, Dr. Patrick O’Mahoney, Prof. Klaus Amman, Dr. Tom McLoughlin, Mark Cantley, Prof. Jonathan Gressel, Tyler Lacombe, Tereza Cundy, Jennifer Balcom, and Dr. Peter McKeown plus all the Spillane Lab members (past and present) for their expertise, technical help and on-going support and encouragement. I particularly wish to thank Vincent Ngan who has been patient and supportive beyond words and all my colleagues at the Regulatory Affairs Sector of the Treasury Board of Canada Secretariat without whose friendship and help this thesis would have never been completed.

I am very grateful to Prof. Charles Spillane whose insights, knowledge and expertise coupled with a supportive and always engaging style ensured this thesis came to be. Within academia
there is often a focus internally on one’s field of study, so to find someone as passionate and outward looking as Prof. Spillane who has a genuine desire to make a difference not only for his students and in his university but also on the developing world makes the difference between a good supervisor and a great supervisor.

This research was funded by Teagasc under the Walsh Fellowship but more importantly this fellowship provided support, world class expertise, and knowledge (plus endless patience) through Dr. Ewen Mullins. His guidance and backing ensured the work remained focused and in context. Support for presenting results from this research at a major international scientific conference was appreciatively received via the Thomas Crawford Hayes Travel Award 2011. It is hoped my work has furthered and promoted knowledge in the biological sciences as was the wish of Thomas Crawford Hayes (1843-1909).

Thanks must be given to those interview and survey respondents who took the time to participate and engage in this research. A special thank you goes to Dr. Christine Domegan and Dr. Heike Felzmann who kindly agreed to take the time and effort to act as my GRC Committee members after the work was moved to NUI, Galway. In addition, I wish to thank the external examiner, Prof. Alan McHughen for his time, effort and insights.

Finding the courage and strength to start, continue and ultimately finish a thesis is not obvious. For this, I thank my parents and siblings who, in providing a solid and loving grounding, ingrained the belief into me that anything is possible if you try hard enough. However, in my case I needed more. It was only through the additional encouragement, love and true partnership of my wife, Vardit, that I was able to complete this thesis. For this I am, for all time, deeply thankful and indebted.

“It must be recognized that research on values and public choice (regarding biotechnology) is inherently more difficult than research in biotechnology itself. This, however, neither detracts from its importance, nor indicates it should not be done.”

(Johnson and Thompson, 1991, p127)
Publications


(See Appendix D)

Presentations and Seminars


Chapter 1

The history and science of modern plant biotechnology

“I know of no safe depository of the ultimate power of society but the people themselves, and if we think them not enlightened to exercise their own control with a wholesome discretion, the remedy is not to take it from them but to inform their discretion by education.”

Thomas Jefferson

Letter from Thomas Jefferson to William C. Jarvis, 1820. ME 15:278

The Writings of Thomas Jefferson (ME)
Memorial Edition (Lipscomb and Bergh, editors)

If science and technology are to remain credible in the long term, the scientific community must take on board Thomas Jefferson’s words of the nineteenth century and apply them to science today. Science must \textit{inform} the general public to allow for democratic decision-making, especially about new technologies such as modern biotechnology, which have had and will have numerous profound impacts on many areas and levels of mankind’s future. All technologies can be used either for ethical or for unethical purposes, and modern biotechnology is no exception. An informed public and policy platform is needed to assist scientists in making choices in developing modern biotechnology applications that are in the public’s long term interest (Batra and Klassen, 1987).

Over the past three decades many thousands of people have been asked what they think about science and technology and the scientific developments in plant biotechnology (Zechendorf, 1994). The public attitudes and perceptions of science and technology are becoming
increasingly important in our society and at the science-policy interface. These attitudes can influence the application of modern biotechnology at many levels (McHughen, 2007b), from the consumer to the producer, from the voter to the government minister, from the stock exchange to the boardroom. For this reason, it was decided to undertake an in-depth research project which focuses on the public perceptions and attitudes towards agricultural biotechnology and its effect on public policy and legislation/regulatory affairs in Ireland. The reasons for a focus on Ireland are twofold. Firstly, Ireland relies heavily on agriculture as it is responsible for 8.5% of Gross National Product (GDP) and secondly, Ireland has stated its determination to prioritise its investment in devolving and promoting a knowledge economy where science and technology (e.g. modern agri-biotechnology) play keys roles (Bonetta, 2008).

To understand the science-policy interface for a particular issue it is important to be able to comprehend on both sides of the interface. There is solid evidence that key decision-makers, including those in governments, private companies and the general public, can be influenced in their decisions (to a some degree) by sound, solid scientific knowledge (Watson, 2005, Johnson et al., 2007). As such, there is a need to understand the science and technology applications which underscore a particular policy issue. Therefore, the next sections of this chapter outline and explore key scientific concepts and advances that form the basis of modern agri-biotechnology (Chapter 2 examines the ‘policy’ side of the science-policy interface).

1.1 History of the Term ‘Biotechnology’

By examining the history and evolution of the term biotechnology the technology can be placed in a historic perspective and/or frame. However, a difficulty arises with the word ‘biotechnology’ caused by the fact that there are so many definitions and that it is used to include a broad range of technology applications (Kennedy, 1991). One very broad definition of biotechnology is:

“Biotechnology, broadly defined, includes any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop micro-organisms for specific uses”

(Office of Technology Assessment, 1989, p3)
Or put more simply, biotechnology is a broad term for putting biological processes to practical uses. Alternatively, it can be defined in commercial terms as: “The use of biological systems for industrial purposes” (Moran, 1999, p2).

According to Kennedy “the word biotechnology has been ‘re-developed’ at least four times over the past eighty years and its definition became modified on each occasion” (Kennedy, 1991, p218). Its first documented use in 1919, has been attributed to Karl Ereky, a Hungarian agricultural economist who coined this new term to cover the interaction of biology with technology (Bud, 1989). It was also used in a 1920 commercial publication entitled the Bulletin of the Bureau of Bio-technology. This ‘bureau of bio-technology’ was based in Leeds, England and offered consulting services to the chemical and microbiological industry. It was not until 1933, that an article appeared in Nature entitled ‘Biotechnology’. However, there was no mention of the word in the text of the article (Kennedy, 1991). The article dealt with technology and the problem of maintaining the quality of the human species. According to Kennedy, in 1938, Julian Huxley, when using the term biotechnology, made a remarkable prediction: “Biology is as important as the sciences of lifeless matter; and biotechnology will in the long run be more important than mechanical and chemical engineering” (Kennedy, 1991, p219).

However, a divergence on today’s definition occurred in 1947, with the publication of a paper entitled, ‘Biotechnology: A new fundamental in the training of engineers’. This paper described biotechnology as the form of technology dealing with the development and exploitation of machines to work for the needs of human beings” (Kennedy, 1991). In the same year, the word biotechnology was used to describe ergonomics (Bud, 1989).

Moving forward in time, according to Vivian Moses et al., the Oxford Shorter English Dictionary in 1955 did not list biotechnology at all, skipping from ‘biotaxy’ to ‘biotic’ (Moses et al., 1999, p1). The first use of the term in mainstream science occurred when the ‘Journal of Microbiological Technology and Engineering’ made a significant name change in 1962 to be entitled ‘Biotechnology and Bioengineering’ (Bud, 1994). Noteworthy is the fact that during
1979, E.F. Hutton (& Company) was first issued a U.S. trademark on the word biotechnology to describe a magazine dealing with genetic engineering (Hutton, 1979). During the same year (i.e. 1979), a well-known dictionary, which Moses et al. did not name, was still describing the word as “biotechnology: the U.S. name for ergonomics” (Moses et al., 1999, p1).

The scientific use of the word biotechnology grew to a peak in 1986-1987 (Kennedy, 1991). Since then, the word has evolved along two parallel routes: (1) where another word has been added to the term ‘biotechnology’ to allow it to have a more precise meaning (e.g. Plant biotechnology, fungal biotechnology, etc.) and (2) where the term ‘genetic engineering’ is used to describe a product of biotechnology (e.g. genetically engineered food, etc.). Further evolution of the term has been attempted in recent years to include such phrases as ‘Living modified organisms (LMO)’ as used by Mark Cantley (Cantley, 1996). In addition the terms Green biotechnology, Red biotechnology, Blue biotechnology and White biotechnology have been employed to describe modern biotechnology applications in agriculture (Schmid, 1991), medicine, the marine area and industrial use respectively. More recently the term ‘purple’ biotechnology has been used to describe the area that deals with legal, patent and policy issues related to biotechnology (F Bruschi et al., 2011).

According to the literature, the peak use of the word biotechnology by the business community occurred in 1989, as the usage of the word in the science community was evolving (Kennedy, 1991). The business world has also adapted the word biotechnology for its own use in recent times. One example of this is the use of the prefix bio-, which is now commonly used to describe a specific biotechnological business activity such as biopharmaceuticals, bioinfomatics, bioprocessing, etc. The body representing the Irish biotechnology industry, established by the Irish Business and Employers’ Confederation (IBEC) in 1998, was called the Irish Bioindustry Association (IBIA) (IBEC, 1999). Another area of modern evolution of the word ‘biotechnology’ is evident in the fact that many biotechnology companies have been re-named ‘life science’ companies, especially those employing recombinant DNA technologies.
As the above indicates, there is evidence in the literature showing that, over the course of 180 years, there has been an evolution of biotechnology from heterogeneous specialties and approaches towards a scientific discipline of its own (Buchholz, 2007). As observed by Richard Godown, there are those who would certainly argue for a change in nomenclature relating to biotechnology. However, Godown’s response that indicates while the term biotechnology is not perfect it is what is used paraphrases Professor Higgins in “My Fair Lady” by saying: “We have grown accustomed to the name.” (Godown, 1987, p60)

Consequently the role of biotechnology in plant agriculture is briefly reviewed in the following section and a classification of plant biotechnology types is defined and proposed to allow a basis for policy analysis.

1.2 Summary of the role of biotechnology in Plant Agriculture
Up to the middle of the 19th century, as little was known about plant reproduction and breeding, the field of plant agriculture relied heavily on open pollination and selfing that was unaided by humans. Wind or flying animals carried pollen from one plant to the next. Farmers saved the best or biggest seeds for the next planting season (Skinner, 1985). The first plants and their seeds were selected on the basis of trial and error. During the development of early agriculture, seeds and plants would have been exchanged and better forms/varieties selected by the first farmers for such qualities as yield, high rate of seed germination and taste. The superior farmers carried out selection and recorded their observations which began the first systematic steps in plant breeding by keeping seed lots from different sources separate (Day, 1996). Two types of selection operated (and complemented each other) in plants under domestication: (a) conscious or intentional selection applied by the growers for traits of interest to them and (b) unconscious/automatic selection when plants were taken from their original feral habitats and raised in new (and usually very altered) environments created and controlled by humans. This shift in the ecology created rapid and drastic changes in selection pressures and a move towards domestication of a few plant species (Zohary, 2004).

The history of so-called “scientific” plant breeding date back to work like that of ‘Fairchild’s mule’ which was developed in 1718 to be the first manmade hybrid of a carnation crossed with
the Sweet William, to produce a new so-called ‘artificial’ plant species (Murphy, 2007). By the end of the 19th century several theories regarding inheritance of traits were widely considered. Lamarckian Theory and Mendelian Theories were two largely opposing theories that were popular at the time. Lamarckian Theory proposed that characteristics “acquired” by good rearing during life could be passed on (i.e. be heritable) to offspring. As a result genetic improvement would accumulate through this transfer, generation by generation, and the environment could be used to influence the genotype in a heritable manner (Gould, 1996). Mendelian Theory proposed that parent organisms pass traits onto offspring in what would seem to be separate units. Today, these units are called genes (Davis, 1991), although the definition of what is a gene remains under much debate and revision (Gerstein et al., 2007, Pesole, 2008). Gregor Mendel, an Augustinian monk, recognised this latter principle above in the mid-nineteenth century, while studying the inheritance of peas. Hugo de Vries, a Dutch botanist in collaboration with two colleagues rediscovered Mendel’s works (Davis, 1991). By 1912, R. Briffen working in Cambridge, England demonstrated resistance to yellow rust in wheat was inherited via the Mendelian theory of inheritance (Day, 1996). Mendelian Theory went on to become a readily accepted scientific principle and has founded the fundamentals of modern genetics.

**Hybridization:**
The “classical breeding” programs, which ranged from early agriculture up to the 1930’s, had considerable success. For example, one such successful classical breeder was Luther Burbank (1849 – 1926). As a young man he developed the Burbank potato in his native Massachusetts. He also ‘created’ stoneless plums, white blackberries, near spineless cactus, the Fire poppy and the Burbank rose (incidentally he was a strong advocate of Lamarckian Theory) (Gould, 1996). As early as 1825 John Lorain suggested the concept of maize as a hybrid crop (Fussell, 1992). George Shull subsequently made an important contribution when, in 1908 he identified the role of hybrid vigour (heterosis) in plant productivity (Fedoroff, 2010, Shull, 1908). For example, through successive rounds of forced selfing (inbreeding) a breeder could create inbred lines of maize showing uniform kernel traits but these plants are so weak (due to inbreeding depression) they were of little agronomic value. Crossing two inbred lines, however, produced plants with the uniform characteristics of the parents and yields much
higher than those of the parental inbred lines (Von Wartburg and Liew, 1999). Later Donald Jones showed that crossing two hybrids – so called double-crossing – improved productivity and vigour. The onset of hybridisation within plant breeding practice resulted in new varieties of crops with considerable improvements in selected traits, especially higher yields (Figure 1.1).

*Figure 1.1: A 1914 demonstration of the power of hybrid genetics when applied to the breeding of corn.*

The introduction of F1 hybrid maize in the 1930’s in the USA began to change the face of agriculture (Kloppenburg, 2004, Cooke, 1998). As the inbred lines used for each F1 hybrid were a trade secret, how it was created was kept confidential by the owner of the maize inbred lines. As a result, the owners of the inbred lines prepared the F1 hybrid seed to sell to the farmers. If the farmer planted seed saved from the F1 hybrid crop the following season, it gave rise to an uneconomic mixture of genetic forms caused by genetic segregation of traits from the F1 hybrid. Consequently, fresh F1 hybrid seed had to be purchased each year for planting,
this generated a private business model where the advantages to the farmer of the F1 hybrid seed as a commodity, outweighed the additional costs of purchasing the F1 hybrid seed from the first plant breeding companies. Like most new technologies, F1 hybrids were controversial to the extent that their pros and cons are still being debated in some plant breeding, agronomy and farming quarters to the present day (Griliches, 1957, Harris, 1946, Kloppenburg, 1988, Ewens, 1999, Aoki, 2003, Winston, 2008, Mooney, 1979). In the U.S., during the 1910’s and 1920’s, the increased use of hybrids (particularly in nursery stocks such as apples), the resources to breed them and the need to certify seeds to ensure buyer got what they paid for all combined to pave the way for the U.S. Plant Patent Act of 1930 (Fowler, 2000) which was applicable to asexually reproduced plants and did not include tuber propagated plants. By 1960, in the U.S. hybrids plants made up 99% of maize, 95% of sugar beet, 80% of spinach, 80% of sunflowers, 62% of broccoli, and 60% of onions (Goodman and Redclift, 1991). Not all plant species lend themselves to hybridisation, for example, beans and peas are not commercially hybridized because they are cleistogamous (having flowers that do not open and are self-pollinated in the bud). In 1970 the U.S. Plant Variety Protection Act was legislated to allow breeders exclusive right of control for 25 years of new, distinct, uniform, and stable sexually reproduced or tuber propagated plant varieties. Amendments in 1980 removed the patent protection exemptions for carrots, celery, cucumbers, okra, peppers, and tomatoes. A further amendment in 1994 allowed F1 hybrids to be patented (Alston and Venner, 2002).

In the 1950 and 1960 efforts were undertaken to develop an international framework to recognise plants breeders’ rights and plant variety protection (Pistorius, 1997). The result was the 1961 International Convention for the Protection of New Varieties of Plants (UPOV), as amended in 1972, 1978 and also in 1991. This convention provides a framework for property rights that plant breeders can claim over new plant varieties that they breed intentionally. These treaties “require members to recognize “plant breeders’ rights”, a form of intellectual property protection for plant varieties widely implemented in industrialized countries” (Sahai, 2003, p408).

Soon after the onset of F1 hybridisation as a commercial agricultural platform another tool became available to plant breeders - mutagenesis.
Mutagenesis

Mutations are changes in DNA where one or more of the nucleotide bases are deleted/replaced/rearranged with different bases (Day, 1996). Under Darwinian Theory if a mutation can confer a selective advantage on the offspring it will survive and in some cases replace its progenitor form (Day, 1996). By using particular chemicals (mutagens) and ionizing radiation (neutrons, x-rays, gamma rays [see Figure 1.2], etc.) to cause changes in DNA, plant breeders were able to select the beneficial traits that resulted from mutagen treatments (Murphy, 2007). Induced mutation has become a cornerstone in plant breeding and has been responsible for the creation of thousands of new crop varieties (Maluszynski et al., 2003). Overall, more than 2,252 mutant varieties have been officially released in the last 70 years worldwide (Maluszynski et al., 2003). Of these, 60% were released from 1985 onwards. According to Maluszynski et al., most mutant varieties were released in China (26.8%), followed in decreasing order by India (11.5%), the former USSR (9.3%), the Netherlands (7.8%), USA (5.7%) and Japan (5.3%). Many induced mutants were released directly as new varieties; others were used as parents to derive new varieties. For example, of the 2,252 varieties, 1,585 (70%) were released as direct mutants (i.e. from direct multiplication of a selected mutant and its subsequent release as a new variety). The remaining 667 crop varieties were derived through crosses with induced mutants. Mutation induction with radiation was the most frequently used method to develop direct mutant varieties (89%). The use of chemical mutagens was used much less frequently. Gamma rays were used to create 64% of the radiation-induced mutant varieties, followed by X-rays at 22% (Ahloowalia et al., 2004).
Figure 1.2: Mutagenesis of crops via exposure to gamma radiation at the Institute of Radiation Breeding (IRB), Japan. (The IRB in Japan comprises of three irradiation facilities for the mutation breeding of crop species. The gamma field is a circular field of 100m radius with 88.8TBq Co-60 source at the center. A shielding dike of 8m in height surrounds the field).

Source: Institute of Radiation Breeding in Japan, 2010

The technologies of F1 hybridisation and mutagenesis went on to form the basis of modern plant breeding. These technologies have succeeded due to a host of modern high-tech breeding methods which range from tissue culture technologies (e.g. chromosome doubling, mass propagation, somatic hybridisation, employment of haploids, double haploids and sterile plant varieties), modern screening and selection (e.g. Marker Assisted Selection [MAS]), and transgenesis (i.e. recombinant DNA technology [rDNA]) - methods important to this technology are outlined in the next section. However, it is also important to point out that modern biotechnology applied to plants breeding is constantly evolving with the rapid advance of scientific knowledge and technologies. New approaches such as TILLING, zinc finger nucleases, cis-genesis, etc. or even the employment of synthetic DNA will continue to push technology boundaries but also will push the definition boundaries as the definition and concept of ‘genetic modification’ is likely to be challenged (see Chapter 2). As a result, for the
purpose of clarification in this study it is suggested that there are three broad classes of plant biotechnology (Figure 1.3):

1. Classical Biotechnology
2. Conventional Biotechnology
3. Modern Biotechnology

It is fully recognised that drawing a clear distinct line between plant biotechnology types and classifications is somewhat blunt considering that prior comparisons between plant breeding technologies have been difficult and/or controversial (Gepts, 2002, Hallauer, 2011, Ulukan, 2009). Clearly the three classes defined above are related in certain main areas and share common goals. However, the basis of the three different types rather than suggesting that ‘modern biotechnology’ use in plants is a mere extension of traditional plant breeding it is argued here that it is more akin to a directional shift causing a paradigm change in technological scope and reach. The basis of difference in the three classes is the degree of targeted intervention at the molecular level (Figure 1.3 – vertical arrow) coupled with the fact that they have opened up different possibilities, socio-economic situations, ethical concerns and political issues. There is also the obvious difference in their chronological occurrences.

The three class model proposed above allows new plant breeding technologies to be added either via the time line or via the degree of human intervention required. There is also room in the model to add new classes.

However, notwithstanding the fact that differences clearly exist, the scientific relatedness between the three classes should not be lost completely and should instead be used as a tool in understanding, communicating and managing the risks and benefits allowed for by the different possibilities that the classes of biotechnology bring to plant breeding. To fully understand the advances in modern plant biotechnology a deeper examination of modern genetic transformation techniques is required to be undertaken. The following section explores the key techniques used to develop commercial modern plant biotechnology products such as GM crops.
1.3 Modern Genetic Transformation Techniques

Since the mid 1960’s many methods have been developed to introduce and integrate ‘foreign’ DNA into plant cells, creating transformed “transgenic” plant phenotypes (Murphy, 2007) pg 46). Successful recovery/regeneration of transformed plants finally occurred in the early 1980’s (Christou, 1996). A number of the transformation methods that are employed in commercially approved agricultural crops will be described below. These are methodologies based on (i) biological vectors, (ii) physical or (iii) chemical methods (sometimes used in combination with the process of electroporation). The scientific roots of modern plant transformation which lead to the first successful transformation of maize were based on advances in plant tissue culture, regeneration and a deep understanding of crown gall disease (Figure 1.4) (Sussex, 2008).
Figure 1.4: Chronology of Research Leading to Modern Plant Biotechnology

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Maize transformation (Gordon-Kamm et al., 1990)</td>
<td></td>
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<tr>
<td>1980</td>
<td>• Gene gun transformation (Klein et al., 1987; Sanford, 2000)</td>
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<tr>
<td></td>
<td>• Chimeric genes (Herrera-Estrella et al., 1983b; Fraley et al., 1983; Bevan et al., 1983)</td>
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<td></td>
<td>• Binary vectors (Hoekema et al., 1983)</td>
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<tr>
<td></td>
<td>• Disarmed plasmids (Willmitzer et al., 1983; Joos et al., 1983)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• <em>tms, tmc, tmi</em> identified (Klee et al., 1984; Barry et al., 1984; Akiyoshi et al., 1984)</td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td>• Single cells to somatic embryos (Backs-Hüsemann and Reinert, 1970)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• T-DNA nuclear location (Chilton et al., 1980; Willmitzer et al., 1980)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• T-DNA in plasmid (Chilton et al., 1977)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Plasmids in <em>Agrobacterium</em> (Zaenen et al., 1974)</td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>• Single cells to plantlets (Vasil and Hildebrandt, 1965a, b)</td>
<td>Bacterial virulence transferred (Kerr, 1969)</td>
</tr>
<tr>
<td>1940</td>
<td>• Controlled Organogenesis (Skoog and Miller, 1957)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• First true plant tissue culture (White, 1939a)</td>
<td></td>
</tr>
<tr>
<td>1920</td>
<td>• Attempted single cell culture (Haberlandt, 1902)</td>
<td></td>
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</table>

The following transformation methods, outlined separately in papers by Birch and Ma & Chen, have been used to introduce ‘foreign’ genes into plant genomes (Ma and Chen, 2005, Birch, 1997):

- *Agrobacterium* – mediated transformation
- Microprojectile Bombardment
- Somatic hybridisation: DNA uptake via protoplasts
- Virus – mediated transformation
- Pollen pathway or intact inflorescence methods
- Microinjection
- Silicon corbide fibres
- Electroporation of intact tissues

Source: (Sussex, 2008)
- Electrophoresis of intact tissues

According to Callow et al, the majority of transgenic plants (used commercially and experimentally) are produced using either Agrobacterium, microprojectile bombardment and to a lesser extent, protoplasts (Callow et al., 1997). It is for this reason that a deeper review of only these three technologies (as opposed to the full list above) is undertaken. As a starting point a graphical overview of Agrobacterium-mediated and microprojectile bombardment transformation methods are outlined in Figure 1.5.

**Figure 1.5: Overview off both Agrobacterium-mediated and microprojectile bombardment transformation methods**

![Diagram showing the process of Agrobacterium-mediated transformation](image)

The desired gene is isolated from the donor organism. Then transferred into the genome of the target plant cell to produce desired characteristic. e.g. specific red colour

*Source: Composition graphic from various sources – NIH, Monsanto, 2009*

### 1.3.1 Agrobacterium – mediated transformation.

The capacity to introduce and express diverse foreign genes in plants via Agrobacterium-mediated transformation was first described for tobacco in 1984 (De Block et al., 1984, Paszkowski et al., 1984, Horsch et al., 1984). The basis of the process is that crown gall disease in certain plant species is caused by the transfer and stable incorporation of a portion of DNA (T-DNA) from the bacteria Agrobacterium tumefaciens into the host plant’s
chromosome (Hooykaas and Schilperoort, 1992, Chilton et al., 1977). Agrobacterium species are the only organisms capable of inter-kingdom gene transfer (Pitzschke and Hirt, 2010). Essentially, the pathogenic DNA of A. tumefaciens can be effectively exchanged with other genes (that code for desired traits or activities). This allows for the delivery of desirable so-called ‘foreign’ genes into target cells from which whole plants can be regenerated (Zambryski et al., 1983). Pitzsche and Hirt, in their recent in-depth review of the Agrobacterium–plant interaction outline six main steps for Agrobacterium-mediated transformation. As a result of wounding, the plant produces chemicals that act as signal (step 1) to cause the stimulation the Vir A/G within the Agrobacterium (step 2). This causes the synthesis of the T-DNA (step 3) and expression of the vir gene to produce Vir proteins. By employing a bacterial type IV secretion system (T4SS) both the T-DNA and Vir proteins get transmitted to the host/target plant cell (step 4). The T-DNA then gains access to the target plant cells nucleus (via a T-DNA/Vir protein complex) (step 5) where it is integrated into the target plant cell’s chromosomes (step 6) where it can then express the genes it carried from the Agrobacterium (see Figure 1.6) (Pitzschke and Hirt, 2010). In effect, molecular biologists have taken advantage of Agrobacterium’s natural ability to introduce functioning DNA into a target plant genome. As a result, the successful transfer of a ‘foreign’ gene(s) of interest, within a plant expression cassette, into a target plant genome can occur.
1.3.2. Microprojectile Bombardment:

In 1987, Klein et al. reported on the opportunity for genetic modification with microprojectiles after researchers managed to induce strong (albeit transient) expression of a reporter gene within onion tissues by using microprojectiles fired at high speed (Klein et al., 1987). The microprojectiles employed in this bombardment approach, or “Biolistic”© (the commercial name used for the process by Bio Rad Labs), is premised on the introduction of ‘foreign’ DNA via small, DNA coated, inert microprojectiles literally ‘shot’ into plant cells. The microprojectiles used can be 1 to 4 µm in diameter and generally inert metals such as tungsten or gold are used (Taylor and Fauquet, 2002, Potrykus, 1991). Kikkert et al. have indicated that the microprojectile needs to reach a velocity of 250 ms⁻¹ to penetrate the cell walls and membranes (Kikkert et al., 2004). The efficiency of the gene gun transfer can be impacted by a range of factors which Ma and Chen state include: “cell type, cell growth condition, gene gun settings, culture medium, gene gun ammunition type, and the experimental experiences, etc.” (Ma and Chen, 2005, p29).
The key advantages of using microprojectible bombardment for transformation are:

1. Most re-generable tissue can be used, thus dramatically increasing the number of target tissue types; and
2. There appears that there are no limitations to the type of genome that can have DNA delivered to it via this process. This is opposed to *Agrobacterium*-mediated transformation which has certain limitations on the types of genomes that can be targeted. (Owens and Smigocki, 1988, McElroy and Brettell, 1994).

1.3.3. Somatic Hybridisation:
Somatic hybridisation has been in crop breeding since the 1980’s and was used to produce several key commercial varieties of potato and oilseed rape (Murphy, 2007). More recently somatic hybridisation has been increasingly applied to fruit crops (Mourão Filho *et al*., 2008, Guo *et al*., 2006). An attractive element of somatic hybridisation is that most regulatory bodies do not consider this technology platform “gene modification” (GM) which allows products derived from somatic hybridisation to normally fall outside the scope of “GM” laws. Such a situation reduces considerably the regulatory burden as biosafety, health testing and associated labelling approvals are not required. An example of this is the company Phytowelt GreenTechnologies that was “founded in January 2006 as a merger of Phytowelt GmbH and GreenTec GmbH, which originated as a spin-off company from the Max-Planck-Institute for Plant Breeding Research in Cologne in 1997” (see http://www.phytowelt.com/ accessed May 12, 2010). Previously GreenTec GmbH had stated on their website in 2005 that:

“*The somatic hybrids created by our technology are not considered GMOs (genetically modified organisms) and are not regulated according to the genetic engineering directive of the EU. Therefore, the market approval is not restricted by lengthy and costly investigation imposed for genetically engineered food and feed varieties but only by normal variety registration regulations.***”(Murphy, 2007, p44)

Furthermore, in May 2010, in a press release announcing results of a plant research collaboration carried out by Phytowelt GreenTechnologies and New Zealand’s Pastoral Genomics, it was stated that:

“*These plants offer some of the potential gains from biotechnology but are not genetically modified under New Zealand law.***” (Sözer, 2010, p1)
1.4 An example of a Promoter/ Expression Regulatory Sequence - CaMV 35S:

A major element that controls the phenotype of the inserted DNA sequence coding for a desired trait is the type of regulatory sequences operating on the coding sequence. Such regulatory sequences are usually found either upstream (promoters and enhancers) and/or downstream (terminator) (Lewin, 2008). When modifications are made to the genome via genetic engineering the regulatory sequences play a key role on various levels which include tissue/organ specificity, gene expression levels, developmental expression and responses to key abiotic/biotic pressures or cues. For successful transformation a gene cassette is usually engineered. This consists of the ‘foreign’ gene(s) of interest plus the necessary regulatory sequences to control its expression (i.e. a promoter, a terminator, etc.). It is this group of genes that is then introduced to the host genome in the form of a gene cassette.

Various hybrids of combination promoters have been developed and used commercially from the CaMV 35S promoter which can improve expression of transgenes. The following are examples:

1. A double 35S promoters (Fang et al., 1989);
2. A combination of CaMV 35S with mannopine syntase elements (Comai et al., 1990); and
3. A combination with Adh1- and OCS- promoter elements with CaMV 35S for expression in monocotyledons (e.g. cereals) (Last et al., 1991).

How the promoter acts on the selectable marker in a transgenic plant is an important factor owing to the fact that it not only effects the transformation frequency but can also influence the copy number of the transgene in the produced transgenic cells/plants (Shiva Prakash et al., 2008). There has been a degree of debate over the use of CaMV 35S which has been considered questionable by a small number of anti-GM researchers who suggest that there is a “potential to reactivate dormant viruses or creating new viruses in all species to which it is transferred, particularly in view of the modularity and interchangeability of promoter elements” (Ho et al., 1999, p197). However, the majority of the published literature and government regulatory safety assessments on the issue indicates the use of this promoter is safe (Hull et al., 2000, Batista and Oliveira, 2009).
1.4 Cases Studies of the Application of Genetic Engineering

Since being commercialized in the USA in the mid 1990’s certain GM crops have rapidly become a cornerstone of US agriculture and consequently have become an important issue in Irish agri-food value (e.g. as a key animal feed component - see Chapter 6). The two primary GM technology applications are herbicide tolerance (HT) and insect resistance (via the use of *Bacillus thuringiensis* (Bt) genes). Currently 93% of soybeans grown in the US are GM HT. GM varieties of cotton and corn both exceed 65% of the crop grown in these crop types (Figure 1.7) (USDA, 2011a) and the average of all GM cotton is 88% of all cotton grown in the US while GM corn is 90% of all corn grown. The availability of stacked trait cultivars in the US continues to fuel the increased planting of GM maize and cotton (Castle *et al.*, 2006, Halpin, 2005).

*Figure 1.7: Adoption of GM crops in the USA*

![Growth in adoption of genetically engineered crops continues in the U.S.](chart.png)

Data for each crop category include varieties with both HT and Bt (stacked) traits. Sources: 1996-1999 data are from Fernandez-Cornejo and McBride (2002). Data for 2000-11 are available in the ERS data product, Adoption of Genetically Engineered Crops in the U.S., tables 1-3.

*Source: USDA, 2011*
In the following section both GM HT maize and GM Bt maize will be reviewed as example crops for the GM traits of HT and Bt.

1.4.1 GM HT crops:
This section reviews the application of modern biotechnology to produce GM HT crops with a focus on glyphosate tolerant maize as an example.

Introduction:
Currently, after three decades and billions of dollars invested in research, only a few transgenic herbicide traits are currently commercially available. As outlined by Green and Owen in 2010, these include two transgenes coding for a glyphosate-insensitive 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS; EC2.5.1.19), the cp4 epsps gene from A. tumefaciens strain CP4 and the mutated zm-2mepsp from corn (Zea mays L.), and three transgenes coding for metabolic inactivation. One gene from Ochrobactrum anthropi strain LBAA encodes for glyphosate oxidoreductase (GOX), and two homologous genes, pat and bar from Streptomyces viridochromogenes and Streptomyces hygroscopicus, respectively, encode N-acetyltransferases that inactivate glufosinate (see Table 1.1) (Green and Owen, 2010). Nevertheless, in 1996, according to Dill, glyphosate-resistant soybean became the first commercial crop on the market in the USA branded as Roundup Ready™. Such herbicide-resistant soybeans have seen exceptionally rapid rates of adoption in the US (Dill, 2005). In 2008, 5.7 m ha of GM HT maize was grown in the world, accounting for 34% of the total area planted with HT GM crops (James, 2009 personal communication). Overall, GM HT crops now represent a key element in US corn, soybean and cotton production (see Figure 1.13). GM HT maize field trials are currently on-going across Europe with trials in Denmark, the Czech Republic, Spain, France, Hungary, Portugal, Romania and Sweden (EU SNIF database: http://gmoinfo.jrc.ec.europa.eu/). For the purpose of this thesis there is a focus on glyphosate resistance trait, as such it will be examined more deeply (i.e. its history and mode of action) in the following sections.
Table 1.1: Summary of Currently Available Transgenic Herbicide-Resistant Corn, Soybeans, and Cotton

<table>
<thead>
<tr>
<th>crop</th>
<th>resistance trait</th>
<th>trait gene</th>
<th>trait designation</th>
<th>first sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>cotton</td>
<td>glyphosate</td>
<td>cp4 epsps</td>
<td>MCN1445</td>
<td>1996</td>
</tr>
<tr>
<td></td>
<td></td>
<td>two cp4 epsps</td>
<td>MON88913</td>
<td>2006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>zm-2mepsps</td>
<td>GHB614</td>
<td>2009</td>
</tr>
<tr>
<td></td>
<td>glufosinate</td>
<td>bar</td>
<td>LLCotton25</td>
<td>2005</td>
</tr>
<tr>
<td>corn</td>
<td>glyphosate</td>
<td>three modified zm-2mepsps</td>
<td>GA21</td>
<td>1998</td>
</tr>
<tr>
<td></td>
<td></td>
<td>two cp4 epsps</td>
<td>NK603</td>
<td>2001</td>
</tr>
<tr>
<td></td>
<td>glufosinate</td>
<td>pat</td>
<td>T14, T25</td>
<td>1996</td>
</tr>
<tr>
<td>soybean</td>
<td>glyphosate</td>
<td>cp4 epsps</td>
<td>GTS 40-3-2</td>
<td>1996</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cp4 epsps</td>
<td>MON89788</td>
<td>2009</td>
</tr>
<tr>
<td></td>
<td>glufosinate</td>
<td>pat</td>
<td>A2704-12</td>
<td>2009</td>
</tr>
</tbody>
</table>

Source: (Green and Owen, 2010).

History:
Glyphosate, N-(phosphonomethyl) glycine (C₃H₈NO₅P), was discovered to have herbicidal properties in 1970 and was commercialised by Monsanto in 1974 (Nandula, 2010). In 1983 Monsanto scientists demonstrated that they were able to create glyphosate tolerance in E.coli by amplifying the aroA gene (Rogers et al., 1983). Subsequently, on the foot on new genetic transformation technologies, Monsanto scientists were able to create a plasmid that allowed for in-vitro transcription and translation within a petunia cell line (Shah et al., 1986) that was able to confer glyphosate tolerance on the plant cells (della-Cioppa et al., 1987). Monsanto used this information and technique to develop highly glyphosate-tolerant plants for commercial use (Kishore and Shah, 1990).

Method of Action:
Glyphosate is normally phytotoxic to a broad spectrum of plants. It operates by binding to and inactivating the enzyme 5-enol-pyruvylshikimate-3-phosphate synthase (EPSPS), which is a key molecule in the shikimate pathway (see Figure 1.8) that leads to the biosynthesis of the
aromatic amino acids tyrosine, tryptophan and phenylalanine (Duke and Powles, 2008, Franz et al., 1997). The disruption of this pathway and the resulting inability to produce key amino acids prevents growth and ultimately leads to the plants death. While EPSPS is found to occur in all plants, bacteria and fungi, it does not occur in animals as they do not synthesize their own aromatic amino acids (Kishore and Shah, 1990). However, in the case of genetically modified glyphosate tolerant maize, genes have been introduced (either via ballistic (Dyer, 1996, Gordon-Kamm et al., 1990) or Agrobacterium transformation (Ishida et al., 1996) that code for the expression of the CP4-EPSPS protein (Green, 2009, Songstad, 2010, Duke and Cerdeira).

Figure 1.8: Overview of the Shikimate pathway

![Shikimate Pathway Diagram](Dill, 2005)

This protein is comparable to the native EPSPS found in wild-type plants but it is not inactivated by glyphosate, thus allowing the crop to be protected from the recommended...
dosages of glyphosate. The source of genes that encode for CP4-EPSPS is the common bacteria *Agrobacterium* sp. strain CP4 which naturally contains a single point mutation in the gene that switches the nucleotide guanine for cytosine, which in turn allows the amino acid alanine to be substituted for glycine (Heck *et al*., 2005). This change allows the shikimate pathway to function normally when exposed to glyphosate. GM HT (NK603) maize varieties are created when dual CP4 EPSPS transgene cassettes are transformed into maize plants accompanied by rice (*Oryza sativa* L.) actin 1 (P-Ract1) that acts as transcriptional regulator along with the enhanced cauliflower mosaic virus 35S (P-e35S) acting as a promoter to allow for full constitutive expression in corn. This confers glyphosate resistance due to the fact the continued action of the glyphosate tolerant CP4 EPSPS enzymes provides the plant with key aromatic amino acids (Figure 1.9) (Heck *et al*., 2005).

*Figure 1.9: Strategy for the development of glyphosate-resistant crops.*

![Image of the shikimate pathway](source: (Dill, 2005))
1.4.2 GM Bt crops
This section reviews the use of a *Bacillus thuringiensis* (*Bt*) toxin and its application in modern biotechnology as an example of the application of modern biotechnology to the agri-food sector.

*Introduction:*
Crop damage/loss due to insects is an important issue. The global yield loss of crops due to herbivorous insects is estimated at between 5% and 30% based on the crop in question (Thurau *et al*., 2010). One key example of such an issue is the Colorado potato beetle (CPB; *Leptinotarsa decemlineata* Say). The CPB shifted to the potato crop from native solanaceous weeds in the American West in 1859, and has been a serious pest ever since. Currently, the CPB is the most important insect defoliator of potatoes in the USA (Weber, 2008, Alyokhin). GM potato cultivars bred to express the *Bacillus thuringiensis* (*Bt*) toxin provided good control of *L. decemlineata* when they were commercially available in the USA from 1996–2000 (Grafius and Douches, 2008). However, other *Bt* crops continue to be developed and in the US, GM varieties of *Bt* cotton and *Bt* maize remain very popular with farmers (see Figure 1.13). The latter became a serious issue for Irish animal feed manufactures and farmers as the regulatory frameworks in the U.S. and the European Union became misaligned leading to approval and supply problems (see Chapter 6).

*History:*
According to Roh *et al*., Ernst Berliner first discovered *Bacillus thuringiensis* (*Bt*) in 1911 after a shipment of flour moths (*Anagasta kuehniella*), sent from Thuringina, were found to be carrying an unknown pathogen that was clearly contagious (Roh *et al*., 2007). Federici *et al.* outline the fact that not long after it become clear that this *Bacillus* species had host specific properties, the first research experiments (between 1928 and 1931) started on this new pathogen to examine its potential as a pesticide (e.g. against the corn borer) (Federici *et al*., 2006). However, it was only when problems with synthetic pesticides began to develop after the Second World War that serious attempts were made to establish *Bt* as a biological pesticide with commercial applications. Organic farmers have used *Bt* sprays for the last 40 years, as an environmentally friendly biopesticide (Murphy, 2007, pg 342). According to Schnepf the biocontrol of insect pests via *Bt* δ-endotoxins is the most successful application a
biological control known (Schnepf et al., 1998, Schnepf, 1995). To underpin this success Kumar et al. make the point that “in 1995 the market volume of Bt preparations was an estimated 90 million US dollars” and that in 1997 there were Sixty-seven Bt preparations registered worldwide (Kumar et al., 1996, p6). However, it should be pointed out that while Bt preparations account for 80-90% of all biological pesticides, its share of the total global insecticide market is approximately 1-2% (excluding Bt transgenic crops) (Baum et al., 1999, Chattopadhyay et al., 2004, Kumar et al., 2008).

The first report of transgenic insect resistant plants using Bt was published in 1987 (Vaeck et al., 1987). As outlined by Perlak et al. in 1993, a modified cryIIIA gene encoding for the insect control protein of Bacillus thuringiensis var. tenebrionis was successfully transformed into potato plants (var. Russet Burbank). Its expression within the plant allowed protection from all forms of the CPB in the laboratory and allowed for much increased levels of protection when tested in the field (Perlak et al., 1993). The first Bt transgenic crop was commercially released in 1996. As early as 1998 GM Bt insect resistant crops had become commercialized in several key countries. As outlined by Schuler et al. research on applying this technology in other crops proceeded rapidly and by 1997 Bt toxins were transferred and expressed in now less than 26 different plant species (Schuler et al., 1998) (see Table 1.2). Since then advances have been swift, approximately 40 different genes conferring insect resistance have been incorporated into crops (see Table 1.2 for selection of crop types and genes) (Kumar et al., 2008). Commercially, Bt cotton and Bt corn have been grown on more than 162 million ha worldwide (Tabashnik et al., 2008).
Table 1.2: Development of some other *B. thuringiensis* transgenic crops for insect resistance.

<table>
<thead>
<tr>
<th>Crop target</th>
<th>Gene</th>
<th>Target pest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td><em>Cry 1A(b)</em></td>
<td>European corn borer</td>
</tr>
<tr>
<td>Soybean</td>
<td><em>Cry 1A(c)</em></td>
<td>Bollworm and Bud worm</td>
</tr>
<tr>
<td>Tobacco</td>
<td><em>Cry 2aa2</em></td>
<td>Cotton bollworm</td>
</tr>
<tr>
<td>Sugar cane</td>
<td><em>Cry 1A(b)</em></td>
<td>Stem borer</td>
</tr>
<tr>
<td>Potato</td>
<td>*Cry 5 <em>B. thuringiensis</em></td>
<td>Potato tuber moth</td>
</tr>
<tr>
<td>Alfalfa</td>
<td><em>Cry 1C</em></td>
<td>Leaf worm</td>
</tr>
<tr>
<td>Tomato</td>
<td><em>B. thuringiensis (k)</em></td>
<td>Tobacco hornworm, tomato pink worm and tomato fruit worm</td>
</tr>
<tr>
<td>Brassica</td>
<td><em>Cry 1A(c)</em></td>
<td>Pod borer</td>
</tr>
<tr>
<td>Cotton</td>
<td><em>Cry 1A(b)/(c)</em></td>
<td>Lepidoptera</td>
</tr>
<tr>
<td></td>
<td><em>Cry 2A</em></td>
<td>Pink Bollworm</td>
</tr>
</tbody>
</table>

Source: (Ali *et al.*, 2010)

Transgenic plants expressing *Bt* toxins are currently the most commercially important insect-resistant transgenic crop (Ali *et al.*, 2010). Transgenic *Bt* crops are seen as an additional tool for insect pest control. As outlined by Krattiger, the advantages of *Bt* crops over conventional insecticides include enhanced targeting of pests residing within the plant, greater protection against challenging weather conditions, rapid biodegradability, a reduction in operator exposure to the toxins in more conventional plant protection regimes and financial savings (Krattiger, 1997). There are, however, certain concerns pertaining to the environmental impact of *Bt* crops. These concerns include insect resistance issues and possible threats to non-pest insects (Tabashnik *et al.*, 2008).

**Method of action:**

As reviewed by Kumar *et al.*, *Bacillus thuringiensis* (*Bt*) is a “*naturally occurring, gram-positive, spore-forming soil bacterium*”, known as *Bt* toxins, δ-endo toxins or crystal proteins that form in its cells through the sporulation process as parasporal crystals (Kumar *et al.*, 2008, p642) (see Figure 1.10). These crystals are principally constructed from one or more proteins (*Cry* and *Cyt* toxins). *Cry* proteins, which form as parasporal inclusions that have been proven to have toxic impacts on target organisms. Equally, as outlined by Berry *et al.* and others, *Cyt* proteins are also parasporal inclusion proteins that display hemolytic (cytolitic) activity (Bravo *et al.*, 2007, Berry *et al.*, 2002). In ‘naturally’ occurring *Bt* strains, toxin production is
normally found to accompany post-exponential growth (Schnepf, 1995). The main pests that Bt insecticides target include various lepidopterous (butterfly), dipterous (flies and mosquitoes) and individual coleopterous (beetle) species (Kumar et al., 2008). In addition, other strains have been found to be detrimental and lethal to nematodes (Edwards et al., 1988).

*Figure 1.10: Bt crystals magnified (x15, 000)*

As pointed out by Perferoen, like with many bacteria, Bt can slow or halt its vegetative growth and encapsulate in a spore when experiencing adverse conditions. Normally, when sporulation begins, the Bt bacterium produces proteins that accumulate as crystals adjacent to the spore. It is understood that in nature, when Bt spores and crystals are ingested by specific organisms, the crystal proteins destroy the gut wall and thus create an excellent situation for germination and vegetative growth of the B.t bacteria (Peferoen, 1997). A proposed mode of action of Bt has been outlined Knowles and Dow as can be seen in Figure 1.11. More recently, Zhang et al. suggest that the Cry toxin produced by Bt causes the death of insect cells by activating a Mg$^{2+}$-dependent cytotoxic event after binding of the toxin to its receptor BT-R$_1$ (Zhang et al., 2005).
At least ten genes encoding for different *Bt* toxins have actually been genetically engineered into plants. These include:

- *cry1A*(a), *cry1A*(b), *cry1A*(c),
- *cry1B*(a),
- *cry1C*(a),
- *cryH*,
- *cryIIA*(a), *cryIIIA*, *cryVIA* and *cryIXC* (Kumar *et al.*, 2008).

The majority of Cry proteins have a characteristic range of insects they can kill. For example, the *cry1A* and *cry1C* genes which code for the Cry1A and Cry1C proteins respectively, are specifically lethal to larvae of lepidopteran pests such as the codling moth (*Cydia pomonella*), the European corn borer (*Ostrinia nubilalis*) or heliothine bollworms. On the other hand, CryIIIA protein is deadly to coleopteran pests (e.g., the Colorado potato beetle) (Schuler *et al.*, 1998).
The above section reviewing modern plant biotechnology of HT and *B.t* GM crops show the different technology applications, different innovation goals, different market uptake and the different outcomes to underline the fact that not all GM crops are the same. This provides a basis for the argument that policy instruments and regulatory frameworks should be developed on a case by case basis on phenotypic output rather than on categories defined by overly simplistic grouping definitions.

### 1.5 Conclusions

This chapter examines the fundamental science and key technologies that have formed the scientific basis for the policy issues that are associated with modern agri-biotechnology (specifically GM crops). A number of key conclusions can be derived which will inform the science-policy interface analysis in later chapters and help contextualise the finding of this thesis.

Firstly, by examining the history and evolution of the term biotechnology it can be placed in a historic perspective. This allows an understanding of the framing that has occurred which is important as ‘framing’ often establishes the science-policy relationship and influences how it changes (Nisbet *et al.*, 2003). Evidence suggests that transition/evolution of biotechnology has occurred over time to allow the formation of a scientific discipline from heterogeneous origins (Buchholz, 2007). This is an important observation, as often such evolution can change the science-policy interface by virtue of the fact that once becoming a ‘scientific discipline’ critical mass can be gained (i.e. in those involved in the discipline, in the flow of funding to support it, etc.). With this critical mass, influence on policy spheres can be brought to bear. As such, biotechnology as a discipline, has become able to assert influence within the institution that is body science and equally within the public and/or private institutions at large in which it is placed (Mukerji, 1989, Jasanoff, 2007, Brown, 2009).

Secondly, the review undertaken in this chapter allows a conclusion to be formed that ‘genetic modification’ is not new but rather that there has been an increasing involvement and investment by humans into an ever more complex and technical endeavour that is plant
breeding today. Moreover, many of technical advancements in plant breeding that have occurred prior to ‘transgenics’ have brought about massive changes in ecology (e.g. seed saving), socio-economic structures (e.g. F1 hybridization), etc. This investment and resulting new technologies is rapidly advancing and current definitions based on GM versus non-GM are unsustainable from a technical stand point. The fact such a level of human investment exists and has increased over time allows for new classifications of certain stages of plant breeding based on increasing levels of human involvement over time (Figure 1.3). Such definitions can thus be used in the policy arena to base key tools such as risk assessment, risk management and risk communication. It is this arena of policy, and its relationship with science, that the next chapter examines.
Chapter 2

Analysis of Irish and EU Plant Biotechnology Policy

“When a scientist says something, his colleagues must ask themselves only whether it is true. When a politician says something, his colleagues must first of all ask, 'Why does he say it?'”


Notation: Elements of this chapter are taken from the papers below where S. Morris researched and wrote all elements used:

2.1 Introduction
This chapter examines the science-policy interface surrounding the making of plant biotechnology policy in Ireland and Europe. Using policy process theory, the factors that shape biotechnology risk management policy in Ireland are examined. The first step in this process is mapping the plant biotechnology risk policy pathway in Ireland and in the European Union (EU) over. The examination and in-depth understanding of policy both at the national level and the European level are necessary as they are both closely intertwined, due to Ireland’s membership of the EU.
All human activities carry inherent risks. Thus the activity of policy-making to manage risk is as old as human society (Sjöberg and Thedéen, 2010). Once a risk issue enters the social realm (e.g. via the application of a new technology) it is subject to the political and intellectual web that is the ‘risk society’ (Beck, 1992, Giddens, 1999). How society (and its elements) handles a risk issue is an area of much research, review and debate (Mythen, 2007, Assmuth et al., 2010, Luhmann and Barrett, 1993, Felt and Wynne, 2007, Pellizzoni, 2010, Stankiewicz, 2009). Policy is one of the primary tools a modern democratic society has to deal with risk issues (Renn, 2008a). A policy can be defined as a statement by a government (i.e. decision makers in a state) of what it “intends to do or not to do, such as a law, regulation, a ruling, decision or order or a combination of these” (Birkland, 2005, p. 139). In general, the policy making process can be envisaged as “a complex system of inputs and outputs” (Easton, 1965, p.43) where problems are identified and considered by government for elucidation after which government institutions develop policy options and political representatives select solutions from policy opinion, and those solutions are executed, appraised and revised if necessary (Sabatier, 2007, p. 3). Policy is also important because it functions as a statement of government intentions, priorities and expenditures thus allowing the public to hold the government accountable (Benson, 2008). Included in expenditures is the public funding of research which can be also driven or influenced by policy (Lomas, 2000) and can lead to tensions between publicly funded scientists and policy makers (Choi et al., 2005).

Key phases in the evolution of policy making include the emergence of liberalism and the “inexorable process of democratisation that stirred in the seventeenth century and gathered speed in the eighteenth and nineteenth centuries in Europe and America” (Spragens, 2008, p86). The term “democracy” finds its roots in Greek where the words demos, meaning “the people”/“the many”, is joined with the word kratos, meaning “rule” or “power”. Information or knowledge are not included in the meaning of the word democracy. Noteworthy is the fact that both Plato and Aristotle held the opinion that democracy is an inferior form of government as it was the rule by the ‘many’, where the many were the unqualified. (Grube, 1992, Reeve, 1998). Nevertheless, Aristotle believed democracy to be “a necessary condition for good government, ... [but] far from a sufficient condition” (Crick, 2002, pg.24).
One challenge in policy making within a democratic society is the design of risk management policies that mitigate risks to society, while taking into account the will of every citizen. Policy design under these conditions is challenging since policy makers are using information (i.e. knowledge and evidence) to choose the best policy solutions while at the same time they are trying to uphold what Thomas Jefferson defined as “the lex majoris partis” [i.e., the law of the majority] which is “the fundamental law of every society of individuals of equal rights” (Hampsher-Monk, 1992, p.228). This challenge is especially difficult within the innovation arena as innovative products can often create new and varied risks to various sectors of society.

2.2 What is the Science-Policy Interface?

While the science-policy interface can be envisaged in several ways, the most complete definition describes it as “a social process which encompass relations between scientists and other actors in the policy process, and which allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision-making” (Van den Hove, 2007, p807). Among all the inputs and outputs in the policy making process, a key element is knowledge (or at least ‘best available knowledge’) (Stiglitz, 1999). Considerable literature exists regarding the role of knowledge and information in the policy making process (Van Kerkhoff and Lebel, 2006, Adams, 2004, Ingram et al., 2007, Birkland, 2005, Sabatier, 2007). Knowledge is used in the policy process to define problems, weigh options and make policy decisions and as such is frequently brought to bear on questions of risk that require consideration from a policy perspective. Risk, as defined by Covello and Merkhofer, is a combination of elements that are not desired and that are ambiguous. More specifically, "the possibility of an adverse outcome, and uncertainty over the occurrence, timing or magnitude of that adverse outcome" (i.e. Risk = hazard X exposure) (Covello and Merkhofer, 1993, p2). According to Slovic et al., within the process in how risk is perceived, there is a set of complex interactions that occur between the ”attraction poles” of emotion and reason (Slovic et al., 2004). This can lead to an alternative and more populist (or political) definition of risk such as “risk=hazard X outrage” (Sandman, 1988).
A pivotal issue is how risk is handled in the policy making process. While science clearly has a role in helping to describe and quantify risk, this role is always limited by the fact that some risks can also be viewed as cultural constructs that could extend beyond the capability of scientific assessment (Hansson, 2010). It is often difficult to separate “hard” facts from “soft” values within the realm of risk in the public policy field. Nevertheless, decision makers tend to be attracted to science-based decision making when partaking in risk management (i.e. deciding what to do about risk). An example of this is the 2008 avowal by the then UK Environment Minister Phil Woolas stating “Government ministers have a responsibility to base policy on science” (Percival, 2008).

The use of science to produce evidence regarding why and how things work is a key role that science and scientists have in the policy formalization process, especially relating to the management of risk pertaining to innovation (e.g. GM crops). Generating scientific knowledge and information to support biotechnology regulatory decisions will continue to be emphasised in the future (McGloughlin, 2000). This is important as “regulations should be to insure safety and efficacy, to limit potential product risks while encouraging innovation and economic development” (McGloughlin, 2000, p201) which is a key element for a knowledge based economy (where the role of scientific knowledge [and derived technologies] becomes a key focus/element to building and maintaining the economy – see below (Motherway et al., 2003, Trench, 2009)).

Scientific ‘evidence’ has now established itself in a very strong and special position within the realm of policy-making (Cartwright et al., 2009, Montuschi, 2009, Laforest and Orsini, 2005). Often how ‘sound’ and publicly defensible (i.e. acceptable) a policy decision is, tends to be measured by how ‘scientific’ and ‘rational’ it is. (Neylan, 2008, Weiss et al., 2008, Parsons, 2002, Pielke, 2007). This occurs as policy decision makers often convert scientific knowledge and/or ‘best available evidence into a programmatic idea as part of policy making, in the hope that the authoritative nature of science would provide a degree of legitimacy thus helping to protect policy choices from subsequent challenge (Salter et al., 1988). As a result, science can clearly be employed as a foundation to support political or moral claims (Nisbet et al., 2003). In fact, science is not only a source of legitimacy for advancing new policies, but can also be
used for delaying or avoiding action (e.g. the precautionary principle) and for justifying unpopular decisions e.g. carbon taxes (Boehmer-Christiansen, 1995). In addition, from a socio-economic perspective most OECD nations (including Ireland) are attempting to mould a knowledge-based economy where the role of scientific knowledge (and derived technologies) becomes a key focus/element to building and maintaining the economy (Motherway et al., 2003).

At the same time, definite tensions now reside in the relationship between science, regulation and political decision-making (Taylor, 2006) which is a policy challenge that is firmly rooted in the ‘biopolitics’ of biopolicy (Meyer-Emerick, 2007). This is reinforced by the fact that “biopolitics will be largely articulated around the politics of knowledge; the politics of the definition and legitimation of risk” (Delanty, 1999, p43). The argument that the predominance of science in the policymaking arena pertaining to risk suppresses democracy adds to this tension. This belief is based on the premise that to be active at the science-policy interface currently demands a level of scientific expertise or a position of decision making power thus defining, in a limiting fashion, who can be included in the elitist ‘science based’ decision making process. Furthermore, it has been suggested that the image of science as being neutral in terms of the global economy and related issues of globalization is misleading. This image is not very consistent with the global economy’s high dependence on constant technological innovation supported by investments. This has led some to the impression that scientific discovery and technological innovation “appear to be inescapably directed and supported by the interests of capital” (Tovey, 2009, p15) and can explain the emerging social distrust of science that has occurred in many societies (Pellizzoni, 2003, Tovey, 2009, Nowotny et al., 2001). Others propose that certain technology types (e.g. biotechnology) could be deemed a ‘religion’ (Turner, 2004). Certain sociologists put forward the idea of science as an ‘institution’ which embodies particular and contentious social assumptions such as being self-protectionist, power centric and elitist (Hartung, 1951). Some believe “institutional science” has overreached scientific knowledge and understanding to become an “arrogant scientism”. Coupled with a denial of ignorance by scientists (i.e. concerning levels of uncertainty) on a “repeated, habitual basis” (described as an act of “irresponsibility”), ‘science’ is even deemed
by some as a form of “violence” as it destroys the legitimacy and integrity of the cultural ‘other’ (Wynne, 2007, p350-368).

The basis for such extreme characterizations of science’s role in risk management has its roots in the notion (and narrative) that the evidence basis for decision-making is confronted with a growing number and type of scientific uncertainties and does not properly integrate society’s values and concerns that requires the institution of science to carry out some reflex thinking. However, Beck (1992) proposes that reflexivity could cause a lack of trust in experts and scientific establishments. Nevertheless, in Beck’s ‘World Risk Society’ thesis, the concept of the global risk society where a “reflexive modernity” exists, is one where key and often central elements of the modern industrial civilisation are questioned (Beck, 1999). For example, the idea that science and technology cannot and do not provide definitive answers/solutions to key social and environmental problems. In addition, it has been proposed that the relationship between established science and unconventional knowledge has become unclear and that political pressures play on the scientific process changing the boundaries of expert and lay knowledge (Beck, 1999, Irwin and Michael, 2003, O'Mahony, 1999). Beck suggests that when scientists acknowledge publicly that scientific uncertainties exist within the realm of scientific and technological developments, a space is created for broader societal involvement and enhanced democratization (Beck, 1999). As a result, he and others have pleaded for a cultural change in science that would make it more democratic, take greater inter/transdisciplinary approaches (e.g. ‘post normal science’), and would apply a greater level of reflexivity (Funtowicz and Ravetz, 1994, Power and McCarty, 2006, Welsh and Ervin, 2006). However, theses authors tend to be unclear about how they want to deal with the often subjective nature of risks (Hansson, 2010, Guehlstorf and Hallstrom, 2005) or how such inter/transdisciplinary approaches should be incorporated into the realpolitik of decision-making (e.g. how should the science-policy interface be changed in practical terms to meet their suggestions).

To further understand the intersection of the so-called science ‘culture’ with the world of policy, a deeper examination of the science-policy interface is required as this interface is a critical part of the policy process. As evident by the definition of a science–policy interface
provided by Van den Hove above, connections and dynamics are involved in the relationships between the actors at the interface (Figure 2.1). As a result, how a science-policy interface is constructed and how it works is key for how questions of risk are handled and processed (e.g. risk assessments, etc.) within the policy process (see section 2.3) (Cash et al., 2003, Cash and Moser, 2000, Siebenhüner, 2003). Yet, within the literature there is currently little if any agreement on how to either model or bridge the gap between science and policy making (Turton et al., 2007, Godfrey et al., 2010, Pullin et al., 2009, Bäcklund et al., 2010, Juntti et al., 2009).

Figure 2.1: An example of a science-policy interface between forest scientists and forest policy-makers in Europe

There are numerous reasons for the absence of a single model to describe or explain the science-policy interface. A major challenge is the fact that the path to answer questions on a
risk issue relies on knowledge elements that are often produced in a narrow discipline of research, synthesized into studies and then translated into the world of policy making via what one can describe as “chaotic diffusion” (Irwin and Michael, 2003). This is aggravated by the fact that often important and particularly difficult policy questions (e.g. GM technology, climate change, geo-engineering, poverty, etc.) are considered “wicked” policy problems (Rittel and Webber, 1974, Coyne, 2005). Such problems are typically linked with other challenges or issues while being multidisciplinary in nature. Consequently, as outlined by Legge and Durant, they involve “trade-offs among competing scientific, ethical, social, ideological, and moral values and often challenge the regulatory predilections and acumen of governments” (Legge and Durant, 2010, p62). As such, policy making can quickly turn into a “collective puzzlement on behalf of society” (Heclo, 1974, p305). This complexity can be visualized in the triologue science-policy representation model (see Figure 2.2) as proposed by Turton et al. (Turton et al., 2007) to capture the critical relationships between government, society and science.

Figure 2.2: Triologue science-policy representation model

Source: (Turton et al., 2007)
Apart from the complexity of the subject-matter and the complexity of the policy space, such issues raise the problem of a clash of cultures, as scientists are generally far more comfortable dealing with notions of risk and uncertainty than policy makers (Bradshaw and Borchers, 2000). This can lead to a mutual misunderstanding of the science and the policy processes. For example, decision makers and the public often expect science to produce black and white evidence on tap. However, in reality the scientific process and the evidence output it produces often take time and are bound by variables, conditions, and assumptions which often fail to make the evidence conclusive in all possible circumstances. A case in point is attempting to answer the seemingly simple question of what are the risks and benefits of GM crops. Scientists cannot give a simple list as the evidence is bound by variables such as what type of crop, in what location, in what environment, etc. This can lead some to claim that “science is uncertain”. However-or “indeed”, by definition all science is uncertain. Furthermore, as more risk and science information/knowledge become available, it becomes more difficult to translate the often enormous amounts of data/evidence into politically organised conduct, such as policy making or regulation making (Bertilsson, 2002). From a policy perspective, Beck points out that even with much scientific input this input tends to add to the uncertainty thus undermining its’ the intention of the scientific intervention (Beck, 1992).

To compound the matter further, attempting to reach scientific consensus regarding a piece of evidence can be very difficult as a broad range of considerations must be taken into account. These include social, cultural, political, and economic elements in addition to epistemic ones. The building of scientific consensus can take years or even decades (Shwed and Bearman, 2010). Nevertheless, even when what can be defined as scientific consensus is obtained, scientific uncertainty is never fully eliminated (Webster, 2007). By definition there is no such thing as scientific certainty to a level of 100%. Scientists are used to debating epistemic and methodological issues in their own specialties that have a degree of uncertainty or as yet lack concrete evidence. However, such debates do not often involve the public or public institutions at large. Lack of consensus (and the related uncertainty this causes) in itself can, as pointed out by Naomi Oreskes:

“become a public policy issue when there is a public stake, i.e. a moral, political, or economic stake. In such cases, science can play a policy role by providing informed
opinions about the plausible consequences of our actions (or inactions), and by monitoring the effects of our choices” (Oreskes, 2004, p381).

Nevertheless, even when solid ‘best available’ evidence exists, the obtainability of information does not necessarily automatically transform into policy action as information needs to be received, believed, and be found to be relevant and operationally valuable to the policy makers. Policy makers must decide to translate the information but must also have the capacity (i.e. knowledge, capability) to turn it into tangible policy. (Lahsen and Oberg, 2006).

As outlined above, there is a long list of issues that make the science-policy interface a challenging place for both the policy maker and the scientist. Sybille van den Hove outlines these challenges under four headings: outputs, processes, actors and context (see Figure 2.3) (Van den Hove, 2007).
The position of the science-policy interface within the policy process is also critical to the management of risk. In the past, a uni-directional and linear model of the science-policy interface described a policy process starting with scientific risk assessment producing “evidence”, which risk managers then accepted and processed with other information during the risk management step to produce policy outputs, which would then be communicated via risk communication (see Fig 2.4). This was known as the Red Book Model, as it was based on the red covered US National Research Council’s 1983 publication: *Risk Assessment in the Federal Government: Managing the Process*. The model was adopted by the US government
(Jasanoff, 1990) and also adopted as a standard approach by the WHO and the OECD (Millstone, 2009).

**Figure 2.4: The Red Book Model**

![Red Book Model Diagram](source)

Such models assumed that the applicable scientific knowledge was objective and essentially neutral from a political standpoint. However, within social science literature several authors posit that risk assessment is subject to political, social and regulatory contexts and factors (Winickoff et al., 2005, Covello and Merkhofer, 1993). Covello and Merkhofer went as far as stating that “The idea that scientific data are entered into a risk assessment that is free, or nearly free, of policy considerations is considered beyond the realm of possibility” (Covello and Merkhofer, 1993, p319). It has been suggested that political culture can and does influence how governments risk manage uncertainties that are related to technological innovation (Jasanoff, 2005b). This has led to the suggestion that scientific cultures are at one and the same time political cultures (Jasanoff, 2005a). Jasanoff has also pointed out that these so-called culturally different contexts found in different political arenas/countries can help explain why judgments about the same hazard, based on the same scientific knowledge and evidence, do not always lead to the same estimates of risk in different national regulatory systems (Jasanoff, 2000).
In suggesting that science and policy should be acknowledged for their close relationship instead of claiming that they are separate, Eric Millstone has proposed a “co-evolutionary approach” to replace the linear ‘Red Book’ model, where science-based risk assessment is “sandwiched between up-stream framing considerations and down-stream interpretative judgments” (Millstone, 2009, p627) (see Figure 2.5).

Figure 2.5: Millstones Co-evolutionary approach model

The Co-evolutinary Approach Model assumes that the upstream and downstream contexts can affect the content, direction and outcome of risk assessment deliberations (Millstone, 2009). An attractive element in this model is the fact that interaction at the science-policy interface occurs before the output of evidence from the risk assessment step, as key elements in the framing of the risk assessment step would be decided upon with the risk assessors (i.e. scientists) together with interested parties earlier in the policy process in a transparent manner.

2.3 Policy Process Theory
To further explain, examine and analyse the importance of the science-policy interface it is useful to consider policy process theories. Such theories can provide insights, via diagnostic
and prescriptive inquiry, into policymaking pertaining to a certain arena (in this case, plant biotechnology risk management policy). In doing so it becomes possible to illuminate why public policy choices and their outputs evolve, stay static, vary between sectors, and differ in terms of their impacts on publics that consume and appraise them. A number of key theoretical frameworks exist today to explain policy process (Nowlin, 2011). However, the traditional concept of the policy process assumes policy making occurs in progressive stages from issue emergence to enactment of policy to policy evaluation (Easton, 1965)(see Figure 2.6).

**Figure 2.6: Easton’s Stages model of the Policy process (Easton, 1965)**

![Easton's Stages model](image)

Source: adapted from (Easton, 1965)

The stages heuristic or “textbook approach” played a very important role in the 1970’s and 1980’s, often dividing exceptionally complex policy questions into discrete and manageable segments that stimulated some excellent research within these component stages (Sabatier, 2007). Nevertheless, some problems were identified with this approach. These included the following key criticisms:

1. Causal drivers that operate across stages are not identified (Sabatier, 2007)

2. While normative in nature, the policy process in reality does not often follow the sequence of stages (Nakamura, 1987).
3. The stages approach focuses on one policy pathway at a time. It does not incorporate well the normal process of multiple and interacting policy cycles, involving numerous policy proposals and legal outputs (Hjern and Hull, 1982, Sabatier, 1986).

Over the past 30 years a broader range of models of the policy process have been developed (Birkland, 2005, Nowlin, 2011, John, 2003). These include five prominent models that are often used in both the science-policy interface and the risk policy development literature and one emerging model, namely:

1. Kingdon’s multiple streams model,
2. Advocacy Coalition Framework model,
3. Punctuated Equilibrium model
4. Institutional Analysis and Development Framework model
5. Narrative Policy Framework model

2.3.1 Kingdon’s Streams Model:
This theory proposes that policy issues gain agenda status and solutions are decided upon when multiple (two or more) “streams” (i.e. the problem stream, the policy stream and the political stream) meet to allow a window of opportunity for policy change to occur (Kingdon, 1995). The streams consist of actors and processes: the problem stream consists of information about various problems and the proponents of various problem definitions; the policy stream contains the possible action avenues to solve the problem; and the political stream consists of elected officials, elections and public opinion (Birkland, 2005, Zahariadis, 2007). It is clear that Kingdon’s streams theory puts expert-based information within two of its streams. First, in the problem stream, science is employed by actors to highlight the gravity and source(s) of a problem. Science can also be used by actors to help assess the efficacy of current policies and programs. Second, in the policy stream, science can offer ideas, form the basis for solutions and alternatives, bestow creditability and legitimacy to ideas, and equip policy makers/entrepreneurs with a method to advocate for the technical feasibility of an idea (Birkland, 2005, Weible, 2008). Overall, from a science-policy perspective, it is noteworthy that according to this model those involved in the policy process can thus use science in problem identification and solution evaluation. However, the effect or impact of this science based expert-based information will depend on the political abilities of an advocate to
communicate and make relevant this information to successfully shape agendas and policies (Weible, 2008).

Figure 2.7: Kingdon’s multiple streams policy model

Criticism of Kingdon’s multiple streams model is focused on two areas. Firstly, the distinct policy streams as conceived by Kingdon are in fact too independent of each other. In reality separation into one stream or another is not clear cut. Secondly, factors which may exist outside the streams that can evolve to influence the streams are not captured by the model (Mucciaroni, 1992)
2.3.2 Advocacy Coalition Framework:

The advocacy coalition framework (ACF) is a model of the policy process that attempts to deal with “wicked” problems (Coyne, 2005, Rittel and Webber, 1974). This model centres on the interaction between advocacy coalitions within a policy arena. The model proposes that such advocacy coalitions are comprised of actors/interest groups from different institutions who have or choose to share a set of policy beliefs and/or principles (Sabatier, 2007). As such, the competition that develops between actors or between groups of actors (coalitions) is mediated by policy brokers who are invested in finding a solution to the problem in question. The policy brokers have a greater chance of success if they can create compromises between competing advocacy coalitions that do not injure a coalitions’ core beliefs and values (Birkland, 2005, p. 226). Essentially, the advocacy coalition framework considers policy as the exchange or translation of beliefs to and from different coalitions around an issue (Sabatier and Jenkins-Smith, 1993). These coalitions often use science and those within their groups who claim scientific expertise will use it to marshal allies and to engage with opponents at the science-policy interface (Weible, 2008). In this context it is envisaged that expert-based information can impact policy in a non-direct manner by “policy-oriented learning” where the attitudes and/or beliefs actors are modified based on new evidence (e.g. new scientific evidence) (Sabatier, 1998). However, it has been shown that ‘policy-oriented learning’ normally occurs at the level of the organisation or group over time (as turnover of members and leaders occur) as individuals’ core beliefs do not change easily, even in the face of new evidence (Bandelow, 2006). As such, the distinguishing element of the ACF is that the value system that advocacy members hold may not change regardless of the ‘evidence’. Their beliefs can be related to core values that individuals and groups hold and share (e.g. a coalition’s perception about the appropriate distribution of resources in society) which they express and advocate for via a coalition in an effort to translate their beliefs into public policy by mobilising political resources etc. (e.g. anti-abortionist groups, religious groups, etc.).
While the above demonstrates that the ACF model offers benefits in understanding policy creation and its evolution, it has also been argued that the model has a number of weaknesses. These include the suggestion that the ACF model does not incorporate coalition behaviour very well (Schlager, 1995) nor adequately deals with the concept of self-interest in the policy process (Compston and Madsen, 2001). In addition it has been claimed that it does not address the stages of the policy cycle in a robust manner (Marzotto et al., 2000). Proponents of the ACF model, have been open to incorporating the lessons and insights gained over the last 25 years of its use and have addressed many of the past criticisms to the extent possible (Weible et al., 2011).
In 2002 an Irish doctorate research project employed a form of the ACF to the GM debate (Desmond, 2002). While this research shed light on the debate and its actors (suggesting actors mutually co-constructed each other) it was relatively limited in time (i.e. less than 10 years) and scope (i.e. it only focused in ‘elite’ actors and the micro-processes of the regulatory framework).

2.3.3 Punctuated Equilibrium Theory:

The punctuated equilibrium model is derived from the field of evolutionary theory where it is used to explain the process in how change occurs on the evolutionary pathway of a species and has been also imported into the policy domain (Prindle, 2012). It proposes that policy change pertaining to an issue occurs when after long periods of stability, these stable periods are ‘punctuated’ by relatively sudden shifts in attention and/or interest toward the issue in question (Baumgartner, 1993, Baumgartner and Jones, 1991). These punctuations lead to policy change opportunities that can result in a policy tipping point which can cause sharp and explosive policy change (Baumgartner and Jones, 2002, Baumgartner and Jones, 2009, True et al., 2007, Sabatier, 2007, Givel, 2010). Seen via a political power lens, the model proposes that political power relationships between groups of interested parties remain relatively stable over long periods of time, punctuated by relatively sudden shifts in public, political or media understanding of problems and in the balance of power between the groups seeking to promote their policy solutions (Birkland, 2005, p.228). Punctuated equilibrium theory builds on the observations that policy processes are often subject to lurches and jolts rather than proceeding on a stable incremental development path (Sabatier, 2007). As outlined by Weible, “the causal driver in the punctuated equilibrium theory is the pace with which actors process information, shift their attention, and change the policy image. Policy images reflect both emotive and empirical social constructions of an issue” (Weible, 2008, p618). In 2009, Baumgartner and Jones also posited that punctuated equilibrium type changes in policy can result from "disruptive dynamics" that can include interfaces between interest groups, elected officials, political parties, and legislative committees, as well as via military conflicts, new technologies and scientific changes, radical economic change, and more (Baumgartner and Jones, 2009, Repetto, 2006).
From a science-policy interaction perspective, those wishing to protect the status quo might use science to fortify or disrupt the legitimacy of current policies while those wanting punctuations will use science to challenge the legitimacy of current processes (which includes publicizing research that supports their position and mobilizing allies in the science arena) (Pralle, 2006). The seminal example is the nuclear power industry (Duffy, 1997, Sabatier, 2007). In this policy arena scientists were used/helped to develop the positive policy image of the industry after World War II. Nevertheless, scientists in the 1960’s, also leaked safety concerns that led to a change in policy image resulting in key changes in the industry in the 1970’s (e.g., new flow designs to prevent fuel blockages (Krivit et al., 2011)). Larger impacts were caused in nuclear policy by the incidents at Three Mile Island and Chernobyl. More recently, the events at Fukushima Dai-1 Nuclear Power Station on March 11, 2011 has again caused dramatic punctuations in nuclear power policy around the world including sharp and rapid shifts in Germany’s, Italy’s and Switzerland’s national policies. For example, on March 14, 2011, German chancellor Angela Merkel temporarily shut down the country’s seven oldest nuclear power plants and then on May 30 Germany announced it would cease operation of all nuclear reactors by 2022. Commentators have suggested this was the “swiftest change of political course since [German] unification” (Anon, 2011b).

Several elements of science-policy interface dynamics can be explained from a punctuated equilibrium vantage point. These include the observations that:

“(i) the causal driver within the punctuated equilibrium theory is the pace with which actors process expert-based information; (ii) disproportionate risk information processes result in creating, maintaining, or destroying a policy image; (iii) expert-based information affects the expansion of conflict and the mobilization of political interests; and (iv) expert-based information can be a contributing factor to both incremental and major policy change” (Weible, 2008, p618).
One key criticism of the punctuated equilibrium model is that it measures only two elements of change: mode (incremental vs. paradigmatic) and rate of change (Cashore and Howlett, 2007) and is not particularly interested in analysing the content and quality of policy change (Capano, 2009). However, the theory has evolved based on prior critical analysis (Jones and Baumgartner, 2012).

2.3.4 Institutional Analysis and Development Framework
Institutional Analysis and Development Framework (IAD) is a model based on institutions who make decisions regarding final policy actions (Ostrom, 2011). As such, these institutions are defined by the common ideas employed by people who are subjected to rules and system norms, however this definition can also include individuals who can become “self-governing institutions” (Ostrom, 2007). Within the IAD framework it is proposed that the policy processes and its results are influenced to varying degrees by the impacts of four main variable
sets, namely: (a) characteristics of the physical world, (b) attributes of the community in which actors reside (c) incentives creating rules and constraints, and (d) interactions with others (Figure 2.10) (Ostrom, 2005). An important element of the framework is the ‘action situations’ and the resulting configuration of interactions and results (outcomes). Action situations are the “social spaces where individuals interact, exchange goods and services, solve problems, dominate one another, or fight (among the many things that individuals do in action situations)” and can be employed to “describe, analyse, predict, and explain behaviour within institutional arrangements” (Ostrom, 2011, p11). The key advantage of the IAD framework is that it is very flexible and has the ability to allow for broad analysis of a policy issue or political arena (e.g. (Basurto and Coleman, 2010). However, it functions as framework as opposed to a model which has drawbacks in terms of applicability across issues.
Figure 2.10: Institutional Analysis and Development Framework

Figure 1. A Framework for Institutional Analysis. Source: Adapted from E. Ostrom (2005, p. 15).

Figure 2. The Internal Structure of an Action Situation. Source: Adapted from E. Ostrom (2005, p. 33).

Source: adapted from (Ostrom, 2011)
2.3.5 *Narrative Policy Framework:*

This is an emerging area, (under development since 2004 in response to criticisms of postpositive approaches in public policy as being “*largely nonfalsifiable*”), that examines the policy process in terms of how they are influenced by narratives (Jones and McBeth, 2010). From this perspective, it is posited that the public perceive policy issues as narratives where there are all the components of a story: plots, context, characters (including heroes, victims, villains, etc.). This framework outlines how the narrative can operate at both a micro level (the individual) and a meso (group or coalition) level. At the micro level, the variables that can impact the policy level include the individual’s view of the world; who the individual believes are the heroes, villains, etc.; and the link that the narrative has with prior beliefs of the individual and the individual’s level of trust in the source of the narrative. At the meso level, Jones and McBeth propose that such narratives are used strategically during the policy debate and/or process. As such, it is postulated that “*winners*” will contain the conflict using narratives, “*losers*” will try to expand or inflame the debate via narratives and both will try to employ narrative to split opposing coalitions. This framework is attractive as it is flexible and clearly easily applicable, even to complex policy issues. It lends itself to being used in conjunction with other policy process theories as has already been done with the actor coalition framework (Figure 2.11) (Shanahan *et al.*, 2011). However, as it is an emerging area it has not yet been employed very extensively in policy analysis studies.
Figure 2.11: Narrative Policy Framework

Source: (Shanahan et al., 2011)
2.3.5 Comparisons of policy process theories/models and frameworks:

While the above theories, frameworks and models of the policy process are all different in both approach and application comparing them is made difficult as the literature indicates that there is not a general recognition of the differences between models, theories and frameworks (Ostrom, 2007). However, attempts have been made to compare and contrast three of them, namely Kingdon’s stream model, the actor coalition framework and the Punctuated Equilibrium theory. Analysis developed by Schlager and Blomquist (Schlager and Blomquist, 1996, Edella Schlage, 2007) shows a comparison based on (1) the role of the individual, (2) collective action, (3) institutions, and (4) the policy change focus. As such the following comparative points are made:

1. Role of the individual: If the assumption is made that individuals are rational, then the punctuated-equilibrium theory shows that the individual’s preferences can evolve over time in ‘stops’ and ‘starts’; the advocacy coalition framework can be applied to empirically categorize individuals into interactive groups; while Kingdon’s stream model indicates the importance of individuals in certain streams and their need to come together.

2. Collective action:
Collective action (the working together of groups in an organised manner) is a key driver in policy change. The punctuated-equilibrium theory suggests that collective action grows over time and leads to sporadic changes in policy. The advocacy coalition theory defines a collective’s actions and how they occur via coalition definitions that can change or be changed. Kingdon’s Stream model shows how collective action can occur based on crossing issue streams.

3. Institutions:
Institutions can set the frame in which decisions are taken and they are crucial in how policy change decisions are made and by whom. In the punctuated-equilibrium theory, institutional structure and power arrangements are critical defining the context in which decision makers act to bring about policy change.
4. Policy change:
While all the three policy change approaches deal with measuring policy change differently they all however on major policy shifts.

Another approach to comparing and contrasting the three policy change models/theories applies has been proposed by Giliberto Capano who has applied both an epistemological and theoretical lens to the comparison question. He has used various aspects of epistemological and theoretical choices on which to compare policy change frameworks (see Figure 2.12) (Capano, 2009).

This review of policy change process model/theories allows an understanding of the various approaches for examining policy change. Consequently, in the next section Irish policy related to plant biotechnology risk management in Ireland is examined to explore whether the punctuate equilibrium theory can describe the policy change process that has occurred.
Figure 2.12: Comparison Table of Policy Process Framework Models

<table>
<thead>
<tr>
<th>Epistemological choices</th>
<th>Kingdon’s Multiple Stream</th>
<th>Punctuated Equilibrium Model</th>
<th>Advocacy Coalition Framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Way of event progression</td>
<td>Non-linearity (ambiguous and unpredictable)</td>
<td>Disconnected linearity (partially predictable)</td>
<td>Linearity (partially predictable)</td>
</tr>
<tr>
<td>Dynamics of development</td>
<td>Not prefigured but predominantly evolutionary</td>
<td>Evolutionary (sequence slow/rapid changes)</td>
<td>Not prefigured</td>
</tr>
<tr>
<td>Motors of change</td>
<td>Partially constrained chance and entrepreneurship</td>
<td>External crisis, partisan change, conflict</td>
<td>External factors, partisan change, confrontation, learning</td>
</tr>
<tr>
<td>Theoretical choices</td>
<td>Particularly focused on agenda setting. No distinction among different types of policy change</td>
<td>Particularly focused on punctuations in agenda setting, in policy image construction, and in legislative behaviour</td>
<td>Covering the entire process. Tripartition of content of changes (based on a tripartition of policy beliefs)</td>
</tr>
<tr>
<td>Definition of policy development and change</td>
<td>Not prefigured even incremental oriented</td>
<td>Structural link between both types</td>
<td>Both</td>
</tr>
<tr>
<td>Type of change (incremental or radical)</td>
<td>Not prefigured</td>
<td>Reversible</td>
<td>Reversible</td>
</tr>
<tr>
<td>The output of change</td>
<td>Co-evolutionary perspective</td>
<td>Macro</td>
<td>Linking macro, meso and micro levels</td>
</tr>
<tr>
<td>The level of abstraction</td>
<td>Structural prevalence but with room for individualistic strategic behaviour</td>
<td>Structural prevalence</td>
<td>Linking constantly structure and agency</td>
</tr>
<tr>
<td>The structure-agency dilemma</td>
<td>Random combinative causality mixing exogenous and endogenous variables, but the exogenous ones seem prevalent</td>
<td>Combinative causality with the prevalence of exogenous variables</td>
<td>Combinative causality – the composition of which depends on the type of change. Major changes are exogenously determined,</td>
</tr>
</tbody>
</table>

Source: adapted from (Capano, 2009)
2.4 Mapping plant biotechnology risk management policy in Ireland

2.4.1 Introduction:
This section reviews and maps the key policy events and the regulatory profile of plant biotechnology risk management in Ireland from 1996 to 2011. Ireland presents a unique opportunity to examine plant biotechnology policy formulation considering its relative Government stability, until recent times (as there was one main majority political party in power during the last decade, with the same prime minister from 1997 to 2008), and minimal restriction on resources during this period due to exceptional economic growth at that time. Such a mapping examination, via the lens of the Punctuated Equilibrium model [as done in other recent studies (John and Bevan, 2012, Jennings and John, 2009, Alexandrova et al., 2012)], allows the construction of how policy is formed, managed and changed around the risk issue of plant biotechnology applications (in particular GM crops as a subset of plant biotechnology) and their derived products in the Irish agri-food value chain.

Ireland experienced exceptional growth during the period of 1996 to 2008 earning the nation the title of “Celtic Tiger”. In 2005, Ireland had the second highest GDP per capita in the EU 27 at €161.2 billion which, expressed in terms of purchasing power standards, was 38.9% above the EU 25 average. Ireland had the third lowest unemployment rate in the EU 27 and the long-term unemployment rate in Ireland was 1.4% in 2005, which was lower than the EU27 average of 4% (CSO, Ireland). Much of the commentary on change in Ireland over recent decades, be it social, political, cultural or economic, shares the common theme of a picture of modernization (Motherway et al., 2003). Ireland has been looking to the knowledge economy, via the research and development sector, to drive renewed growth. Ireland has been focused on fashioning an ecosystem of research and innovation that can guarantee its prosperity into the future (Crawley and O'Sullivan, 2006). This is evident from numerous Irish Government policy statements such as the Irish Prime Minister’s speech on November 13, 2006 at BioIreland 2006 during which he stated

“the Irish Government is committed to the development of Ireland as a world-leading knowledge economy, founded on research, development and innovation, and a highly developed skills base. We are determined that Ireland will continue to be a leading location for the key growth sectors, including biotechnology” (Ahern, 2006, p 1).
During a budget delivery on December 5, 2007 the Government stated that significant and sustained investment in Science, Technology and Innovation (STI) "is an essential part of the drive to make Ireland a more knowledge-driven economy" (Cowen, 2007). In 2008 the Irish Government released a report entitled “Building Ireland’s Smart Economy - A Framework for Sustainable Economic Renewal”, further supporting the concept of a knowledge-based economy which stated “Science, Technology and Innovation are vital to our economic and social progress”(2008). On foot of this initiative an Innovation Taskforce was established to examine how best to position Ireland as an “international innovation hub”. In March 2010 the Innovation Taskforce issued a report on its work in this area. One of the key policy areas covered by the report included the need for a regulatory environment ‘fit for purpose’. The report stated that:

“We must ensure that regulation, where introduced, improves on existing regulation without being overly burdensome on business. We must also look at ways that regulation (e.g. in the clean tech sector) can actually serve to encourage investment. Reform must be achieved through dialogue between the regulatory authorities, Government Departments and the enterprises operating in the sector. We must strike the right balance between business advancement and control, and establish a regulatory environment that is ‘fit for purpose’” (Cowen, 2010, p67).

In September 2010 the Irish Department for Enterprise, Trade and Innovation announced the membership of a new “high-level group to work on a five year prioritisation plan for Government investment in research and 'smart' jobs” within a knowledge-based economy. The aim of this group is to develop priority areas of focus for Irish research. The results of this initiative are yet to be released/published.

Agriculture biotechnology clearly fits within the remit of the knowledge-based economy (Bevan and Franssen, 2006). In addition, at an EU level advances in plant science and agricultural biotechnology have been previously identified as important in ensuring a healthy, safe and sufficient food and feed supply, meeting the challenge of achieving sustainable agriculture, enhanced forestry and landscape systems, developing green products and
improving competitiveness and consumer choice (European Commission, 2004). The Irish Advisory Science Council (established under Irish Government legislation in April 2005) in its *Strategy for Science, Technology and Innovation (2006 - 2013)* declared that a main priority for its seven year strategy is to build a knowledge economy in the agri-food sector. The strategy identified the importance of building a capability in the agri-biotechnology arena in order to assess, harness and adopt new technological innovations and stated:

“potential areas for application include animal and plant sciences, food innovation, forestry and wood chain and other non-food crops, as well as risk evaluation of GMOs and their implications for agri-food. A strong base in bio and nanotechnologies is vital to building and profiting from the bio-economy” (Irish Advisory Science Council, 2005, p61).

In February 2010 the Irish Government, under the auspices of the Department of Minister for Agriculture, Fisheries & Food, announced an initiative “to draw up a long-term strategy for the agri-food, forestry and fisheries sectors”. As part of this initiative a committee was established and public consultations were held. In July, 2010 the committee produced a report entitled ‘Food Harvest 2020’ which contains over 200 recommendations outlining key targets and objectives for the Irish agri-food sector to reach by 2020 (Brady, 2010). From a plant science/plant biotechnology perspective these policy recommendations include the following elements:

- “Relevant state agencies should foster product and production innovation, the adoption of emerging technologies and plant breeding.”

- “With the aim of ensuring the competitiveness and viability of Irish production, DAFF should monitor and appraise policy, trade and commercial developments at EU and other relevant levels with respect to the use of existing and emerging technologies in areas such as biotechnology and genetically modified organisms (GMOs).”
“Teagasc should continue to provide an impartial research programme on the issues of GM crop cultivation to policy makers, tillage farmers, and the general public, in order that Ireland can engage in scientific discussions on new crop technologies and be to the forefront of technology should EU policy on GM crop cultivation alter and broader acceptance of the merits of GM technology emerge.”

“Growers should place a greater emphasis on diversification in the tillage crops grown, with greater consideration given to beans, peas, oilseeds, biomass crops etc. to increase overall returns per hectare.”

“DAFF should convene a forum of relevant stakeholders including tillage farmers, pig producers and pig processors to investigate potential economies and efficiencies that could be achieved through enhanced cooperation in these sectors.”

“Industry needs to urgently prepare for the impact of the new EU pesticide regulations to ensure the sustainability of crop production in Ireland.”

“Research should be undertaken into high value areas such as biopharmaceuticals, bioplastics and bioremediation”.

The above extracts from the Food Harvest 2020 report indicate that the Irish Government recognises the importance of plant biotechnology and has not ruled out the use of GM crops in the future.

With the back drop of this general innovation policy context as outlined above, the Irish Governments approach to GM technology between 1974 and 2011 can now be explored to examine key drivers and issues.
2.4.2 GM policy and Regulatory Approach:
Ireland has yet to grow GM crops on a commercial basis and the debate that surrounds the issue of GM crops has become highly polarised, making it increasingly difficult for the public and decision makers to decipher scientific fact from speculation and conjecture (Meade and Mullins, 2005). On a chronological basis, four clear phases regarding GMO policy development in Ireland have been identified by this research (see Figure 2.13 and 2.14 below).

Phase 1: Initial Policy and Regulatory Development Stage
First initiatives in GM policy development in Ireland date back to 1974, when the Irish Government’s Department of Health requested the Medical Research Council to report any recombinant DNA (rDNA) research in Ireland. The Medical Research Council established an expert committee which was then broadened in 1977 to include representatives of the National Science Council and the Agriculture Institute. At the same time, the Royal Irish Academy set up a committee to provide advice regarding scientific, medical, legal and political issues relating to recombinant DNA (McGloughlin, 2000). However, prior to the creation of the above groups, the first experimental procedures involving rDNA were already being approved and carried out in Trinity College Dublin that had set up its own institutional rDNA Review Committee, based on similar committees operating in US research centers at the time (Personal Communication McConnell, 2008). In 1981, after the 1980 EU Council recommendation that member states should have a national authority overseeing and managing notifications of recombinant DNA, a National rDNA Committee replaced both the Medical Research Council and the Royal Irish Academy’s committees. The National rDNA Committee consisted of a chairperson and 14 members who included officials from various Government departments (Agriculture, Health and Labour), the National Drugs Advisory board, the Agriculture Institute, and the National Board for Science and Technology. It also included research experts from universities and representatives from trade unions and the Confederation of Irish industry (McGloughlin, 2000).

In 1991 as a result of EU Directives 90/220 and 90/219, the Department of Environment was selected as the national competent authority regarding the use of GMOs in Ireland until regulations in 1994 (S.I. No 345 of 1994) nominated the Environmental Protection Agency
(EPA) competent authority to administer GMO regulations from January 1, 1995. Also in 1995 a twelve member Advisory Committee on GMOs was established under the auspices of the EPA. The Advisory committee consisted of both Government and non-Government organisations and each committee served for a term of three years. This advisory committee still exists today.
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>Irish Government’s Department of Health requested the Medical Research Council to report any recombinant DNA research in Ireland.</td>
</tr>
<tr>
<td>1977</td>
<td>The Medical Research Council established an expert committee on rDNA.</td>
</tr>
</tbody>
</table>
| 1978 | Royal Irish Academy set up a committee to provide advice regarding scientific, medical, legal and political issues relating to recombinant DNA.  
Trinity College Dublin - institutional rDNA Review Committee - first experimental procedures |
| 1981 | Based on 1980 EU Council recommendation that member states should have a national authority overseeing and managing notifications of recombinant DNA, a National rDNA Committee replaced both the Medical Research Council and the Royal Irish Academy’s committees.  
National rDNA Committee: chairperson + 14 members Agriculture, Health and Labour, the National Drugs Advisory board, the Agriculture Institute, the National Board for Science and Technology, universities, unions and industry. |
| 1991 | Base on EU Directives 90/220 and 90/219 the Department of Environment was selected as the national competent authority regarding the use of GMOs in Ireland until regulations |
| 1994 | Regulation made EPA competent authority to administer GMO regulations from January 1, 1995. Also in 1995 a twelve member Advisory Committee on GMOs was established under the auspices of the EPA. |
From 1996 onwards, the Irish legislative framework for GM crops (see Table 1) has been primarily developed based on EU derived direction. However, from a biopolicy perspective, it has been previously noted that GM policy development in Ireland has been far from straightforward (Motherway, 1999). Over the past number of years this observation has proven to be correct, as the only consistency has been the presence of policy inconsistency. In examining the key policy events in Ireland between 1996 and 2011, this work aims to illuminate the policy drivers and dynamics that have existed.
<table>
<thead>
<tr>
<th>GM Issue</th>
<th>Competent Authority</th>
<th>Policy</th>
<th>Irish Legislation</th>
<th>EU Legislation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Safety and Labelling</td>
<td>Food Safety Authority of Ireland</td>
<td>Department of Health and Children</td>
<td></td>
<td>Regulation (EC) 1829/2003</td>
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<td>Commission Regulation 641/2004</td>
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<td>Directive 2000/13/EC</td>
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<tr>
<td>Traceability</td>
<td>Food Safety Authority of Ireland</td>
<td>Department of Health and Children</td>
<td></td>
<td>Regulation(EC) 1830/2003</td>
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<td></td>
<td></td>
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<td></td>
<td>Commission Regulation 65/2004</td>
</tr>
<tr>
<td>Variety Registration</td>
<td>Department of Agriculture,</td>
<td>Department of Agriculture,</td>
<td>Plant Varieties (Proprietary Rights)</td>
<td></td>
</tr>
</tbody>
</table>
Key policy events in Ireland between 1996-2011

As outlined in Figure 2.14 there are several key events that occur in Irish GMO policy from 1996 to 2011 that can be divided in three distinct phases.

Phase 2: Managing the risks in vivo

1996: In December 1996, Monsanto applied to the Irish EPA to carry out experimental field trials of the glyphosate tolerant GM sugar beet (Beta vulgaris). The public was given three weeks to respond to the notification, and the EPA received 189 representations (of these, approximately two thirds were reproductions of similar texts) (Motherway, 1999). In May 1997, the EPA granted permission to Monsanto to test the GM sugar beet for a period of four years; three years for growing purposes and one year for monitoring of test sites after growing (the glyphosate tolerant GM sugar beet was subsequently sown on May 27th in 1997, May 14th in 1998 and 14th April in 1999) (Mitchell, 2000).

1997: On April 27, 1997, weeks before an Irish general election, Fianna Fail (Ireland largest political party), then in opposition but who were the main party in the 2007-2011 Irish government, issued a press statement describing GM food as a “mass experiment”, and vowed to put in place a “moratorium on the release of genetically modified organisms into the environment and on the marketing of any foods which contain any genetically modified ingredient, or which was produced using any genetically modified organism.” (Walsh and Dempsey, 1997, p1)

Also in April, 1997 Genetic Concern, an anti-GM pressure group was established (Hart, 2002). In and around August 31, 1997 the first GM sugar beet field trial in Ireland was
destroyed by a group called the Gaelic Earth Liberation Front (O'Sullivan, 1997). During the three years of GM sugar beet field trials in Ireland a total of six attacks occurred at several different locations.

1998: After entering Government in June 1997, Fianna Fail did not act on their declared aim to impose a moratorium on GM crops or products. Instead on August 24, 1998 the initiation of a “GMOs and the Environment” public consultation process was announced and an in-depth discussion document was published (Dempsey, 1998). The ‘public consultation’ instituted was a two-stage process that allowed input into the formulation of Government GMO policy under the specific auspices of the Department of Environment and Local Government. The first stage called for written submissions from interested members of the public. By the submission deadline, September 30, 1998, over 200 people and organizations had made written submissions (Morris and Adley, 2001).

The second stage of the public consultation process allowed for a two-day debate held on May 25, 1999 and June 3, 1999. A panel of stakeholder representatives participated in the debate sessions, chaired by an independent panel. The stakeholder panels consisted of two representatives from each of three groups: industry; the academic science community; and Non-Government Organizations (NGO)/pressure groups. These representatives were chosen from those who had responded to the advertised Government call for submissions. However, the debate process ran into problems when, on the final day of the two day debate, the vast majority of the NGO/pressure groups boycotted the event. Nevertheless, the independent chairing panel continued its work and submitted its final report and conclusions to the Minister for the Environment on July 28, 1999.

During 1998, Clare Watson, a member of the Irish anti-GM pressure group Genetic Concern, sought a judicial review of the Irish EPAs decision to grant approval for Monsanto herbicide tolerant genetically-modified sugar beet plan. The thrust of Watson’s case was that in issuing consents for trials to Monsanto, the EPA had failed to apply the ‘effectively zero’ test (i.e. to eliminate risk to the environment), a standard she maintained existed in the Genetically Modified Organisms Regulations (1994) (Taylor, 2006). However, on October 6, 1998 Justice
O’Sullivan, in a 58-page judgment, rejected all grounds of the legal challenge (O’Sullivan, 1998). Nonetheless, the case played a major role in raising the profile of the whole GM plant debate in Ireland (Motherway, 2000).

An important actor within the GM debate in Ireland came into existence when the Food Safety Authority of Ireland (FSAI) was established under the Food Safety Authority of Ireland Act, 1998 (enacted in July 1998) which came into force January 1st, 1999. The Authority is a statutory, independent and science-based body, dedicated to protecting public health and consumer interests in the area of food safety and hygiene. It operates under the auspices of the Minister for Health. The FSAI has a 15 member Scientific Committee (including a GMO sub-committee) that assists and advises its Board. Decisions relating to food safety and hygiene take account of the latest and best scientific advice and information available. The principal function of the Food Safety Authority of Ireland (FSAI) is to take all reasonable steps to ensure that food produced, distributed or marketed in the State meets the highest standards of food safety and hygiene reasonably available and to ensure that food complies with legal requirements, or where appropriate with recognised codes of good practice.

1999: An internal government Inter-Departmental Working Group on Modern Biotechnology was established in March 1999 to coordinate an overall Irish Government position on modern biotechnology (including GM plant biotechnology). The Group was chaired by the Department of Enterprise, Trade and Employment (at an Assistant Secretary level) and comprised of senior officials from the Departments of Health and Children; Agriculture, Food and Rural Development; Environment and Local Government; and a representative of the Food Safety Authority of Ireland. Representatives of Enterprise Ireland and Forfás were co-opted onto the Group to assist it in its work, while an official of the Department of Education and Science joined the Group after October 1999 (Cox, 2000).

In October, 1999 the independent panel running the separate Government public consultation on GMOs and the environment publicly issued its report. Moving away from the Fianna Fail pre-election policy the Minister for the Environment Noel Dempsey accepted that if Ireland operates a policy of transparency and scientific assessment with regard to genetically modified
organisms, there should be no risk to health or the environment. The report clearly ruled out a ban on crop trials in Ireland, but stressed the need for full labelling of GM foods. It also warned that if Ireland rejects or ignores biotechnology, it will not remain attractive to investors in high-tech industries or competitive in food production (Coleman, 1999). The outcomes of the public consultation were accepted as Irish Government policy. However, the Irish Government referred a number of specific policy issues to the Inter-Departmental Group on Modern Biotechnology established earlier in 1999. These referred issues included the dissemination and coordination of information on genetic engineering, the case for a biotechnology ethics committee, and future policy and administrative coordination of genetic engineering (O’Donnell, 1999b).

Also established in 1999 was Safefood, an organisation responsible for the promotion of food safety across the whole island of Ireland. It was created in 1999 under the terms of the British-Irish Agreement Act 1999 and the North-South Co-operation (Implementation Bodies) Northern Ireland Order 1999.


The Group’s main recommendations included the following:

- Ireland should take a positive but precautionary approach to GM issues, at both EU and in international forums, which acknowledges the potential benefits of modern biotechnology while maintaining a fundamental commitment to human safety and environmental sustainability;
- Irish field trials of GM crops should continue, subject to compliance with EU legislation and with the conditions laid down by the EPA;
- the Department of Agriculture, Food, and Rural Development should, in consultation with the Environmental Protection Agency, draw up detailed protocols governing the management of GM crops in field trials;
• the Department of Agriculture, Food, and Rural Development should, in cooperation
with other bodies, devise a program for the managed development of GM crops that
would provide for a phased, monitored progression to full commercial cultivation;
(never published)

• the Irish State Laboratory should be designated as the national reference laboratory
for the detection of GM materials in foods and other products;

• in the interests of transparency and public awareness, regulatory bodies should, as a
matter of standard practice, make available the fullest possible information on the
applications for release and marketing approvals of GMOs;

• a national biotechnology ethics committee should be established under the auspices
of the Royal Irish Academy to consider the ethical issues raised by biotechnology in an
informed and dispassionate way;

• independent genetic research should be conducted in Ireland into all aspects of
GMOs, giving consideration to distinctive Irish climatic and geological conditions; (no
field trials were completed)

• new ways of informing the public about biotechnology, its existing and potential
benefits, and the possible risks to health and the environment should be devised and
deployed: A central Government Web site should be established that provides a broad
range of relevant, up-to-date information in a manner readily accessible to the public;
(never carried out)

• new means of promoting public consultation and involvement in debates about
biotechnology should be developed and piloted; (never carried out) and

• the Inter-Departmental Group should be permanently supported to ensure that the
Government has an integrated view of the full range of relevant issues, and the Group
should be expanded to include representatives of the Environmental Protection
Agency; the Food Safety Promotion Board; Teagasc; and the Department of Arts,
Heritage, Gaeltacht, and the Islands (never carried out).
The report also stated that
"in Britain in particular, there have been no shortage of instances in which newspapers—some of which have a sizable readership in Ireland—have misled rather than informed the public about genetic modification. Distorted presentations of the facts, lurid accounts of 'Frankenstein foods', have been commonplace in the treatment of the issue in the mass-circulation newspapers" (pg. 97).

The second interesting acknowledgment is that the Irish government has officially underlined the role the organic movement has played in the campaign against GM crops and foods. The report also points out that the organic movement has much to gain in this opposition, which is reflected in the report's comments that
"Representatives of the organic farming and food sector have also been prominent in the campaign against GM crops and foods.... We appreciate also that the debate about genetic modification has given organic producers an opportunity to draw attention to the merits of their own produce" (pg. 103).

The Irish Government concludes that, even if they accept the concerns of organic farmers regarding possible gene transfer, they "see no reason why [approved GM crops] cannot form part, with organic farming, of a broad mix of crop types and farming practices" (pg. 103-104).

2001: The anti-GM pressure group Genetic Concern disbanded and GM sugar beet trials ended.

**Phase 3: Maturing Regulatory Stage**

2003: In August 2003, the Irish Department of Agriculture and Food established a Working Group to examine the issues relating to the growing of GM crops in Ireland and to develop proposals for a national strategy and best practices for the coexistence of GM crops with non-GM crops. Specifically, the Working Group’s remit was to identify and evaluate issues and implications for crop production in Ireland that will arise from the cultivation of GM crops and to develop proposals for a national strategy and best practices to ensure the coexistence of genetically modified crops with conventional and organic farming. The Working Group
endeavored to ensure that the coexistence measures recommended for Ireland were arrived at in a transparent manner where interests from a wide selection of stakeholders (farming organisations, environmental groups, organic industry, seed trade, the biotech industry and consumers) were balanced equitably.

In 2003 the Irish Government passed legislation to enact the requirements of EU Directive 01/18 into Irish law. As a result the Genetically Modified Organisms (Deliberate Release) Regulations 2003 (Minister for the Environment Heritage and Local Government, 2003) came into force on November 1, 2003 in Ireland. Also in 2003 a new anti-GMO pressure group, the ‘GM Free Ireland Network’, was established.

2004: The Irish Government enacted regulations pertaining to the transboundary Movement of GMOs (Genetically Modified Organisms [Transboundary Movement] Regulations 2004, S.I. No. 54 of 2004) in February 2004 (Minister for the Environment Heritage and Local Government, 2004). These Regulations gave effect to Regulation No. 1946/2003 of the European Parliament and of the Council of 15 July 2003 on transboundary movements of genetically modified organisms. The Regulations detailed the obligations placed on exporters to ensure that all relevant requirements in relation to the transboundary movement of a GMO intended for deliberate release are fulfilled. The Environmental Protection Agency, as competent authority, was empowered to give directions to an exporter as it sees fit. The EPA is also designated as the focal point for the purposes of the EU Regulations.

2005: On 7 December 2005 the Irish Government’s Co-existence Report of GM crops with non-GM crops was released for public comment (Downey, 2005). The 144 page report had several key recommendations included pertaining to the mandatory and voluntary arrangements that the working group considered best to meet the objective of implementing coexistence measures. The report outlined a mix of mandatory measures require that they be given legal status, with voluntary measures should be specified in a Code of Good Farming Practice.
On January 13, 2006 BASF Plant Science GmbH (Germany) submitted a notification for consent to the Irish Environment Protection Agency (B/IE/06/01) for the deliberate release of GM potato lines (resistant to late potato blight) into the environment for purposes other than for placing on the market (McLoughlin, 2006). In May 2006 the Environmental Protection Agency granted consent to BASF, subject to specified conditions, to conduct the field trials until 2010 (McLoughlin, 2006). However, these BASF GM potato trials were never proceeded with.

**Phase 4: Political Realignment Stage**

The Irish Government policy entering the election in the summer of 2007 was ‘positive but precautionary’ towards GM crops and GM products. Ten years of policy formulation and delivery while in Government provided the basis for this approach. After the election Fianna Fail invited the Green Party to join them to form a coalition Government. As a result of Program for Government discussions the resulting vague policy to “Seek to negotiate the establishment of an All-Ireland GM-Free Zone” (Ahearn et al., 2007, p.29) was agreed upon. This policy, which sets aside previous Government policy developed via consultations and came about without any public or stakeholder consultation. However Ireland’s Agriculture Minister Mary Coughlan has since clarified that this wording did not mean a definite policy had been decided upon. (Irish Farmers Journal, September 22, 2007). Further adding to the policy confusion Minister of State at the Irish Department of Agriculture and Food, Trevor Sargent, has dramatically redefined ‘GM Free Ireland’ by stating a “GM free zone is not about banning imported GM feed” (Irish Farmers Journal, October 6, 2007).

In July 2007, a screening Regulatory Impact Analysis (RIA) related to proposed legislation to transpose the EU Environmental Liability Directive (Directive 2004/35/EC of 21 April 2004) into Irish law was published by the Department of the Environment, Heritage and Local Government for public comment (DOE, 2007). No comments pertaining to GMOs were received by the Irish Government during the public comment period (DOE, 2008b). However, when the draft Bill was released in July 2008 for public comment (after the Green Party had joined the coalition Government) major changes were included relating to GMOs. For example, operators would normally be exempt from liability for environmental damage when
the operator demonstrates that the damage was caused by activity/emission expressly authorised by a regulatory authority (i.e. 'permit' defence). However, the revised proposed Irish Bill included wording that would not allow the use of genetically modified organisms (GMOs) for cultivation (including field trials) to be exempt from liability via the permit defence. Similarly, under the EU Environmental Liability Directive operators are exempt from liability where the operator demonstrates that the activity/emission was not considered likely to cause environmental damage according to the state of scientific and technical knowledge at the time, i.e. 'state-of-the-art' defence. Again, the proposed Irish legislation included an exception to this defence for the use of genetically modified organisms (GMOs) for cultivation (including field trials). GMOs were the only technology type exempted in such a manner. Moreover, the justification for this special approach in the case of GMOs provided by the Irish Government was that there was “concern amongst some members of the scientific community and the public in general, especially in relation to environmental risks arising from the cultivation of these products.” (DOE, 2008a, para. 45). No specific evidence or supporting documentation for this statement was provided. The Irish Environmental Liability Bill has yet to published and considered in the Irish Parliaments (planned to be tabled in the Irish Parliament before the end of 2012 (Hogan, 2012).

2009: On October 10, 2009 a Renewed Program for Government was published by the parties in Ireland’s coalition Government to provide the political basis of Government action until 2012 (Cowen and Gormley, 2009). There were two sections pertaining to GM crop/food policy included. First, there was a statement that the Irish Government intends to “declare the Republic of Ireland a GM-Free Zone, free from the cultivation of all GM plants”. Secondly, the Irish Government aims to introduce a “voluntary GM-Free logo for use in all relevant product labelling and advertising, similar to a scheme recently introduced in Germany”.

2010: The Irish Government launched a major initiative to draw up a medium-term strategy for the agri-food, forestry and fisheries sectors on February 16, 2010. Entitled Food Harvest 2020, the strategy was to specifically ensure that the agri-food, forestry and fisheries sectors were seen to be an integral part of the 'Smart Economy' and at the forefront of this country’s export-led economic recovery. On July 19, 2010 the Government launched its Food Harvest
2020 report which contained over 200 specific recommendations (Brady, 2010). As outlined above, the recommendation relating to GM technology was listed under the title of “Restoring Competitiveness” and stated:

“Teagasc should continue to provide an impartial research programme on the issues of GM crop cultivation to policy makers, tillage farmers, and the general public, in order that Ireland can engage in scientific discussions on new crop technologies and be to the forefront of technology should EU policy on GM crop cultivation alter and broader acceptance of the merits of GM technology emerge.” (p 50).

In addition, another recommendation in the same section of the report stated: “Research should be undertaken into high value areas such as biopharmaceuticals, bioplastics and bioremediation” (p 45).

2011: In February, 2011, after a general election, there was a change of Government in Ireland. Neither Fianna Fail, nor the Green party are currently part of the new Government. To date, there has been no expressed new policy issued by the new Government regarding GM crops and the issue was not part of the new Program for Government negotiated by the incoming coalition parties.

2.4.3 Discussion:
To better understand the policy process that has occurred in Ireland surrounding modern plant biotechnology, an analysis will be offered to examine the policy dynamics that have occurred and to define the patterns of policy change over time (these can be gradual and incremental, sudden and episodic, or some combination of the patterns). It is clear that over the last 15 years (broken down into four phases) the Irish Government’s GM policy has changed direction on several occasions. These changes occurred even under relative political stability (i.e. while under the same Taoiseach [Prime Minister] and senior Cabinet Ministers remained constant and relative prosperity during the Celtic Tiger years (i.e. relative abundance of resources). As outlined in Figure 2.15, a number of developments occurred that can illuminate the policy dynamics at play. First, the transition from the moratorium proposed in 1997 to the ‘positive but precautionary’ policy of 2000 based on public consultations and an Inter-
department working group report. Second, in 2005, co-existence recommendations where developed as a result of considerable stakeholder input. Third, in mid-2007 Government policy was for Ireland to be a “GM free zone” but by September 2007 GM feed products were again acceptable and the Government claimed they fall outside the definition of ‘GM free’. Examining the various policy positions and initiatives over this period of political stability demonstrates how even a first world country and an aspiring leader in knowledge based economy struggled to find a stable policy position on the issue of agri-food GM products. In Ireland’s case, policy has ranged from a proposed moratorium to a supportive position after a public-consultation process changing back to a GM free policy which has since allowed exceptions for GM feed products.

Figure 2.15: GM Crop Policy Flow in Ireland from Positive to Negative from 1997 to 2010

- ““Moratorium on the release of genetically modified organisms into the environment and on the marketing of any foods which contain any genetically modified ingredient, or which was produced using any genetically modified organism.”
  (Fianna Fail, Press Release, 26 April 1997).

- “Ireland should take a positive but precautionary approach to GM issues......
  Irish field trials of GM crops should continue”
  November 20, 2000

- “Seek to negotiate the establishment of an All-Ireland GM-Free Zone”.
  Irish Program for Government June 2007

- Teagasc should continue to provide an impartial research programme on the issues of GM crop cultivation to policy makers.
  July 19, 2010
To develop an assessment of modern plant biotechnology policy in Ireland, several key questions can now be answered, namely:

Q1. What drivers were key contributors to changes within the European plant biotechnology policy arena when they occurred? From what domain did these factors originate? A1. In Ireland policy drivers were from various sources with most being endogenous to the system. They included:

- **Political drivers: endogenous**
  
  In 1997, just prior to a general election a politically driven policy was made to ban GM food by an incoming political party.

  In 2007, as a result of an election and the subsequent coalition negotiations with the Green Party (during which their support for the coalition was required), it was decided to declare Ireland’s intention to become a ‘GM free zone’.

- **EU Legal drivers: exogenous**

  EU law prevented Ireland from banning GM field trials or food and was used as a reason why the Government could not act on either their 1997 pre-election policy nor fulfil the 2007 policy intention to be a ‘GM free’ country.

- **Feed industry as a driver: endogenous**

  The Irish feed industry has been active to mitigate proposals to ban GM feed as envisaged by Green Party policy in 2007.

- **Irish Government working groups as drivers: endogenous**

  Three Irish Government working groups played roles in policy development on GM plants. These included the 1999, Chairing Panel for the National Public Consultation on Genetically Modified Organisms and the Environment, the 1999 Inter-Departmental Working Group on Modern Biotechnology, and the 2010 ‘Food Harvest 2020’ groups.

Q2: What was the role and relevance of the science-policy interface in the policy change process in terms of producing evidence?
A2: The drivers and the dynamic of policy change within the Irish plant biotechnology arena relied on the science-policy interface only to minor extent.

Q3. Do the observed patterns of policy change in this system align with common models of change?
A3. Policy change within the Irish plant biotechnology arena has proceeded according to a punctuated equilibrium model in that several sharp rapid shifts in policy have been identified rather than policy following a route of gradual evolution.

2.5 Mapping plant biotechnology risk management policy in the EU
As Ireland is a member state of the European Union and is subject to its directives and regulations in regards to products of modern biotechnology any policy analysis of Irish policy must examine EU policy as the two are so interdependent upon each other. The debate in the European Union over the release of genetically modified (GM) crops and the use of GM agriculture products has been on-going for over a decade. Attempts to explain the European Union’s and their member states’ approach to the risks regarding GM crops and their derived products have been numerous (Sylvie Bonny, 2003, Bernauer and Meins, 2003, Levidow et al., 2005, Murphy et al., 2006, Jank et al., 2005, Wager and McHughen, 2010, McHughen, 2007a, McHughen, 2007b). They include suggestions that Europeans care more about the natural environment, have less trust in their food safety regulators than do Americans, the existence of a different European relationship with food and failed public communication efforts are to name just two.

Clearly no simple explanation exists considering the numerous variables at play including a country’s cultural background, specific country agronomic situations (e.g. Denmark and Austria as outlined by Spöök (Spöök et al., 2004)), the political interplay and relationships between specific member states and pre-existing relationships/agreements with non-EU member states who may produce GM products, etc. Consequently, a set of “complex entanglements among knowledge, technical capability, politics, and culture” (Jasanoff, 2005a, p290) can said to be at play. Sociocultural systems and technological systems interact in enormously complex ways and multiple factors (regulation, communication and culture) must
be taken into account in trying to explain the dynamics of technology adoption – or rejection (Bauer and Gaskell, 2002) as is the case with GM crop technology in the EU.

**Introduction to EU GM policy:**
Over the last 20 years the EU has largely failed to create a stable regulatory and policy environment regarding GM crops and their products that is efficient, predictable, accountable, inter-jurisdictionally aligned and durable. This section lays out the EU’s past regulatory policy pathway regarding GM crops, critically assesses the science/policy interface base at key points and examines some of the key lessons learned as the EU moves forward into its next phase of GM governance. It is suggested herein that due to the lack of a balanced comparative approach to risk assessment, which could include all crop varieties produced by GM or other approaches, the EU’s regulatory framework may be overly focussed on managing biopolitical risks in the face of public perceptions, perceptions that are largely manifest as public opinion. However, in terms of policy coherence, such regulatory policies are likely to be to the detriment of the EU’s ambitious goal to create a knowledge-based economy by 2010, which the EU member states agreed to in the Lisbon Agenda (Rodrigues, 2003). It is certainly true that the strict regulatory requirements and the largely negative attitude engendered towards GM crops within the EU have affected applied plant research within the EU. Many biotech companies, EU university field trial researchers and the agricultural industry have shifted their research enterprises outside the EU to North America and Asia and now favour foreign direct R&D investments regarding agricultural biotechnology in non-EU locations a move that also has knock-on detrimental effects for fundamental research that is the basis from which all applied research innovations are derived. A recent example is the January 16, 2012 decision by BASF to relocate its plant science division to the U.S. (Laursen, 2012).

**Historic Review of the EU GM Crop Regulatory Framework**
The EU has a long history in its regulatory approach to the technology of rDNA and its applications (see Chapter 1). Building on Galloux et al.’s analysis of the EU’s public policies in the area of biotechnology (Durant et al., 1998) five regulatory policy phases can be identified along the EU GM crop regulatory policy pathway, namely:

5. Third legislation period (2002 – today)

1. Non-legislation period (1973-83)
Regulation in the European Union pertaining to the use of rDNA stems from the early 1970s. In July 1974, resulting from the ‘Berg letter’ published in Science (Berg et al., 1974), the United Kingdom established a Committee (the Ashby Working Party) to advise on whether rDNA research should proceed in the UK. In December 1974, the Ashby Working party recommended that such research should continue, provided adequate safeguards were put in place (HMSO, 1974). By reporting so promptly, the concepts developed by the Ashby Working Party were used by UK scientists and other scientists during the February 1975 Asilomer conference in the USA. In 1978 the European Commission proposed an approach to research on rDNA that would have required statutory notification and authorisation by national authorities for all activities involving recombinant DNA (i.e. European Commission Proposal for a Council Directive establishing Safety Measures against the Conjectural Risks associated with recombinant DNA Work – C301/5-7 1978) (Fredrickson, 2001, Ramjoue, 2007, Cantley, 1995). In this document the definition of rDNA work was identical to that of “genetic manipulation” in the UK regulations that came into force in August, 1978 (Regulations on Genetic Manipulation – SI 1978 No. 752). It is notable that the proposed approach was later replaced by a non-binding Council Recommendation (Council Recommendation 82/472/EEC of 30 June 1982 concerning the registration of work involving recombinant deoxyribonucleic acid (DNA). Official Journal, L 213, pp. 15). This recommendation, which was based on the US and UK’s experiences regarding rDNA and the desire of the Commission to avoid fixed statutory controls, simply asked EU member states to adopt laws, regulations and administrative provisions requiring "notifications” as opposed to “authorizations” to carry out rDNA work (Cantley, 1995).

In October 1983, a European Commission communication (COM (83)672) addressed the regulations of biotechnology under the following three headings:

- biological safety
- the consumer and the bio-industry
- the regulation of products and their free circulation.

At that time there was clear intent by the Commission to attempt to “ensure regulatory provision to maintain rational standards”.

Also in 1983, the OECD first published its Recombinant DNA Safety Considerations booklet that is now known as the “The Blue Book” (OECD, 1983). This OECD document was a first step in the process of harmonizing biosafety principles. It contained guidelines for assessing the safety of large scale use of rDNA organisms. In the mid-1980s several European member states introduced national biotechnology regulatory frameworks (e.g. Denmark was the first European country to adopt legislation specifically on rDNA, with its June 1986 Gene Technology Act).

At the end of 1983, Etienne Davignon, then EU Commission Vice-President and the EU Commissioners for agriculture and internal markets, proposed the formation of a Biotechnology Steering Committee (BSC) to be chaired by the Director-General of DG XII (Science, Research and Development). This proposal was adopted early in 1984. In 1985, another new body, the Biotechnology Regulation Inter-service Committee (BRIC), was also formed. It was jointly chaired by DG III (Internal Market) and DG XI (Environment). The aims of BRIC were formulated *inter alia*:

“To ensure the coherence of scientific data which will form the basis of risk assessment, and in particular to avoid unnecessary duplication of testing between various sectors” (Sehnal and Drobník, 2009, p12).

One of the tasks the BRIC completed was an inventory report of Community biotechnology regulations. While the report drawn up by BRIC highlighted the desire for a pan EU regulatory framework, it did state that:
“Some States, particularly the U.K., France and the Netherlands, seemed inclined to view existing legislation as a basic requirement to which countries might add further requirements relevant to their particular situation – geographical, climatic or regional” (European Commission, 1989, p12)

In November 1986, the EU Commission’s communication to the European Council (COM (86) 573) entitled A Community Framework for the Regulation of Biotechnology (drawn up by the BRIC) put forward a more restrictive approach than had been advocated by industry or by Member States with the greatest experience of biotechnology. In May 1988, when the communication COM (88)160 was published, it contained proposals for two Council Directives: one “on the contained use of genetically modified microorganisms” and the other “on the deliberate release to the environment of genetically modified organisms” (EU Commission Proposal for a Council Directive on the contained Use of Genetically Modified Microorganisms and a Proposal for a Council Directive on the deliberate Release to the Environment of Genetically Modified Organisms, COM (88)160). The 1988 proposals did have some concessions to scientific considerations in the preamble and the explanatory sections. However, the scope and content of the proposed Directives departed from the scientific advice of the time. For example, the European Molecular Biology Organisation (EMBO) formally considered the proposed Directives and came to a unanimous opinion that:

“....any legislation should focus not on the technique but on the safety or otherwise of the products generated with it. ...Over the last 15 years, experience has shown that recombinant DNA methods, far from being inherently dangerous, are an important tool both for understanding properties of life and for developing applications valuable to humankind and the environment. EMBO strongly believes that there is no scientific justification for additional specific legislation regulating recombinant research per se. Any rules or legislation should only apply to the safety of products according to their properties, rather than according to the methods used to generate them” (EMBO, 1988, p4)
On May 18, 1989 sixteen European Nobel Laureates in Medicine and Chemistry wrote an open letter to the President of the European Parliament, the EC Council and the Commission in support of EMBO’s ‘product’ rather than ‘process’ approach. The European Council adopted a common position in November 1989 and the proposed Directives returned to Parliament for second reading. When the directives were discussed at committee level in the European Parliament there was a noticeable increase in restrictive amendments. Some commentators felt that the rise of the ‘Green’ party in the mid-1980s in the European parliament and throughout continental Europe focused many Members of the European Parliament (MEPs) on the “acute sensitivities of public opinion to gene technology” (Cantley, 1995, p522). It is likely that within this climate, support for restrictive amendments to the proposed directives was exceptionally forthcoming. Nevertheless, the 16 EU Nobel Laureates wrote another letter before the second Parliament reading on February 8, 1990.

During the Parliament’s plenary session in 1990, where the Directives were voted on, there was also a narrow defeat of an amendment proposing a five-year moratorium on GMO field releases (Cantley, 1995). The two Directives 90/219/EEC and 90/220/EEC were finally adopted on April 23, 1990. Directive 90/219/EEC dealt with the contained use of GM microorganisms, while Directive 90/220/EEC regulated the deliberate release of GMOs into the environment within the EU. Both used the process of “genetic modification” as their regulatory trigger.

Directive 90/220/EEC never fully achieved its primary goal of regulatory harmonization across the EU. If compliance with rules is the foremost indicator of legitimacy, by the mid 1990’s the EU GMO regulatory framework was beginning to lose its legitimacy (Skogstad, 2008). Several member states had begun using the “safeguard” clauses in Directive 90/220/EEC to prevent the commercial release within their jurisdiction of certain GM products. Directive 90/220/EEC started to be seen as deeply inadequate, and eventually fell apart during the infamous so called de facto moratorium on new authorizations. Following declarations from twelve (of then fifteen) Member States that they were opposed to further authorisations of GMOs, the Commission stopped putting GMOs through the authorisation
process; hence a \textit{de facto} moratorium was established (Lee, 2010). Clearly, failures within the regulatory policy system forced the EU into this \textit{de facto} moratorium situation which stalled approvals of GM products (predominantly GM crops). These arose because of differing concepts of risk, cultural and historical elements between Member States, and also the continued rise of “biopolitics” (Morris and Adley, 2000a). Thus under renewed political pressure and with a \textit{de facto} moratorium in place, the EU once again returned to the legislative process to put in place a new Directive relating to GMOs.

In June 1999, the Council of Ministers met for a marathon twenty-hour session in Luxembourg to discuss the topic of GMOs. Before the meeting, European politics had become intensified because of the EU parliamentary elections taking place that year. In addition, GM crops had become a hot topic in the public sphere due to the extensive media reporting of the infamous Arpad Pusztai rat experiments (Ewen and Pusztai, 1999) and experiments reporting possible effects of \textit{Bt} pollen on Monarch butterflies (Losey \textit{et al.}, 1997). In fact, during the EU Parliament election of 1999, GM crops were a topic that many MEP candidates faced on the campaign trail. At the Council meeting in June, there was a French-sponsored declaration calling for a moratorium on all GMO approvals. A British Department of Environment spokeswoman accused the French of playing politics with the issue. She was cited as saying “\textit{The French Minister made it clear there was no legal basis for a blanket moratorium. What they were putting forward was a political declaration.”} (Anon, 1999, p1). In essence, the French position could be construed as biopolitical posturing (Morris and Adley, 2000a).

During the Council of Ministers meeting, it emerged that there were actually two separate substantial declarations. The first statement asked the Commission to:

“\textit{...without delay draft rules ensuring labelling and traceability of GMOs and GMO derived products and state that, pending the adoption of such rules, in accordance with preventive and precautionary principles, they will take steps to have any new authorisations to allow for growing and placing on the market suspended}” (Trittin, 1999, p5).
The member state signatories included France, Greece, Italy, Denmark and Luxembourg. The second declaration requested that it would:

“...not authorise the placing on the market of any GMOs until it is demonstrated that there is no adverse effect on the environment and human health” (ibid).

This was signed by Austria, Belgium, Finland, Sweden, Germany, Spain and the Netherlands. Interestingly, Britain, Ireland, and Portugal did not sign any of the above declarations. Eventually, the Environment Ministers agreed that there was no legal basis for a moratorium. They also agreed on proposals that included:

- Post-marketing monitoring of GM crops
- New risk assessment rules
- Phasing out of the use of antibiotic marker genes
- Formal bioethics studies
- Examination of the liability clause; and
- Increased public input and information.

The meeting highlighted the deep political divisions within the EU on the issue of GM crops. Not only were there divisions between Member States, but also there were considerable differences on the issue between the institutions of the EU, namely the Council, the European Parliament and the European Commission.

During this period, the biopolitical issues faced by policy makers at the science/policy interface became very evident. One such example was a speech to the EU Parliament by Commissioner Margot Wallstrom during the consideration of the new Directive. In her address she stated:

“I am also fully aware of the political importance of certain other aspects raised by the proposed amendments. It is clear that antibiotic marker genes need to be phased out and be replaced with alternatives as soon as practically possible. A phase-out is already foreseen in the common position. The Commission agrees to strengthen this political message” (Session Document A5-0083, 2000, p5).
Yet she simultaneously flipped between the two sides of the science/policy interface when she added in the same speech that:

“At the moment there is no scientific evidence that all GMOs of this type (i.e. containing antibiotic resistance marker genes) present adverse effects to human health and the environment. Instead we should continue to carry out a comprehensive case by case risk analysis” (ibid).

While the amendments that would have banned such GMOs immediately were rejected, it was decided that the year 2005 should be the definite date for the ‘phasing out’ of GMOs that contain antibiotic resistance marker genes rather than phasing them out progressively. It is noteworthy that an EU funded review study subsequently published in 2007 stated:

“Our conclusion, supported by numerous studies, most of which are commissioned by some of the very parties that have taken a position against the use of antibiotic selectable marker gene systems, is that there is no scientific basis to argue against the use and presence of selectable marker genes as a class in transgenic plants” (Ramessar et al., 2007, p 261).

The new legislation, Directive 01/18, was exceptionally difficult to pass due to the entrenched position of the EU Parliament. It was finally adopted in March, 2001 by co-decision between the EU Council and Parliament (Shaffer and Pollack, 2009).

3. Third legislation period (2001 – today)

The so-called de facto moratorium on GM approvals did not lift until the final outcome of the political process that produced the new Directive 2001/18/EC (which took effect in 2001, along with the later entry into force of Regulations 1829/2003, 1830/2003 and 1946/2003). The European Commission then sent to ten Member States a letter of “mise en demeure” because it was considered they had not implemented Directive 2001/18/EC in time, and in some cases proceedings were brought by the EC pursuant to Article 228 EC to the European Court of Justice (ECJ) (Lee, 2010).
Throughout this legislative period the EU’s regulatory framework regarding GM crop cultivation still did not function effectively. What appeared to be the unified European stance against GM crops was the result of a complicated balancing of different countries’ changing views and interests through the European political institutions (Carrau, 2009). Certain Member States have continued to invoke safeguard clauses and at the EU Council level divisions have continued to be indecisive thus forcing the EU Commission itself to make decisions on GM dossiers. This situation revealed profound differences from country to country on the issue of GM which translated into a major source of tension at the science/policy interface. This is not surprising as the Member States have faced continued internal political pressures regarding GM crops. For example, since 2000 there have been over 70 attacks of vandalism on GM experimental field trials across the EU (Kuntz, 2010) which have resulted in trials of GM plant technology being relocated outside the EU (Meldolesi, 2010).

The political pressure experienced internally by Member States can be very clearly observed in three particular cases where the political manipulation of the risk assessment process has been evident:

1. GM HT Crops:
On April 5th 2006, the EU Environment Commissioner, Stavros Dimas, at the Freedom of Choice conference on genetically modified organism (GMO) co-existence declared: “As an environment commissioner, I am keen to ensure that the environment is protected from potential risks arising from the cultivation of GMOs” (Dimas, 2006). He further proclaimed, “we should not ignore the use of “upgraded” conventional varieties as an alternative to GM crops, particularly where similar characteristics can be introduced without genetic modification”. The heralding of these non-GM ‘upgraded’ varieties by Commissioner Dimas exposes the fact that the current EU regulatory framework poorly covers possible environmental risks arising from the cultivation of non-GM so-called upgraded crops. One example of currently available upgraded non-GM varieties with similar characteristics to GM crops are the herbicide-resistant (HR) CLEARFIELD™ crops developed by BASF. The Weed Science Society of America (WSSA; http://www.weedscience.org/paper/definitions.htm) defines herbicide resistance as “the inherited ability of a plant to survive and reproduce
following exposure to a dose of herbicide normally lethal to the wild type”. The CLEARFIELD™ trait enables these upgraded crops to survive a broad-spectrum herbicide normally lethal to the crop. This trait is heritable and potentially transmissible through pollen to adjacent crops of the same species and progenitor in addition to weedy relatives. This suite of HT crop varieties have been developed using mutagenesis and/or traditional breeding methods and contains no introduced genetic material; as a result, they are not considered to be a GMO by the EU and thus are not covered by Directive 2001/18/EC. In Europe, these HT crops include rice, maize, oilseed rape and sunflowers, with wheat possibly soon to follow. BASF has even instituted a Grower Stewardship Plan, to help mitigate the environmental risks that they feel could exist. Tan et al. state that:

“Management of herbicide-resistant weeds and gene flow from crops to weeds are issues that must be considered with the development of any herbicide-resistant crop. Thus, extensive stewardship programs have been developed to address these issues for CLEARFIELD™ crop” (Tan et al., 2005, p246).

It is interesting to note that four of the five authors of this publication are BASF scientists, Currently, BASF has the largest portfolio of non-GM herbicide-resistant (HR) traits in the world and they believe that the potential sales value of the CLEARFIELD™ concept is in excess of €300 million (Morris, 2007b).

A simple, albeit technocratic, definition of risk is ‘the probability that an outcome will occur times the consequence, or level of impact, should that outcome occur’ (Kammen and Hassenzahl, 2001). Consequently, there are three basic questions of risk assessment (Conner et al., 2003): what can go wrong (i.e. environmental concerns or harm), how probable is it that harm will occur and what are the consequences of that harm happening?

Some of the environmental concerns raised by European commentators regarding GM HT crops include:

• the appearance of superweeds as a result of gene flow (Weil, 2005);
• the fertilization of the sympatric compatible wild relatives (Devos et al., 2004);
• spatial and temporal dispersal of seeds: oilseed rape might lead to feral oilseed rape
populations outside the cropped areas and oilseed rape volunteers in subsequent crops in the rotation (Devos et al., 2004);
• effects on wildlife biodiversity (Dale et al., 2002); and
• potential irreversibility of any negative impact(Frewer et al., 2004).

Such environmental risks have been summarized well in several other publications (Velkov et al., 2005, Marvier and Van Acker, 2005, Conner et al., 2003). These risks and the quantitative potential for their mode of occurrence, incidence and impact remain debated (Gressel, 2005). Such concerns are a result of the well-documented scientific opinion concerning possible risks arising from gene flow to wild relatives (Gealy et al., 2003, Waines, 2003, Seefeldt et al., 1998, Hall et al., 2000, Rieger et al., 2002, Wolfenbarger and Phifer, 2000, Hails and Morley, 2005), although a considerable number of studies have focused only on GM crops when examining environmental gene flow concerns (Hails and Morley, 2005, Stewart et al., 2003, Ammitzbøll et al., 2005, Krayer von Krauss et al., 2004, Chapman and Burke, 2006). In fact as pointed out by Brûlé-Bable et al., some of the possible gene flow-related environment risks concerning HT GM wheat transgene movement (e.g. it could alter farming practices…or irreversibly alter the ecosystem), contains substantial sections that can equally be applied to non-GM HT upgraded wheat (Brûlé-Bable et al., 2006). This and other articles discuss at length the various risks associated with GM HT crop gene flow but never refer to non-GM ‘upgraded’ HT crops and their gene flow risks. Nevertheless, Brule-Babel, suggest genes such as herbicide-resistance that confer a fitness advantage to the recipient population may have considerable impacts on population structure and dynamics. (Brûlé-Bable et al., 2006, Van Acker et al., 2004).

Even with numerous gene flow studies focusing intensely on GM crops, no scientific evidence indicates that the process of genetic modification, per se, causes potential environmental risks. Rather, it is the new phenotypic trait, such as herbicide resistance, bestowed upon the crop that carries the primary environmental risk. In missing this fact, it would seem that the EU Commission has chosen to ignore the obvious risks associated with upgraded non-GM HT crops that are clear and present but remain unregulated.
The reasons behind such an oversight are a matter of speculation, but it is plainly evident that by using the relevant potential direct and indirect impacts of GM crops on the environment, outlined in Dale et al. (as applicable to herbicide resistant crops), a comparative risk assessment comparing both GM HT and non-GM HT varieties can be produced (see Table 2.2).
Table 2.2: Potential impacts of GM herbicide tolerance crops versus non-GM herbicide tolerance crops on the environment

<table>
<thead>
<tr>
<th>Impact type</th>
<th>Risk Class</th>
<th>Examples</th>
<th>GM HR (regulated in the EU)</th>
<th>“Upgraded” Non GM HR (not regulated in EU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Impact</td>
<td>Change in persistence or invasiveness of the crop</td>
<td>Persistence in agricultural habitat (weediness); Invasiveness in natural habitats</td>
<td>Risk possible</td>
<td>Risk possible</td>
</tr>
<tr>
<td>Direct Impact</td>
<td>Gene flow by pollination to weeds and feral plants</td>
<td>Transfer of herbicide resistant to weeds</td>
<td>Risk possible</td>
<td>Risk possible</td>
</tr>
<tr>
<td>Indirect Impact</td>
<td>Reduced efficacy of weed control</td>
<td>Development of weeds resistant to herbicides by evolution and selection from within the weed gene pool</td>
<td>Risk possible</td>
<td>Risk possible</td>
</tr>
<tr>
<td>Indirect Impact</td>
<td>Effect on wildlife biodiversity</td>
<td>Effects of broad-spectrum herbicides</td>
<td>Risk possible</td>
<td>Risk possible</td>
</tr>
<tr>
<td>Indirect Impact</td>
<td>Effect on soil and water</td>
<td>Change in herbicide use; Change in soil cultivation</td>
<td>Risk possible</td>
<td>Risk possible</td>
</tr>
</tbody>
</table>

Source: adapted from (Dale et al., 2002)
From an environmental concern perspective, Table 2.2 demonstrates that there is little or no difference between GM-derived and non-GM HT crops. For equivalent traits, the technology type chosen to obtain the expression of herbicide resistance does not have a direct bearing on the potential environmental risks. It is not suggested that the lack of risk differential should cause HT GM crops to forego EU regulatory oversight; however, it does suggest that, from a policy perspective, the EU should explain why non-GM upgraded HT crops are not being subjected to some form of environmental risk assessment in accordance with the precautionary principle and current EU policy, considering they have the same phenotypic traits as their GM counterparts. The current disparity in environmental risk assessment also leaves the EU open to the reverse question: if non-GM HT crops obtained through mutagenesis are currently cultivated without restriction, why is there an environmental need to regulate equivalent HT GM crops?

2. Germany and MON810 Maize
The German government in April 2009 suspended the cultivation of the genetically modified maize varieties containing the Bt insect-resistance trait MON810 based on alleged new data on a potential environmental impact of these varieties. However, the German Central Committee on Biological Safety (ZKBS) concluded on July 7, 2009 that based on all available scientific information the cultivation of MON810 poses no risk to the environment (German Central Committee on Biological Safety [ZKBS], 2009) Subsequent analysis of the case has clearly shown the German government selected several individual studies to justify their political U-turn while ignoring the vast majority of research relating to Bt maize expressing Cry1Ab protein (Ricroch et al., 2010a);

3. France and MON810 Maize
On October 31, 2007, the French government temporarily suspended the cultivation of maize MON810. On December 7, 2007 the French Ministry of Ecology created a committee composed of 34 experts (including 15 scientists) entitled the Comité de Préfiguration pour une Haute Autorité sur les OGM (CPHA) to examine the impact of MON810 on the environment. On January 8, 2008, French President Nicolas Sarkozy stated he was willing to invoke a safeguard measure prohibiting the cultivation of maize MON810 if the committee raised
“serious doubts” concerning the safety of MON810 (Sarkozy, 2008). The next day, the CPHA’s report was submitted to the French government. The French government quickly announced to the press that the CPHA had found “*a number of new negative scientific evidences for impact on flora and fauna,*” raising “serious doubts” (Souche, 2008). The following day (January, 11 2008) twelve of the 15 CPHA scientific experts protested publicly as the report was supposed to be only a draft and did “*not contain the words ‘serious doubts’, nor does it qualify the new scientific evidences as ‘negative’*”. On February 7, 2008, the French government formally suspended the authorization of MON810 cultivation.

Subsequently, the French Food Safety Agency (AFSSA) and the European Food Safety Authority (EFSA) both found the claims used by French political leaders to justify the safeguard clause had no scientific basis. Both organisations confirmed their earlier findings that MON810 was safe for human consumption. The French Ministry of Ecology then justified keeping the safeguard clause, not based on health concerns but on environmental grounds (Ricroch *et al*.). However, this environmental basis was again rejected by EFSA when it renewed approval for MON810 to be used as seed for cultivation on June 15, 2009 (EFSA, 2009). Several journalists have pointed out that the French Government’s U-turn on the only GM crop in commercial use in France was as a result of a 2007 political agreement with environmentalists that ensured the French nuclear industry was not targeted at France’s national environment debate (the ‘Grenelle de l’environnement’) in return for action against GM crops (Thréard, 2009, Riviere-Wekstein, 2008). Furthermore, French Prime Minister François Fillon has admitted that the decision to start the procedure for the approval suspension of GM maize MON810 was based on a "*compromise sealed in the ‘Grenelle de l’environnement’*" («Concernant les OGM, Fillon a défendu sa décision de déclencher la procédure de suspension du maïs génétiquement modifié MON810 en estimant qu'il s'agissait d'un «compromis scellé dans le “Grenelle de l'environnement”» (Jaigu, 2008, p2)

More recently, political moves at high levels within the EU have indicated that the EU will once again revisit the legislative process concerning GM products. In mid-2008, during the French Presidency of the EU, the French Government launched a pan-Europe GM working group to draw up proposals for changes to the current authorisation process for GMOs. At the same time, EU Commission President José Manuel Barroso launched his own high-level
“Sherpa” working group to examine the GM issue in Europe. The prime ministers of each of the EU’s 27 member states were asked to nominate a special representative to take part in this high-level initiative. On December 4, 2008 European environment ministers at the 2912th Environment Council meeting unanimously issued a declaration on GM that included a range of conclusions such that environmental long-term effects of GM crops and the effects of GM plants on the different ecosystems in the EU needed to be assessed (Council of the European Union 2008: Council 2912th Environment Council meeting, Brussels, 4 December 2008 http://www.consilium.europa.eu/uedocs/cms_Data/docs/pressdata/en/envir/104509.pdf). On March 2, 2009 a Dutch proposal to the Environment Council was made that the choice of whether or not to cultivate GM-crops should be left to individual member-states. In June 2009, the EU Commission launched an evaluation by an external contractor of the legislative framework on GM food and feed. While not yet completed, this exercise intends to cover the two major aspects of the current legislation: the risk assessment and regulatory approval process, and the associated labeling requirements. On June 24, 2009 a number of Member States (namely Austria, Bulgaria, Ireland, Greece, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, the Netherlands, Poland and Slovenia) requested that the Commission give Member States the freedom to cultivate GM plants based on “relevant socio-economic aspects”. On July 13, 2010 the EU Commission announced a proposal for the addition of one article to Directive 2001/18/EC, which would explicitly allow Member States to restrict or prohibit cultivation of GMOs on their territories. Member States could use any grounds to do so, other than those covered by the health and environmental risk assessment of the EU authorization process. In recent months the EU changed its regulations to allow a new threshold of 0.1% for unapproved GM events in feed as long as the trait had been approved in another jurisdiction and was previously submitted for approval under the EU regulatory framework (Viju, Yeung et al. 2011).

A Basic Regulatory Impact Assessment
While the EU Commission has not yet officially consulted stakeholders (e.g., university scientists) nor carried out a formal regulatory impact assessment on the proposed changes to the GM regulatory framework, a number of potential qualitative risks and benefits can be identified. Any assessment is currently only cursory in nature due to the very limited
information provided by the EU Commission in their proposal. Based on such scant information the proposed amendments carry the following qualitative risks:

**Market/Economy risks:**

A. An inefficient, unstable and fractured market for GM seeds in the EU based on a myriad of inter-jurisdictionally unaligned GM cultivation approval regulations amongst Member States, due to the fact Member States could apply very different socio-economic aspects to their respective cultivation regulations that could shift and change over time;

**Political risks:**

B. Those wanting to establish GM free Regions envisage such regions as free from both GM commercial cultivation and GM research field trials. However, the Commission’s new proposals currently only cite/apply to commercial cultivation.

**Legal risks:**

C. There is a risk that the European Court of Justice (ECJ) might be requested to determine the proportionality of the adopted regulation and it seems unlikely that absolute measures such as total bans on cultivation based on socio-economic grounds would pass the test of EU law conformity.

D. Member States may encounter conflicts between the obligations stemming from WTO law and the Cartagena Protocol depending on the criteria they apply.

**Innovation/Competiveness risks:**

E. A stable regulatory and policy environment is required for innovation to flourish. Considering the high turnover rate of Member States governments, the national GM cultivation approval systems will be highly susceptible to national political fluctuations thus impeding and preventing long term innovation strategies. This could lead to incomplete research programs, cancelled EU funded projects and employment uncertainty within the plant research community making the EU a highly unattractive research and development location for the agri-food sector.
F. The precedent of establishing a non-harmonized socio-economic regulatory framework could form the basis for future regulatory policy in other emerging technology areas leading to ever increasing diversification across EU Member States in their regulatory responses to products of innovation.

The proposed amendments carry the following qualitative benefits:

*Market economy benefits:*

A. A socio-economic rational for a ban on GM crop cultivation could offer slight savings in identity preservation costs to a small subsection of the market.

*Political benefit:*

B. National and local political benefits could be realised by certain political groups that have had political goals to introduce GM cultivation bans.

C. Political benefits could be accrued by the EU Commission in conceding on the issue of GM cultivation in return for more flexibility by Member States towards issues pertaining to GM food (increased thresholds for the presence of GM material) and GM feed (a non-zero threshold for the adventitious presence of unapproved events).

D. Potential reduction in the frequency of Member States implementing health and environmental safeguard clauses on approved GM crops.

**Key outstanding issues with the current EU regulatory framework:**

While the EU Commission’s current proposal yet again attempts to modify the European regulatory framework for GM crop cultivation, it leaves a number of key issues unresolved. These issues arise from the fact that the current EU regulatory framework regulates on the basis of the ‘process’ that is used to create the traits in a new plant variety (i.e., singling out genetic modification from an entire host of modern plant biotechnology applications) rather than regulating the impacts of the new traits themselves.
First, as Directive 01/18 is based on the precautionary principle (PP), it is expected that the directive would follow the EU’s own official guidance on the PP (European Commission, 2000). These guidelines state that the PP should be used in a proportional, non-discriminatory and consistent manner to examine the benefits and costs of an action or lack thereof and the scientific developments pertaining to the risk in question. In particular, the principle of non-discrimination decrees that similar risks should not be treated differently:

“measures taken under the precautionary principle should be designed to achieve an equivalent level of protection without invoking the geographical origin or the nature of the production process to apply different treatments in an arbitrary manner” (European Commission, 2000, p19).

The section that refers to “the nature of the production process” is notable because it contradicts the EU’s current policies and regulatory framework that focus exclusively on ‘genetic modification’ and ignores other non-GM plant biotechnology applications which have been shown to be possibly as risky as GM crops from an environmental and health risk perspective (Morris, 2007a). For example, the UK’s regulatory body, the Advisory Committee on Releases to the Environment (ACRE), addressed this resulting incongruity in its final report of May, 2007. The report stated that: "in recent years, it has become apparent that there are inconsistencies in the [EU] regulatory assessment of the environmental impact of GM crops in comparison with other agricultural crops and practices” (Environment, 2007, pii). In addition, the report criticized the current EU regulations by stressing that:

“this inconsistency is further illustrated by GM herbicide-tolerant crops that require an extensive environmental risk assessment before approval for cultivation and marketing whilst herbicide-tolerant crops produced by non-GM breeding methods can be grown without an equivalent assessment” (ACRE, 2007, p. ii).

The scientific support for this conclusion comes from farm-scale evaluations of GM and non-GM crops in the UK, which demonstrated that the impact of GM crops on the environment is comparable to that of non-GM crops expressing the same herbicide resistance trait if the crop management regime is the same (Firbank et al., 2005). Another example is the fact that the
current process of the safety evaluation of GM versus conventionally bred plants is considered not well balanced as:

“it may be that the current distinction between GMO-derived and so-called conventionally bred new plant varieties does not in all cases provide the best framework for an adequate safety assessment of new plant varieties as the basis for a safe food supply also in the years to come. It seems advisable to screen all new plant varieties for their new characteristics by applying the comparative safety assessment, which may have different end-points” (Kok et al., 2008, p109).

These examples coupled with the evidence that the current ‘genetic modification’ processes used to produce GM crops can have a lesser effect on the target genome or on gene expression than other breeding methods (Coll et al., 2010), (Baudo et al., 2006, Shewry et al., 2007, Lehesranta et al., 2005, Batista et al., 2008, Barros et al., 2010) or even different cultivation techniques (Coll et al., 2010) highlight systemic weaknesses in an EU regulatory framework that is intended to be based on the PP (Morris and Spillane, 2008, Devos et al., 2010).

Moreover, the current EU regulatory framework rarely, if ever, applies the PP to assess the long-term social, environmental and economic costs of inaction—such as not deploying and supporting a new technology, including GM crops. This may reflect the current lack of an effective evidence-based system to balance both the risks and benefits of applying new biotechnologies. A more effective regulatory mechanism—for instance, a regulatory impact assessment framework by which bodies such as the EFSA could be mandated to also assess the benefits of GM crops relative to the perceived or potential risks—could create a more balanced and transparent risk/benefit assessment system. Currently, the EU lacks such a balanced framework to assess comparative risks and benefits from different crop improvement technologies—conventional breeding, induced-mutagenesis breeding, genetic modification, and others—and different production systems—conventional, organic, biodynamic, etc.

Second, the current EU’s regulatory framework for GM crops is not likely to be sustainable in its current form on a long term basis, particularly given the rapid pace of advances in plant biotechnology. Such shortcomings of the EU’s current process-based GM policy were highlighted in a report by the Netherlands’ Commission on Genetic Modification (COGEM),
which advises the Dutch government regarding potential risks of genetic modification to human health and the environment. The COGEM report stated that:

“with the advance of technology, the distinction between genetic modification and other plant biotechnological techniques gradually blurs. In addition, such technological developments also outgrow the GMO legislation. At times it is not clear whether the products of some techniques are subject to the prevailing GMO legislation” (COGEM, 2006, p4).

Such new plant biotechnology techniques include: *inter alia*, the selection of spontaneous mutants (sports); classical chemical and radiation-induced mutagenesis; selection of somaclonal variants (Arun *et al*., 2007); inter-specific hybridisation, somatic hybridisation and cybridisation (Guo *et al*., 2004); mutagenesis owing to naturally occurring mobile DNA elements (transposons) (Lai *et al*., 2005, Morgante *et al*., 2005); novel targeted mutagenesis approaches, including TILLING (McCallum *et al*., 2000), zinc-finger nuclease (ZFN) strategies (Lloyd *et al*., 2005), and allele replacement via homologous recombination (Tzfira and White, 2005); heritable epigenetic modifications, such as gene silencing (Cubas *et al*., 1999); grafting of non-GM components on genetically modified rootstock (Gal-On *et al*., 2005, Kelley *et al*., 2005) and cis-genesis (Schouten *et al*., 2006). In 2008 the EU Commission informed the EU Parliament (via a response to a parliamentary question) that a specific working group of external experts had been created to determine which of the newly developed plant breeding techniques would result in being captured by or excluded from EU regulations (Parliamentary question P-6606/07 2008).

To deal with the above issues it is clear that the EU would have to make the transition from a purely ‘process’ based regulatory framework to a ‘product’ based framework. This would allow a refocus of the risk assessment criteria to both better meet the current EU guidelines on the PP and to make the regulatory framework more sustainable in the face of ever advancing plant biotechnologies. This has been reflected in recommendations made to the EFSA regarding the challenges and approaches for risk assessment of GM plants which stated:

“A paradigm shift would be required to change from risk assessment as it is currently practiced, to a more sophisticated assessment which balances risks and benefits: (i)
The focus on only GM crops defies scientific evidence. In the longer term, risk assessors could develop an alternative approach on a scientific basis. ‘Novelty’ is one option. (ii) The status quo, in which risk assessment is interpreted very narrowly in terms of adverse impacts, is not sustainable, and perceptions of the quality of environmental risk assessments suffer as a result. A framework for the future is required. (iii) There is a need to build decision support tools for the risk assessors to better consider impacts of whole farming systems” (EFSA, 2008, p161)

Discussion
The history of the development of EU regulations pertaining to plant biotechnology and specifically genetic modification, supports the observation that science and policy making are two arenas that are not “cognitively and culturally distinct” but rather “engaged in processes of constant exchange and mutual stabilization” (Jasanoff, 2004). Notwithstanding the complex relationship that exists at the science/policy interface, four key considerations are considered critical in regards to the development of good regulatory oversight models pertaining to emerging technologies: (1) public confidence and trust in the utility and relevance of a technology and its regulatory oversight; (2) regulations should avoid discriminating against particular technologies unless there is a scientifically-based rationale for such disparate treatment; (3) regulatory systems should to be more flexible and adaptive to rapidly-changing technologies; (4) ethical and social concerns of the public about emerging technologies that are based on evidence and not scientifically unfounded narratives should to be expressly acknowledged and addressed in regulatory oversight (Marchant et al., 2009). However, the current wording of the EU Commission’s proposed new changes to Europe’s GM crop regulatory framework do not satisfy any of Marchant et al’s regulatory considerations outlined above.

In developing an assessment of modern plant biotechnology policy in Europe by using the same approach as in the case of Ireland, key questions can be answered, namely:
Q1. What drivers were key contributors to changes within the European plant biotechnology policy arena when they occurred? From what domain did these factors originate?
A1. The European level policy drivers are from various sources. They were both exogenous and endogenous to the system. They include:

- Political drivers: endogenous/exogenous

  In the late 1990’s the Green political movement had begun to increase their influence at all levels of the EU political structure (the Commission, the Parliament and in national governments in Member States)

  Certain Member States, due to their internal political pressures have, from time to time, become more negative towards GM technology. As a result, efforts for these countries to make political gains in the GM arena can allow impacts on GM technology to occur at the European level (e.g. delays in commercial approvals, etc.)

- Trade drivers: endogenous/exogenous

  Internal industry stakeholders such as the feed industry have been key drivers (in particular of the recent change in legislation allowing a new threshold of 0.1% for unapproved GM events in feed as long as the trait had been approved in another jurisdiction.

- International Law drivers:

  The threat of legal action via the World Trade Organisation (WTO) has been suggested as driver for policy in the EU regarding modern plant biotechnology.

Q2: What was the role and relevance of the science-policy interface in the policy change process in terms of producing evidence?

A2: EU policy on modern biotechnology relies relatively heavily on the science-policy interface as can been in the way approvals of GM crops and products are managed. On a very regular basis the science-policy interface becomes very clear in the fact that EFSA will offer advice that GM products under consideration for approval are safe only to have the political decision makers refuse to approve the GM products in question.
Q3. Do the observed patterns of policy change in this system align with common models of change?
A3. Evidence presented suggests that policy change within the EU concerning plant biotechnology is not easily described as fitting a punctuated equilibrium model. This is in light of the fact that the process-based as opposed to product-based approach to risk managing biotechnology which still exists today was adopted prior to the main public discourse regarding GM technology in the mid to late 1990’s. However, the role of biopolitics is certainly evident and plays a very strong role.

2.6 Conclusions

Ireland:
As the analysis presented makes clear, Irish policy on modern plant biotechnology, while reflective of the punctuated equilibrium theory of policy change, is marked by its haphazard and exceptional reactionary nature. The policy actions (or reactions) that have taken place have largely been driven by political factors (i.e. biopolitics). To date, the positive directions taken on GM crops and food to date have usually been driven by internal government forces (inter-departmental committees, appointed working groups, etc.) whose work has tended to serve as a course correcting exercise to move policy from a negative standpoint back to a central/neutral position. The negative positions that need correcting have resulted from efforts to mitigate political risk at election times as opposed to mitigating/managing identified risks resulting from risk assessments pertaining to environmental, health, socio-economic or moral hazards.

If the EU decides to implement current proposals to return decision making authority regarding GM crops to member states Ireland will likely be required to have a more structured/robust manner of developing and implementing policy related to modern plant biotechnology. However, irrespective of the decision made by the EU, Ireland should identify better ways of developing its own plant biotechnology policy, from a starting point that is not a result of political risk management but rather from a place where all sectors of society (e.g. innovators, farming, agri-food industry, forestry, bioenergy, consumers) can be engaged with openly via meaningful democratic consultation. A step in such a direction could
be for the Government to establish a forward- and outward-looking advisory “foresight”
committee on GM technology, to develop evidence-based policies in a democratic manner in
this area that is of strategic importance to Ireland’s society, environment and economy.

European Union:
It is clear that the EU regulatory system concerning modern plant biotechnology is
dysfunctional and likely unsustainable albeit not easily described as fitting a punctuated
equilibrium model. The analysis above suggests a more appropriate regulatory framework,
that would better reflect the ideals of the precautionary principle and regulatory sustainability.
Such a framework would focus on comparatively assessing the potential environmental, health
and socio-economic risks versus the benefits of a product (e.g. a novel crop phenotype), rather
than simply overly focusing on (often hypothetical) risks of a very specific and narrow process
(such as ‘genetic modification’ as defined in EU legislation) through which a new plant
variety was created. Such an approach would also have ‘biopolitical’ benefits of allowing
decision makers greater scope and flexibility to frame and communicate risk mitigation
options pertaining to products derived from an ever growing range of plant biotechnologies in
terms of comparative risk and benefits of the plant trait in question rather than the process by
which the trait was produced. This would provide the EU with the option of escaping the
regulatory roundabout it currently finds itself on regarding GM crops and successfully
complete its journey on the road to resolution via rational risk mitigation measures.

With an analysis of the key policy changes and issues regarding the risk management of
modern plant biotechnology pertinent to Ireland (both a national and EU level) over the last
three decades outlined above, the next chapter examines Irish public attitudes to plant
biotechnology (with a focus on GM technology). This will allow both the policy issues to be
put in context and provide insights into some of the key public attitudes that can influence
public policies and approaches to modern plant biotechnology risk management.
Chapter 3

Irish Public Attitudes to Modern Plant Biotechnologies

“The meaning of things lies not in the things themselves, but in our attitude towards them.”

Antoine de Saint-Exupéry, The Wisdom of the Sands, 1950

Notation: Elements of this chapter are taken from the papers below where S. Morris researched and wrote all elements used:


3.1 Why Public Attitudes?

Public attitudes towards modern plant biotechnologies have been the focus of intense research since the late 1980’s. In many OECD countries, where research on public attitudes towards plant biotechnology and its products (e.g. GM food) has been the most voluminous (Hoban, 2004), the public’s attitude has been considered highly important for numerous political reasons ranging from inter alia: public policy considerations (Tsioumani, 2004, Simon, 2006), and consumer acceptance or rejection (Frewer et al., 2011, Costa-Font et al., 2008), to gaining insights into the public understanding of science and technology (Allum et al., 2008). Moreover, while certain consumer and environmental pressure groups are firmly against the sale and the growing of GM crops and frequently cite negative public attitudes as a reason for banning such products, it is less clear how engrained this negative feeling is in the public
consciousness and if/how it translates into actual consumer behaviour (Spence and Townsend, 2007).

This chapter investigates public attitudes in Ireland toward plant biotechnologies, identifies key changes in these attitudes and examines possible drivers for these changes. To put this chapter in context, a literature review of attitudinal theory is carried out coupled with an overview of empirical studies that assessed Irish public attitudes towards plant biotechnology and their products (e.g. GM crops) since 1989. Building on the background of attitudinal theory and a review of previous surveys, two quantitative explorations of public attitudes to GM food and crops are carried out, in order to allow greater insight into the Irish public attitudes to modern plant biotechnology. Such insight can provide a basis for building improved science communication tools/options (Trench, 2008, Domegan et al., 2010, O'Mahony, 2011, Nisbet and Scheufele, 2009, Whitmer et al., 2010). First, a longitudinal analysis is performed on Irish biotechnology Eurobarometer surveys from 1996 to 2010. The areas of this longitudinal analysis of the Irish surveys examined are grouped under: knowledge, awareness, disposition and trust (based on the concept of using broad headings as defined in a recent review of public attitudes surveys towards science issues (Trench, 2009, Gaskell et al., 2003a)). Second, data regarding phone calls received from the public by Food Safety Authority of Ireland (FSAI) concerning GM food from 2000 to 2010 is also analysed to allow insights into the level of concerns that GM food safety issues invoke. This data combined with the policy research (in Chapter 2) and the media analysis (Chapter 4) can form a basis for accepting or rejecting the hypothesis that the theory of punctuated equilibrium is at play within the Irish context of plant biotechnology.

3.2 Attitudinal Theory

Why examine attitudes? Attitudes, both at the individual level and at the public level have many functions as reviewed below. However, one critical function is the role attitudes play in influencing policy making. Policy making and public attitudes (and the need to measure and understand them) have a relationship where each is constantly influenced by the other (as outlined in Chapter 2 and Chapter 4) (Richardson, 2007, Jacobs, 1992, Holsti, 1996, Manza
and Cook, 2001, Birkland, 2010). As a result, to understand a key driver of policy an understanding of attitudinal theory is required.

3.2.1 Defining Attitudes:

To fully understand the role of public attitudes, one must comprehend what an attitude is, what purpose it serves, how it functions and what its relationships are to information gathering and/or behaviour. An initial understanding of attitudes can be achieved by exploring key aspects of attitudinal theory. Through a review of attitudinal theory literature (taken from the disciplines of psychology, marketing and public policy) spanning the last hundred years, one can gain an appreciation not only of the history of attitude definitions but also of how the concept evolved.

Following an extensive literature review, the nearly thirty definitions for an attitude were found, namely:

1. “By attitude we understand a process of individual consciousness, which determines real or possible activity of the individual counterpart of the social value; activity in whatever form, is the bond between them” (Thomas and Znaniecki, 1918, p526).

2. “An attitude is a complex of feelings, desires, fears, convictions, prejudices or other tendencies that have given a set of readiness to act to a person because of varied experiences” (Chave, 1928, p365).

3. “An attitude is a predisposition to act, which is built up by the integration of numerous specific responses of a similar type. These exist as a general neural ‘set’ and when activated by a specific stimulus results in behaviour that is more obviously a function of the disposition than of acting” (Allport, 1929, p221).

4. “Attitudes are modes of emotional regard for objects and motor ‘sets’ or slight, tentative reactions against them” (Ewer, 1929, p136).
5. “An attitude denotes the general set of the organism as a whole toward an object or situation, which calls for adjustment” (Lundberg, 1929, p127).

6. “An attitude is a tendency to act toward or against something in the environment, which as a result becomes a positive or negative value” (Bogardus, 1931, p62).

7. “We shall regard attitudes here as verbalised tendencies, dispositions or adjustments toward certain acts. They relate not to the past nor even primarily to the present but as a rule to the future. Sometimes of course it is a hypothetical future.... the ‘attitude’ is primarily a way of being ‘set’ towards or against things” (Murphy and Murphy, 1931, p96).

8. “An attitude is a residuum of experience, by which further activity is conditioned and controlled...we may think of attitudes as acquired tendencies to act in specific ways toward objects” (Krueger and Reckless, 1931, p238).

9. “An attitude is a more or less permanently enduring state of readiness of mental organisation, which predisposes an individual to react in a characteristic way to any object or situation with which it is related” (Cantril, 1932, p263).

10. “An attitude is a mental predisposition of the human individual to act for or against a definite object” (Droba, 1933, p445).

11. “Attitudes are literally mental postures, guides for conduct to which each new experience is referred before a response is made” (Morgan, 1934, p47).

12. “Attitude: the specific mental disposition toward an incoming (or arising) experience, whereby that experience is modified for a certain type of activity” (Warren, 1934, p196).
13. “An attitude is a mental and neural state of readiness, organised through experience, exerting a directive or dynamic influence upon the individual’s response to all objects and situations with which it is related” (Allport, 1935, p810).


15. “An attitude is a syndrome of response consistency with regard to a set of social objects” (Campbell, 1950, p31).


18. “An attitude is a ‘tendency’ or ‘disposition’ to evaluate an object or the symbol of that object in a certain way” (Katz and Stotland, 1959, p428).

19. “An attitude is a relatively enduring organisation of beliefs around an object or situation predisposing one to respond in some preferential manner” (Rokeach, 1968, p112).

20. “The attitude, or the basis of the thought process in advance of an actual response, constitutes an important determinant of ensuring social behaviour. Such neural settings with their accompanying consciousness are numerous and significant in social life” (McDonagh, 1976, p72).

21. “Responses towards most objects are prefaced by attitudes towards these objects, which in proximal sense determine responses” (Campbell, 1980, p28).

22. “An attitude is a combination of a perception and a judgement which often results in an emotive orientation toward a phenomenon” (Jarvis, 1990, p14).
23. “At attitude is a general feeling or evaluation -- positive or negative -- about some person, object or issue” (Vaughan and Hogg, 1998, p117).

24. “An attitude is a learned cluster of beliefs, feelings and behaviours, which are derived from a deeply held conviction or 'opinion', that give rise to a response in a consistently favourable or unfavourable manner with respect to a given attitude object. Being learnt this cluster is available for change when further information becomes apparent, or other influences come to bear, thus changing the nature of the original motivation for the attitude” (Roguska, 2002, p41).


26. “An attitude is a relatively enduring organisation of beliefs, feelings, and behavioural tendencies towards socially significant objects, groups, events or symbols” (Hogg and Vaughan, 2005, p150).

27. “Attitudes, like all psychological constructs, are latent, we cannot observe them directly. So all attitude measurement depends on those attitudes being revealed in overt responses” (Albarracín et al., 2005, p22).

28. “An attitude represents an evaluative integration of cognitions and affects experienced in relation to an object. Attitudes are the evaluative judgments that integrate and summarize these cognitive/affective reactions. These evaluative abstractions vary in strength, which in turn has implications for persistence, resistance, and attitude-behaviour consistency” (Crano and Prislin, 2006, p347).

29. “Attitude objects comprise anything a person may hold in mind, ranging from the mundane to the abstract, including things, people, groups, and ideas” (Bohner and Dickel, 2011, p392).
As shown through the multiple definitions of attitudes presented above, despite the fact that the concept of attitude is over 100 years old, social psychologists are yet to provide a single, universally accepted definition (Manstead, 1996; Olson & Zanna, 1993 (Eagly and Chaiken, 2007, Gawronski, 2007)). Still widely cited in current literature, Allport’s early definition of an attitude implies that the term refers to a very general “state of readiness”. Murphy and Newcomb, however, restrict the state of readiness to reaction “towards or against” certain objects. Their phrase ‘towards or against’ implies a certain degree of evaluation (Manstead, 1996). The more recent definitions focus on the affective (i.e. emotionally based) tendency to favourably or unfavourably evaluate objects and entirely discard the notion that any overt behaviour is implied (Bohner and Dickel, 2011). However, an analysis of the past trends in attitude research (Banaji and Heiphetz, 2010, Crano and Prislin, 2008, McGuire, 1985) highlights the fact that there have been four main areas of research. First, during the 1920’s and 1930s, researchers focused on the central nature of an attitude and how attitudes are measured. Second, work in the 1950s and 1960s, examined the drivers of attitude change. Third, from the 1980s to the mid 1990’s, research concentrated on attitude systems that include a ‘structuralist surge’ and concentrated on the content and structure of attitudes (Fabrigar et al., 2005). Fourth and most recently, there is new focus on the implicit measurement of attitudes (Greenwald et al., 1998) and how it differs from traditional self-reporting measurement (Dimofte, 2010). For the purpose of this research the Crano and Prislin definition of an attitude is used (see definition no. 28 above), as it includes an acknowledgement of the cognitive integration step that occurs when an attitude is formed towards an issue or object but it also speaks to the role this can then play in a person’s subsequent reactions (Crano and Prislin, 2006). Moving beyond the challenges of defining what an attitude is, the following areas of attitudinal theory help us focus on how an attitude is conceptualised, constructed, what purpose it serves, how it functions and what its relationships are.

3.2.1 The Conceptualisation of Attitudes:
Reflecting on both the evolution of the definition of an attitude and the types of attitudinal research that has occurred (as outlined above), the conceptualisation of an attitude currently
has two main schools of thought with a spectrum of concepts between them. The two schools are:

1. A model of an attitude as a stable entity stored in an individual’s memory that can be accessed when needed (Visser and Mirabile, 2004, Fazio, 2007, Petty et al., 2007) and;

2. A model that reflects a constructionist view portraying attitudes as temporary judgements constructed on the spot based on the available information (Gawronski, 2007, Schwarz and Clore, 2007, Conrey and Smith, 2007). Between these two models other concepts of an attitude exist such as Eagly and Chaiken’s model of an “umbrella definition” that sees an attitude as a tendency to view an entity (or attitude object) with only some evaluation of the information currently available (Eagly and Chaiken, 2007).

Another model that is positioned between the ‘stable-entity’ and the ‘constructionist’ models is the iterative reprocessing model proposed by Cunningham et al. that takes the view that “current evaluations are constructed from relatively stable attitude representations” (Cunningham et al., 2007, p736). These models and their respective positioning between the ‘stored in memory’ concept of an attitude and the concept that an attitude is ‘constructed on the spot’ are outlined in Figure 3.1 below (Bohner and Dickel, 2011).

Figure 3.1: Theoretical Models of an Attitude

Source: (Bohner and Dickel, 2011)
Other key considerations are necessary in order to put the above models in context and to allow a deeper understanding of the concept of an attitude, these include those facts that:

Attitudes can be learned:
Attitudes are learned through the “course of socialisation” (Shook and Fazio, 2009). Parents, peers, schools, and the mass media all play an important role in shaping social attitudes. Social scientists have put forward a number of theories to account for how children and adults learn social and political attitudes. For the most part, these theories emphasize that attitudes are developed and impacted via conditioning, exposure to novel stimuli, and modelling via others’ influential behaviour (Perloff, 1993, Perloff, 2010).

Attitudes can be enduring:
Attitudes are not transient phenomena – they do not disappear fully as soon as we have made a public statement, nor do they leave as soon as we have told a survey researcher what we think about an issue. Attitudes are relatively stable dispositions (how stable is debated) that can influence our cognitions and behaviours in a variety of ways (Fazio, 2007, Petty et al., 2007, Visser and Mirabile, 2004, Perloff, 2010).

Attitudes can have affective elements:
Attitudes have a strong affective or emotional component (Walther et al., 2011, Smith and Nosek, 2011, Edwards, 1990, Kim et al., 1998, Pratkanis and Breckler, 1989, Perloff, 1993). Contemporary scholars have emphasized that attitudes are evaluative labels that individuals employ to categorize social objects as good or bad, strong of weak, active or passive, etc. Attitudes colour our perceptions and guide our interpretations of social objects (Miceli et al., 2011, Fazio, 1989, Pratkanis, 1989).

Attitudes can exert a directive impact on behaviour:
Attitudes predispose people to act in particular ways. Attitudes are believed to guide and influence behaviour (Fazio, 1996, Ajzen and Fishbein, 2005). To what extent and via what processes attitudes impact behaviour is an area of extensive on-going research (Ajzen and
Fishbein, 2005, Dohmen et al., 2011). To date, no one model or attitude-behaviour dynamic has been proven to exist.

The above concepts naturally provoke the question of how and why an attitude functions. Although several attitude functions have been proposed and analysed (Maio and Olson, 2000) there are five main functions of an attitude namely:

1. **Utilitarian Adaptive Function:**
The utilitarian adaptive function of an attitude guides beliefs and behaviours toward desired objectives and away from adverse situations (Katz, 1960). This function describes attitudes as mechanisms that allow individuals to acquire rewards and avoid punishment (Perloff, 2010). Another theory postulated by Smith, Bruner and White, called the ‘group theory’ (Smith et al., 1956) speaks of the social adjustment function, by which attitudes can serve in facilitating relationships between people. According to Smith et al, holding certain attitudes (akin to world views) can serve in facilitating identification with certain reference groups or with significant others. This social-adjustive function allows attitudes to help individuals relate to or “adjust” to their reference groups. Typically, attitudes help cement relationships with important others in a peer group (Oskamp and Schultz, 2005, Perloff, 2010).

2. **Ego-defensive or externalisation function:**
This function relies heavily on psychoanalytic notions, which are extensively incorporated into this function’s definition. There are two main schools of thought on this subject. First, in 1960, Katz proposed that the ego defensive function of an attitudinal protects against “internal conflicts and external dangers” and occur due to internal conflict (Katz, 1960, p192). Thus attitudes can help protect individuals from having to acknowledge unpleasant truths about themselves (Zanna, 1990, Watt et al., 2008) or about the external world (Perloff, 1993). As a result, this function may be used to defend ones’ self against hurtful realities about themselves (Petty et al., 1981). Second, as outlined by Sornoff in 1960, attitudes can function by acting in support of a course of action (intended or taken) to offer consistency in approach to the individual (Sarnoff, 1960). According to these two schools of thought, those attitudes which
serve ego-defensive functions do not seem to be easily susceptible to change by conventional methods of persuasion.

3. **Value Expressive Function:**
Attitudes help individuals express their central values (Ajzen, 2005). An attitude can aid in the expression of a certain value or set of values believed by an individual (Petty et al., 1981). Katz in 1960 and Smith, Bruner and White in 1956, defined this function as the quality of expressiveness of an attitude. People can use attitudes to express themselves and to assert their own identity, gaining satisfaction and ensuring the continuity of a particular attitude.

4. **Knowledge function / Object appraisal:**
This function permits individuals to better understand their environment (Petty et al., 1981). It has been argued that in order to understand the world in which they reside, people need standards or frames of reference, and that attitudes help define such standards. In this way, attitudes can provide a framework for understanding ambiguous or unpredictable occurrences (Perloff, 2010).

5. **Social utility functions:**
Attitude can play important social roles such as 1) a social adjustive function and 2) a social identity function. The social adjustive function allows the individual to adjust to a particular reference group in order to be accepted. As an example, this has been shown to be a key driver of why people purchase counterfeit luxury goods (Warren, 1934). The social identity function of an attitude suggests a person can hold a specific attitude in order to communicate to others who they are and/or what they wish to be (or seen as) (Shavitt and Nelson, 2002, Morgan, 1934). As such, the use of certain products by an individual or group can be used to express ones/their attitudes which are considered to reflect their values (Warren, 1934).

3.2.2 The Components of Attitudes:
The classical divisions of the elements of behaviour in psychology into cognitive, affective and conative, can be applied to attitudes (Perloff, 2010).
1. The ‘cognitive’ component of an attitude is said to refer to the way in which the attitude object is perceived and conceptualised, and thus represents the individual’s picture of the attitude object and the individual’s beliefs about it.

2. The ‘affective’ component is concerned with emotional underpinning of these beliefs and represents the levels of negative or positive sentiment an individual displays towards the attitude object. There are three important sub-divisions within this component, namely:
   (a) Extremity/ Intensity
   (b) Salience: this is the importance of an individual’s attitude in a given context
   (c) Involvement: this is the personal involvement in the attitude object (Doob, 1947).

3. The ‘conative’ component can be conceived as the individual’s intention to behave in certain ways (or his actual behaviour) (Ajzen and Fishbein, 2005). It can be deemed as a consequence, as well as a corollary of the other two components above.

There is some evidence to suggest that while the division into cognitive, affective and conative components may have some heuristic value, such a breakdown is not readily apparent at an empirical level (Campbell, 1950). As a result, the relationship between the components of an attitude is an area of debate. There are three main approaches, namely:
- The tri-componential approach
- Separate entities approach
- Latent process approach

The Tri-componential approach:
The tri-componential approach suggests that the three components of an attitude, as outlined above, interact with each other to varying degrees to cause an output of an attitude (Figure 3.2 below) (Oskamp and Schultz, 2005, Spooncer, 1992).
Figure 3.2: Components of an attitude

Separate entities approach:
This approach suggests that the three components of an attitude are very distinct, may not be related and may be congruent with each other (Ajzen and Fishbein, 2005). For example, one may have several different beliefs on the same topic and these beliefs are not necessarily related.

Latent process approach:
The latent process approach gives the attitude the role of an intervening variable (produced via a hidden process with a person) that can impact on one’s cognitive, affective and behavioural aspects when one is presented with a stimulus (Rosenberg, 1956). The changes that are incurred can also feedback on to the attitude in a dynamic manner.

The preceding section is necessary to “set the scene” regarding how complex the identification and measurement of attitudes can be, irrespective of the attitude object. In the next section of Chapter 3 a review of key Irish studies which have examined the publics’ attitudes to modern biotechnologies is presented. This will rely on the theory above to allow for interpretation of the findings in other studies.
3.3 Review of studies and polls containing questions that examine public attitudes to modern plant biotechnologies in Ireland

There have been 21 quantitative and 1 qualitative studies investigating public attitudes to modern biotechnology in Ireland (see Table 3.1). Two publications that focus on the agri-biotechnology elements of these studies have been published (O’Connor et al., 2005, Morris and Adley, 2001). In this review, the focus is on survey highlights and key findings in the areas of knowledge, overall support for biotechnology, support for GM food and crops and levels of trust in sources of information.

Table 3.1: Quantitative National Survey Review in Ireland 1989-1999

<table>
<thead>
<tr>
<th>Year</th>
<th>Organizer</th>
<th>Number of Respondents</th>
<th>Publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>Bioresearch Ireland/Lansdowne Market Research</td>
<td>1003</td>
<td>(Úi Ghallachoir, 1990)</td>
</tr>
<tr>
<td>1992</td>
<td>Eurobarometer 46.1, EU Commission DGXII</td>
<td>1003</td>
<td>Report and processed data obtained (Eurobarometer, 1996, Gaskell et al., 1998)</td>
</tr>
<tr>
<td>1999</td>
<td>Eurobarometer 52.1, EU</td>
<td>1002</td>
<td>Report and processed data obtained (Eurobarometer, 1999)</td>
</tr>
<tr>
<td>Year</td>
<td>Study Title/Institution</td>
<td>Sample Size</td>
<td>Report Type/Notes</td>
</tr>
<tr>
<td>------</td>
<td>------------------------</td>
<td>-------------</td>
<td>------------------</td>
</tr>
<tr>
<td>1999</td>
<td>Commission DGXII</td>
<td></td>
<td>data obtained</td>
</tr>
<tr>
<td></td>
<td>Genetic Concern/Lansdowne Market Research</td>
<td>1397</td>
<td>Report (Genetic Concern/Lansdowne Market Research, 1999)</td>
</tr>
<tr>
<td>1999</td>
<td>Amarach Consulting Ltd., Dublin</td>
<td>2592</td>
<td>None (processed data obtained) (Amarach Consulting, 1999)</td>
</tr>
<tr>
<td>1999</td>
<td>California Polytechnic State University &amp; NUI, Galway.</td>
<td>Phase 1: 197, Phase 2: 100</td>
<td>Book Chapter (Wolf et al., 2004)</td>
</tr>
<tr>
<td>2000</td>
<td>University College Cork</td>
<td>200</td>
<td>(Vilei and McCarthy, 2001)</td>
</tr>
<tr>
<td>2001</td>
<td>Fórsa</td>
<td>1000</td>
<td>Report</td>
</tr>
<tr>
<td>2001</td>
<td>Agri-aware/UCD</td>
<td>400</td>
<td>Report (Finnegan and Phelan, 2001)</td>
</tr>
<tr>
<td>2002</td>
<td>Food Safety Authority Ireland</td>
<td>800</td>
<td>Report (Food Safety Authority of Ireland, 2003)</td>
</tr>
<tr>
<td>2002</td>
<td>Eurobarometer 58.0, EU Commission DGXII</td>
<td>999</td>
<td>None (processed data obtained) (Eurobarometer, 2002)</td>
</tr>
<tr>
<td>2004</td>
<td>Teagasc/UCD</td>
<td>297 (segmented clusters)</td>
<td>Report (O’Connor et al., 2006)</td>
</tr>
<tr>
<td>2005</td>
<td>Eurobarometer 64.3, EU Commission DGXII</td>
<td>1000</td>
<td>Report and processed data obtained (Eurobarometer, 2006)</td>
</tr>
<tr>
<td>2009</td>
<td>Geary Institute, UCD</td>
<td>350</td>
<td>Report and (Kennedy et al., 2009)</td>
</tr>
</tbody>
</table>

This study entitled ‘Biotechnology – Awareness and Attitudes’ was undertaken in December 1989 by Lansdowne Market Research (a Irish commercial survey company) and surveyed Irish public opinion towards modern biotechnology (n=1,004). Results indicated a very tenuous public awareness of biotechnology developments. In response to an open ended question, most respondents were unable to state a single biotechnology application, only 25% had any spontaneous knowledge of the subject and only 10% of respondents felt they had any knowledge of the topic. However, there was overall positive attitudes expressed to biotechnology in general (over 55%) and those with more knowledge on the topic tended to have a more positive attitude towards modern biotechnology (Lansdowne, 1989).

1990: Bioresearch Ireland/Lansdowne Market Research.

This 1990 nationwide and statistically significant study (n=1,003) sponsored by Bioresearch Ireland (a state sponsored research promotion agency) showed there was a relatively poor knowledge of biotechnology applications within the Irish public sphere (Ui Gallahior, 1990) (re-enforcing the findings of the previous 1989 study). This study also showed that (at that time) the Irish perception of risk associated with biotechnology applications is relatively low, and that the acceptance of plant and microbial genetic engineering is high. A total of 83% of respondents found the genetic engineering of crop plants acceptable.
The first biotechnology-related survey in the Eurobarometer series was conducted in 1991. The 12 countries which formed the European Community at the time were surveyed. The Eurobarometer covered 12,800 individuals (in Ireland n=1,003). The survey explored the attitude of Europeans towards scientific developments in the area of biotechnology. In addition, it tested levels of knowledge in this field and explored which sources of information are more or less trusted. A significant result was the high number of ‘don't know’ responses given by Irish respondents, as well as by Greek and Portuguese respondents (all over 28%). In these countries, the highest numbers of ‘don't know’ responses were given both to questions regarding biotechnology and to questions regarding genetic engineering. This result reflects a complex reality, since an objective knowledge scale regarding biotechnology and genetic engineering showed that Irish respondents had low levels of knowledge and that of the 12 EU member states they ranked 10th (Greece and Portugal ranked 11th and 12th respectively). At the same time, when measuring overall support for seven different biotechnology and genetic engineering applications, Irish respondents ranked among the top three Member States, a result that indicates high levels of support. Irish respondents mentioned environmental organisations as the most reliable source of information regarding biotechnology and/or genetic engineering (27%). These were followed by schools or universities (21%) and by consumer organisations (16%).

1992: Dublin Institute of Technology/ EOLAS
In November 1992, structured telephone interviews were carried out with 37 leading food and drink companies. From this sample, 28 companies were considered front line consumer firms while the remaining nine were industrial or supply companies. Results from this study indicated that consumer resistance to modern biotechnology was expected by 83.8% of respondents. 51% of respondents indicated that consumer resistance was the most important barrier preventing the continued and future use of genetically engineered food and drink. The majority (60%) of respondents suggested education was the “remedy” to possible adverse consumer reaction. 85% of companies interviewed who had an interest in using new biotechnological techniques were in favour of positive labelling.
1993: Eurobarometer 39.1:

The second survey in the Eurobarometer biotechnology series was carried out in Ireland between May 15 and June 4, 1993. This survey, like the previous one, was administered in the 12 Member States and covered 13,032 individuals and including majority of the questions that were included in the 1991 survey. This 1993 survey consistently showed that Irish respondents (n=1001) had some of the highest number of ‘don't know’ responses (across all knowledge testing questions at approximately 45%) coupled with a relatively low knowledge level regarding specific biotechnology and genetic engineering. An example of this was when asked if it was possible to change the hereditary characteristics of plants, enabling them to develop their own defence against certain insects, Irish respondents had the second highest number of incorrect responses (10.9%) and the third highest number of ‘don’t knows’ (40.8%) (after the ‘don’t know’ responses in Spain [46.4%] and Portugal [45.9%]). When comparing Irish responses with the EU average it was shown that Irish respondents were relatively supportive of modern biotechnology applications (e.g. 66.7% of Irish respondents believed that the use of biotechnology and genetic engineering to change plants was worthwhile and should be encouraged) and considered them relatively low risk. Overall, compared with the previous Eurobarometer survey of 1991, there were no significant changes in Irish attitudes towards modern biotechnology.

1996: Eurobarometer 46.1:

The third Eurobarometer survey was conducted between 18 October 1996 and 22 November 1996 in the 15 member states of the European Union. A total of 16,246 people were interviewed on the basis of a majority of new question types (Ireland n=1003). Only twelve of the questions from the previous study were retained. Within the context of the Irish responses, this survey showed an overall drop in support levels for modern biotechnology applications compared with the previous Eurobarometer polls. However, questions designed to gauge the respondents understanding of modern biotechnology applications (e.g. GM technology) highlighted that the relatively strong support levels was not matched by high levels of understanding of the topic. This paradoxically runs contrary to the premise of the deficit model (See Chapter 5) which suggests greater knowledge of a technology leads to support of a technology.
An example of the lack of knowledge regarding GM technology can be found in the fact that Irish respondents answered the question of whether it was “true or false that ordinary tomatoes do not contain genes whereas GM tomatoes do”, 79.8% answered incorrectly or said they ‘didn't know’ (28.5% responded ‘true’ and 51.3% responded ‘don't know’). Correct answers were given only by 20.2% (saying the statement is false). This was the highest number of incorrect answers combined with ‘don't know’ answers of all EU Member states (with Greece being another country to reach the same figure). The absence of fundamental knowledge regarding modern biotechnology, or even genetics and evolution, was added to the result of another question (“Is it true or false that by eating genetically modified fruit, a person's genes could also become modified?”) for which Ireland again had the highest number of ‘don't know’ answers (43.7%). Only 33.8% answered correctly (i.e. ‘false’) and the other 22.5% answered incorrectly that this statement was correct. Ireland had a relatively low score on the trend knowledge scale and the highest number of ‘don't know’ answers throughout the survey. The Irish public expressed a relatively high degree of support toward medical applications of biotechnology but low and medium degrees of support toward transgenic animals and agri-food biotechnology.

Two questions were designed to measure whether people had previously heard or talked about biotechnology. These questions were: 1. “Is it true or false that ordinary tomatoes do not contain genes whereas GM tomatoes do?” and 2. “Is it true or false that by eating GM fruit, a person's genes could also become modified?” The results of these questions show that the Irish public had a low level of acquaintance with biotechnology. Irish respondents tended to have slightly positive expectations regarding biotechnology developments in the next 20 years, (see Figure 3.12 effect of GE food or Food Biotechnology). Furthermore the Irish public was did not express serious concerns regarding the risks of biotechnology (48% compared with EU average of 52%) and regarding the regulation of biotechnology. Individuals mostly believed that current regulations were sufficient and agreed that some risk must be accepted in the interests of economic competitiveness (the Irish [42%] and British [40%] were most willing to accept some degree of risk regarding biotechnology). Irish respondents also tended to have slightly positive expectations regarding biotechnological developments in the next twenty
years (on a scale that measured means where the EU average was 2.65 the Irish responses were fifth highest at a mean of 2.9).

1999: Eurobarometer 52.1.
The 1999 Eurobarometer (number 52.1) surveyed 1,002 Irish people between November 1st and December 15th, 1999. This survey was carried out directly after a period of intense Irish media coverage of GM technology in the preceding 15 months (see Chapter 4). Again the relatively high number of ‘don't know’ responses was a distinguishing feature of the Irish survey (an average of 41.4%). The data collected in Ireland showed similar results to that of Portugal, especially in the number of ‘don't know’ responses. The Irish survey indicated a relatively negative attitude towards GM foods. Irish respondents now believed that the risks involving both GM food and animal cloning (this was 2 years after Dolly the sheep was cloned) were not acceptable. Irish respondents also expressed a drop in support for modern biotechnology applications compared with results from the previous Eurobarometer surveys. However, when compared with the 1996 Eurobarometer results, there was an increase in the number of individuals who gave an incorrect answer, that is, those who believed that the statement “ordinary tomatoes don't contain genes whereas GM tomatoes do” was correct (Table 3.2).

Table 3.2: Responses to: Is it true or false, that ordinary tomatoes do not contain genes while GM tomatoes do?

<table>
<thead>
<tr>
<th>Eurobarometer result</th>
<th>True (%)</th>
<th>False (%)</th>
<th>Don't know (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ireland 1996</td>
<td>28.5</td>
<td>20.2</td>
<td>51.3</td>
</tr>
<tr>
<td>Ireland 1999</td>
<td>36.8</td>
<td>22.2</td>
<td>41.0</td>
</tr>
<tr>
<td>EU average 1996</td>
<td>30.6</td>
<td>35.8</td>
<td>33.6</td>
</tr>
<tr>
<td>EU average 1999</td>
<td>34.8</td>
<td>35.1</td>
<td>30.1</td>
</tr>
</tbody>
</table>

Source: (Morris and Adley, 2001).

Regarding the second question (“is it true or false that by eating GM fruit a person's genes could also become modified”), results from Irish respondents show a rise in the incorrect response (i.e. ‘true’) from that of 1996, which supports the above result. The results also show
an increase in the level of ‘don't know’ responses and a corresponding drop in the correct response of those who responded ‘false’ (Table 3.3).

Table 3.3: Responses to: Is it true or false, that by eating genetically modified fruit a person's genes could also become modified?

<table>
<thead>
<tr>
<th>Eurobarometer result</th>
<th>True (%)</th>
<th>False (%)</th>
<th>Don't know (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ireland 1996</td>
<td>22.5</td>
<td>33.8</td>
<td>43.7</td>
</tr>
<tr>
<td>Ireland 1999</td>
<td>25.1</td>
<td>29.5</td>
<td>45.4</td>
</tr>
<tr>
<td>EU average 1996</td>
<td>23.2</td>
<td>48.6</td>
<td>28.3</td>
</tr>
<tr>
<td>EU average 1999</td>
<td>23.7</td>
<td>42.3</td>
<td>34.0</td>
</tr>
</tbody>
</table>

*Source:* (Morris and Adley, 2001)

Respondents were asked whether they felt sufficiently informed about biotechnology. 82.5% tended to disagree while only 7.9% tended to agree (9.6% stated ‘don't know’). These results show that knowledge levels regarding GM food in Ireland have not improved although the public was increasingly exposed to media coverage and despite the fact that there was information available in the public domain. This suggests that the information provided by the media was either: (1) not factual; (2) at insufficient levels to make an impact; (3) not in the correct format to cause knowledge gain or (4) outside the latitudes of acceptance of the reader/listener. It could also suggest that there has been a successful campaign to promote a menacing image of GM food, which in turn would suggest failure by those promoting GM food.

1999: Genetic Concern/Lansdowne Market Research

Genetic Concern, an Irish NGO/Pressure group commissioned a number of questions as part of a Lansdowne Market Research survey omnibus survey with a view to obtaining a measure of consumer attitudes to genetic engineering. This survey was conducted between January 4th and 14th, 1999. A total of 1,397 people were interviewed at various locations throughout Ireland. This was deemed to be a statistically representative sample of the Irish population. The main conclusions drawn by Genetic Concern outlined in their press release were:
1. Very few people consider that they know much about genetic engineering (78% said they know little or nothing about the technology).

2. Generally speaking, women - especially married women - were more concerned than men about genetic engineering. This could be explained by the fact that married women do most of the food shopping for the family and therefore face decisions regarding food safety / risk daily and in a more concrete way.

3. When asked if they were concerned about genetic engineering, a clear majority of all those who were interviewed said that they were. Only 184 people out of 1397 were unable to answer the question.

4. When prompted, 62% of those who responded said that they were either “very concerned” or “fairly concerned”, compared with just 24% who were either “not very concerned” or “not concerned at all”. A further 14% were “neither concerned nor unconcerned”.

5. Those who considered that they knew most about genetic engineering were also the most concerned about the implications of genetic engineering for food safety. Of those who felt they knew a lot about genetic engineering, 89% were concerned, compared with just 8% who were unconcerned.

After prompting the respondents with a number of food safety issues, 62% of those who responded were concerned with genetic engineering compared to just 24% who were unconcerned. Highest levels of concern were from married women (68%) and the lowest levels were single men (52%) (Table 3.4). In addition, a very substantial majority (89%) of those who responded wanted clear labelling of genetically engineered food against just 2% who disagreed with the need for labelling.
Table 3.4: After prompting the respondents with a number of food safety issues, level of concern about genetically modified foods was assessed.

<table>
<thead>
<tr>
<th>Group</th>
<th>Male</th>
<th>Female</th>
<th>Male Married</th>
<th>Male Single</th>
<th>Female Married</th>
<th>Female Single</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Concerned</td>
<td>35%</td>
<td>30%</td>
<td>39%</td>
<td>35%</td>
<td>26%</td>
<td>44%</td>
</tr>
<tr>
<td>Fairly Concerned</td>
<td>27%</td>
<td>28%</td>
<td>27%</td>
<td>29%</td>
<td>26%</td>
<td>26%</td>
</tr>
<tr>
<td>Neither</td>
<td>14%</td>
<td>13%</td>
<td>16%</td>
<td>13%</td>
<td>13%</td>
<td>14%</td>
</tr>
<tr>
<td>Not Very Concerned</td>
<td>14%</td>
<td>16%</td>
<td>11%</td>
<td>16%</td>
<td>16%</td>
<td>10%</td>
</tr>
<tr>
<td>Not at all Concerned</td>
<td>10%</td>
<td>13%</td>
<td>8%</td>
<td>8%</td>
<td>19%</td>
<td>6%</td>
</tr>
<tr>
<td>Don't know/No</td>
<td>15%</td>
<td>14%</td>
<td>17%</td>
<td>9%</td>
<td>18%</td>
<td>14%</td>
</tr>
</tbody>
</table>

Source: (Morris and Adley, 2001)

It is very clear from the survey that at the time, few people knew very much about the biotechnology (Figure 3.3).

Figure 3.3: Respondents Self-Declared Knowledge of Genetic Engineering

Source: (Morris and Adley, 2001)
The lack of knowledge regarding genetic engineering was almost uniformly spread amongst all age groups (Table 3.5), a noteworthy fact given Ireland’s aspirations to become a knowledge-based economy.

**Table 3.5: Knowledge levels of genetic engineering by age group in Ireland.**

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Age 15-24</th>
<th>Age 25-34</th>
<th>Age 35-49</th>
<th>Age 50-64</th>
<th>Age 65+</th>
</tr>
</thead>
<tbody>
<tr>
<td>I know a lot about GE</td>
<td>4%</td>
<td>4%</td>
<td>4%</td>
<td>5%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>I know a reasonable amount about GE</td>
<td>17%</td>
<td>16%</td>
<td>22%</td>
<td>18%</td>
<td>20%</td>
<td>8%</td>
</tr>
<tr>
<td>I know very little about GE</td>
<td>42%</td>
<td>43%</td>
<td>43%</td>
<td>45%</td>
<td>43%</td>
<td>34%</td>
</tr>
<tr>
<td>I know nothing about GE</td>
<td>37%</td>
<td>37%</td>
<td>31%</td>
<td>33%</td>
<td>33%</td>
<td>56%</td>
</tr>
</tbody>
</table>

Source: (Morris and Adley, 2001)

The general low levels of knowledge about genetic engineering that are found in this survey are consistent with the findings from other surveys. However, Genetic Concern drew the conclusion that

“**those who considered that they knew most about genetic engineering were also the most concerned about the implications of genetic engineering for food safety. Of those who felt they knew a lot about genetic engineering, 89% were concerned, compared with just 8% who were unconcerned**”.

This conclusion is misleading because only 4% of the total sample said that they knew a lot about genetic engineering (this figure had no knowledge testing question) which amounted to only 56 people. Thus, because of the very small figure, it is not probable that the suggested relationship could be established by statistical testing. A second point that was not highlighted in the Genetic Concern conclusion was the fact that genetic engineering consistently came last in the list of food safety issues that concerned respondents (even after prompting).

**1999: Amarach Consulting Ltd. Survey**

Between May 14th and June 22nd, 1999, Amarach Consulting administered an omnibus survey by interview to 2,592 people between the ages of fifteen and seventy-four. The survey was
weighted to be a statistically representative sample of national residents. The survey contained two questions relating to GM food. The first asked respondents if they were concerned about the safety of genetically modified foods. The second then asked those who had indicated a level of concern regarding GM food whether their concern influenced the purchases of food they made. Of the respondents, 82% stated that they were concerned about the safety of GM foods (39% were very concerned and 43% were somewhat concerned; Table 3.6). The remainder, 18%, stated that they were unconcerned.

**Table 3.6: Level of concern about the safety of genetically modified food in 1999**

<table>
<thead>
<tr>
<th></th>
<th>Totals</th>
<th>Gender</th>
<th>Marital Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Very Concerned</td>
<td>39%</td>
<td>42%</td>
<td>58%</td>
</tr>
<tr>
<td>Somewhat Concerned</td>
<td>43%</td>
<td>53%</td>
<td>47%</td>
</tr>
<tr>
<td>Unconcerned</td>
<td>18%</td>
<td>61%</td>
<td>39%</td>
</tr>
</tbody>
</table>

*Source:* (Morris and Adley, 2001)

Responses also show that Irish men were less likely to be concerned about GM food than Irish women. Among those respondents who claimed to be unconcerned about the safety of GM food, 61% were men whereas only 39% were women. Analysis of the responses also indicates that single people were less concerned about the safety of GM food than those who were married or widowed. More than 50% of those who were unconcerned were single. The youngest respondents (aged 15–24 years) and oldest (≥65 years) tended to be the least concerned about GM food whereas those aged 35–49 years were the most concerned. Social class seemed to have little, if any, effect on the level of concern whereas increased education tended to elicit a somewhat higher level of concern regarding the safety of GM food. Of those who were ‘very concerned’ about the safety of GM food, 50% classed themselves as homemakers.
The second question regarding GM food in this survey was only asked of those who had stated that they were concerned about GM food. It attempted to derive what level of influence this concern regarding GM food had on the actual purchasing of food (Table 3.7). The results show concern for the safety of GM foods had a possible influence on purchasing. However, care should be taken when examining the results from this question as it applied only to a subset of the sample. In addition, the possibility of influence of cannot be discounted fully as empirical evidence has shown that what interviewees say they will do does not always translate into actual behaviour (Katz and Stotland, 1959, Campbell, 1980).

Table 3.7: Do concerns about the safety of GM food influence what you buy? (1999)

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always - I try to ensure that nothing I buy is GM.</td>
<td>27%</td>
</tr>
<tr>
<td>Most of the time - but sometimes it is impossible to find out if something is GM.</td>
<td>33%</td>
</tr>
<tr>
<td>Some of the time - if I have time I will read the label but there are often times when it’s too difficult.</td>
<td>27%</td>
</tr>
<tr>
<td>Never - Concern about GM foods doesn’t affect my choice of products at all.</td>
<td>13%</td>
</tr>
<tr>
<td>Don’t know</td>
<td>0%</td>
</tr>
</tbody>
</table>

Source: (Morris and Adley, 2001)

Again, men and single people comprised the largest proportion of those who stated that concern about GM foods did not affect their choice of products at all – 70% were men and 50% were single. Females and homemakers tended to indicate that concern regarding GM food did affect what they purchase, although there is no validation that their actions follow up on their perceptions of concern. This second question reinforces the findings from the previous question and also shows similarity with both the Genetic Concern/Lansdowne and the 1999 Eurobarometer 52.1 surveys.

1999/2000: California Polytechnic State University & NUI, Galway:
A two phase study was carried out in 1999 (Phase 1) and 2000 (Phase 2) to compare the attitudes of two communities, one in the US (San Luis Obispo County, California; population
of approx. 42,000 in 2000) and the other in Ireland (Galway City, County Galway; population of approx. 57,000 in 2000) to GM food and related issues during two time periods (Wolf et al., 2004). The first phase of the survey sampled 197 Irish people (n=197) while the second phase had an Irish sample of 100 (n=100). In the second phase of the research additional questions relating to particular uses of GM technology and trust in Government agencies were added. Results pertaining to the Irish sample found that the majority of Irish respondents in both phases of the research were either not very familiar or not at all familiar with GM foods (1999: 56.1% and 2000: 58.6%). Over 90% of Irish respondents, in both research phases, who were very or somewhat familiar with GM food, indicated that newspapers and television news were their main source of information. In the second phase respondents were asked their opinion on the appropriateness of sources of information on GM. In Ireland TV news reporters (88.2%), newspaper reporters (76.3%), and radio news reporters (69.9%) were deemed the top three most appropriate sources. Lower on the scale were science teachers (42.6%), university professors (38%) and farmers (33.3%).

In relation to the likelihood of Irish respondents to buy GM food, there was a large increase between Phase 1 and Phase 2 of respondents claiming they would probably not or definitely not purchase GM food (Phase 1: 27% and Phase 2: 50.5%). The number of Irish respondents indicating that they would definitely, probably or maybe buy GM food remained relatively static at 47.7% (Phase 1) and 49.5% (Phase 2). In both phases of the study a high percentage (over 94%) of Irish respondents believed mandatory labelling of genetically modified food was important (i.e. in 1999 - very important: 70.6%, somewhat important: 25.4% and in 2000 - very important: 68%, somewhat important: 27%).

Results from the Irish cohort show that respondent’s likelihood to buy GM food depended upon the particular attribute it had. GM food derived from crops that were modified to kill pests and use less pesticides had the highest rating (mean score) while those modified to improve taste were rated the least (see Table 3.8)
Table 3.8: How likely are you to purchase a food product that has been genetically modified?

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Mean rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>To kill pests and allow farmers to use less pesticides?</td>
<td>3.05</td>
</tr>
<tr>
<td>To improve nutrition?</td>
<td>3.03</td>
</tr>
<tr>
<td>To help plants withstand weed killers?</td>
<td>2.64</td>
</tr>
<tr>
<td>To improve taste?</td>
<td>2.56</td>
</tr>
</tbody>
</table>

Source: (Wolf et al., 2004)

Irish respondents’ trust in Government agencies did not influence their willingness to buy GM food, while a positive relationship between perceptions of global food producers using environmentally safe methods and their willingness to buy GM food was found.

2000: University College Cork (Vilei and McCarthy, 2001)

In June 2000, a survey of 200 people was carried out in Ireland using a self-reporting questionnaire via mail in three cities (Dublin, Cork, and Limerick). The sample was representative of Irish gender, age and socio-economic groupings in Ireland at the time (based on national statistics from the 1996 census). Of those surveyed all indicated some awareness of the concept of gene technology in food production (Vilei and McCarthy, 2001). However, the levels of awareness were diverse (23% had heard ‘a lot’ about gene technology; 64% had heard ‘a fair amount’ and 14% indicated ‘very little’). The majority of respondents (57%) held the belief that GM food products were being sold in Irish stores (35% indicated that they did not know, while 8% believed they are not sold). 55% were able to name a GM food commodity that they believed was on sale. Once again, no significant relationship was found between increases in level of knowledge about gene technology and increases of levels of acceptance of gene technology.

2001: Fórsa

In September 2001, a survey was commissioned by Fórsa, the Irish national industrial development agency, to determine the level of public knowledge about biotechnology within Ireland. The study consisted of 1,000 telephone interviews to members of the Irish public. 67% of respondents were found to have no knowledge of the term, “biotechnology”. 12% of
respondents linked the term biotechnology to genetically modified organisms (GMOs) or GM food, while 2% linked it to cloning. Only 20% of those surveyed perceived biotechnology as a 'good' thing. Concerns expressed by respondents included biotechnology interfering with nature (28%), human health worries (17%) and ethical concerns (11%). 25% of respondents said they had no concerns. Females and the middle-aged (35-54 age group) expressed more concern about human health and ethics.

2001: *Agri-aware/UCD*

In August 2001, the Irish Agri-Awareness Trust commissioned a study (400 face-to-face interviews with members of the public) to examine Irish public perceptions regarding agriculture and the food industry (including food safety issues, disease scares and GM foods) (Finnegan and Phelan, 2001). 67% of those who responded cited major concern regarding GM foods risks. Noteworthy was the fact that 41.5% cited BSE as a major concern.

2002: *Eurobarometer 58.0, EU Commission DGXII*

This survey was carried out between September 1st and October 7th, 2002 in the 15 EU countries. It was the fifth in a series of Eurobarometer surveys on biotechnology and the life sciences. The Irish component involved a sample of 999 face to face interviews. From the Irish respondents, 24% felt "very" or "fairly well informed" on GMOs which was the lowest of all 25 environmental issues presented in the survey. Ireland had the third highest level of ‘don’t know’ responses amongst all 15 EU countries where the survey was carried out (EU average was 27%). Only Greece and Portugal had higher levels of ‘don’t know’ responses at 44% and 41% respectively. Ireland had one of the lowest engagement levels on biotechnology at only 18%. 26% of Irish respondents were very worried about GMOs which was less than the EU average of 30%. Irish respondents’ support for GM crops was 77% in favour (EU average in 2002 was 89.7%) while support for GM food amongst Irish respondents was the joint second highest at 70% (Spain was 74% and Finland was 70%). Noteworthy is the fact that while Ireland had one of the lowest levels of knowledge or engagement regarding biotechnology, it had comparatively high levels of support for GM food. Furthermore, Irish respondents had the second highest percentage of respondents who would reject all reasons for buying GM food. However, they also had the second highest mean number of acceptable
reasons for buying GM foods amongst those remaining respondents who did not reject all reasons for buying GM food (see Figure 3.4). This indicates that those who did not completely reject GM foods were open to relatively more reasons for buying GM food than the EU average.

Figure 3.4: Acceptance/Rejection Levels of Reasons for buying GM food

Source: (Eurobarometer, 2002)

2002: Food Safety Authority Ireland (FSAI):
Using a nationally representative sampling method, 800 telephone interviews with Irish adults (persons aged 15 and over) was carried out on the issue of food safety between April and May 2002. GM food was rated joint fifth (with food irradiation and additives) from a list of nine food safety concerns. Herbicide and pesticides were listed as the first concern (70%), BSE/mad cow disease the second concern (67%) and food poisoning as third (64%). When surveyed about possible adverse long-term health effects of food consumed nowadays respondents cited cancer (32%), unknown long-term effects of GMOs and mass production (24%), heart disease (15%) and obesity (13%).
**2004: Teagasc/UCD**

Between October and early November 2003, 297 yogurt consumers were sampled via face to face interviews to examine their attitudes to a hypothetical second-generation GM yogurt product (O’Connor et al., 2006). The study was a random sample controlling for gender, age and socio-economic level. Interviews took place at twenty-one sampling points throughout Ireland that were randomly generated to reflect the population’s geographic placement.

Results found that in the sample surveyed an “anti-GM” segment (24.4% of sample) existed that completely rejected all GM foods; while a second grouping (33.4%) specifically rejected second-generation GM products. Another grouping, 20.5% of the sample, were open to the idea of second-generation GM products but had a number of complex reservations. In addition, GM foods that had specific consumer benefits were acceptable to 21.2% of the sample.

**2005: Eurobarometer 64.3, EU Commission DGXII**

The 2005 Eurobarometer 64.3 was carried out during November and December, 2005 via face to face interviews in the 25 EU member states. 68% of Irish respondents (n=1000) claimed they were familiar with GM food which was below the EU average of 80%. 29% of Irish interviewees stated that they were supportive of GM food which was slightly above the EU average of 27%. Outright support and risk tolerance for GM food among Irish respondents was 55% (lower than the 2002 [70%] figure but similar to the 1999 level [56%]). Overall Irish respondents had low levels of knowledge of modern biotechnology coupled with low levels of engagement activities which placed them within the ‘unengaged’ category when compared to other EU Countries (Figure 3.5)
26.7% of Irish respondents rejected all reasons to buy GM food (which is a decrease when compared to the 2002 results). There was a slight increase in the number of reasons to buy GM food (mean = 3.85) Irish interviewees were willing to accept when compared to the results in 2002). This placed Ireland respondents in a very similar position to UK respondents (see Figure 3.6).
2005: Irish Council for Bioethics

In 2005, The Irish Council of Bioethics (ICB) published a report entitled ‘Genetically Modified Crops and Food: Threat or Opportunity for Ireland?’ As part of the development of the report the ICB undertook a public consultation process that used a 17 question survey (16 closed ended questions and one open end question allowing respondents to add any information/comments they wished to) that allowed members of the public to express their views on a number of issues. The sample was not statistically significant or representative of key demographics. A total of 560 submissions were received, of which 311 respondents expressed their individual opinions via the open ended question that allowed free text input. Results show that a vast majority of those who submitted input to the ICB were opposed to controlled cultivation of GM crops in Ireland (77% disagree, 14.3 agree, 8.7% unsure).

Overall, the report found that it was “abundantly clear from the findings of the consultation that those responding are greatly opposed to the introduction of GM crops, and are largely of the view that GM foods currently on sale are not safe for human consumption”. Noteworthy was the fact that there was a diverse range of issues/concerns that were cited in the open end
questions that included health concerns, socio-economic concerns to environmental issues and moral/ethical worries.

2009: Geary Institute, UCD
In December 2008, via the use of an online survey pan (the University College Dublin Food and Health Survey panel), 350 panel members were questioned on various food and health risk issues during a survey regarding the 2008 dioxin incident in Irish pork (Kennedy et al., 2010). GM food was considered by respondents to pose the least risk to human health when compared to the other food related hazard types from the 47 food and non-food related hazards ranked by respondents. Overall GM food was considered the ninth least risky hazard (mean score: 2.43 – where 1=almost no health risk, 4=high health risk) below that of noise levels in night clubs (mean score: 2.52), BSE (mean score: 2.76), moulds (mean score: 2.79), food additives (mean score: 2.82), bacteria in food (mean score: 3.01), pesticides (mean score: 3.16), high fat food (mean score: 3.44).

2010: Eurobarometer 73.1, EU Commission DGXII
This survey was carried out in the 27 EU countries between January and February, 2010. The survey sampled 1,007 Irish people via face to face interviews. This survey supports previous Eurobarometer surveys that show Irish respondents have a high level of ‘don’t know’ and ‘no opinion’ responses. For example, while 80% of Irish interviewees had heard of GM food, 35% of respondents (the highest of all EU countries) in Ireland ‘didn’t know’ if GM food were harmful or not (Malta was second highest at 33%). Irish respondents also had the largest percentage (31%) of all EU countries who responded ‘don’t know’ to a question asking if they agreed or disagreed that GM food is fundamentally unnatural. Ireland also had the smallest percentage of respondents who agreed with the statement (52%). It also had the third lowest percentage of respondents (48%) stating that GM food made them feel uneasy which was below the EU average of 61%. In addition, Irish respondents had the lowest level of disagreement (36%) in all EU countries (EU average was 61%) with the statement that GM food should be encouraged. Nevertheless, Irish respondents (22%) tended to be close to the EU average (23%) on agreeing GM food should be encouraged. 51% of Irish interviewees felt that over the next twenty years genetic engineering will improve our life. As with prior
Eurobarometer surveys, Irish responses were characterised by comparatively high levels of ‘don’t know’ or ‘no opinion’ responses coupled with low levels of complete rejection or concern with GM technology.

Qualitative study:

2002: Food Safety Authority Ireland

The Food Safety Authority of Ireland (FSAI) carried out two surveys in 2002 (between April and May) to examine Irish public and industry attitudes to food safety (800 quantitative phone interviews and 10 qualitative focus groups). In the qualitative research phase, GM foods were not cited as a food safety issue (no prompting took place). When surveyed about possible adverse long-term health effects of food consumed nowadays respondents cited cancer (32%), unknown long-term effects of GMOs and mass production (24%), heart disease (15%) and obesity (13%).

3.4 Longitudinal Analysis of Biotechnology related Eurobarometer Surveys in Ireland (from 1996 to 2010)

3.4.1 Objective:

Over the past thirty years 16,000 plus Irish people have been asked their opinion on biotechnology (Table 3.1), each one of these studies usually polled over 1000 people that were considered representative samples of the Irish population. These surveys paint a general picture of the Irish public’s opinion. However, strictly speaking, it is not possible to directly compare all the surveys to one another. Only polls that use the same questions (i.e. the same wording) and the same methodology, for the same regions at different times are ‘directly’ comparable. Longitudinal analysis, where possible in both survey data and public comment records, can be used to identify trends and patterns that can be extracted (Durant and Legge, 2005, Durant et al., 1998, Gaskell et al., 1998, Gaskell and Bauer, 2001, Trench, 2009, Morris and Adley, 2001, O’Connor et al., 2005).

As a result, the results from seven Eurobarometer quantitative surveys which were all carried out within the same EU research initiative were further analysed to examine the specific Irish results on a longitudinal basis where possible.
3.4.2 Methodology

The longitudinal analysis offered in this chapter that is carried out as part of this thesis uses Irish results from the seven biotechnology Eurobarometer surveys. The Eurobarometer surveys are a set of surveys carried out in each E.U. member state on a specific topic as part of the EU on-going effort to monitor public opinion. Since 1973, the European Commission has been monitoring public opinion in the Member States to aid in the preparation of texts, decision-making and the public’s evaluation of its work. The surveys are organized and commissioned by the E.U. Commission DG XII. There has been a set of seven surveys carried out under the Eurobarometer program on the issue of biotechnology between the years 1991 and 2010 inclusively. These surveys, conducted in each EU Member State, used a multistage random procedure providing a statistically representative sample of national residents aged fifteen and over. Such research allows easy and useful comparisons of results between countries, as responses to questions asked in one EU country can be compared directly to the answers provided to the same question in another EU country during the same Eurobarometer survey.

However, research examining changes in country specific attitudes in Europe over time has been relatively limited (Gaskell and Bauer, 2001, Allum et al., 2008, Gaskell et al., 2003a, Pardo et al., 2002, Durant et al., 1998) and even less has been completed on the evolution of Irish public attitudes to modern biotechnology over time (O’Connor et al., 2005, Morris and Adley, 2001). The primary challenge to such work is that not all Eurobarometers have used the same questions, resulting in a limited ability to compare responses over time to any great extent. In addition, certain methodical issues have been highlighted in both the questions used in the Eurobarometer surveys and the analysis of results derived from the Eurobarometer surveys (Pardo and Calvo, 2004, Pardo and Calvo, 2006).

Notwithstanding the result comparison challenges and the criticism of Eurobarometer questions, all the Irish results from the seven comparable Eurobarometer surveys were examined, collected and analysed to allow (where possible) for the development of a longitudinal data set for identification of trends and changes over time in Irish attitudes. Via this secondary analysis of the Eurobarometer biotechnology surveys results from Ireland, it
was possible to derive - on a longitudinal basis - developments in the areas of knowledge, awareness, disposition and trust. The choice of these areas is based on the concept of using broad headings under which to categorise answers to certain questions. This method, using the same or similar areas as outlined above, has been used in recent reviews of public attitude surveys (Bauer et al., 2007, Rother and Langner, 2004, Allum et al., 2008).

3.4.3 Results:
Results for the longitudinal analysis of Irish responses to plant biotechnology questions in seven different Eurobarometer surveys from 1991 to 2010 were grouped into four main categories: awareness, knowledge, disposition and trust.

Awareness:
A key area of importance in both a policy context and a public involvement/attitude context is the concept of public awareness of an issue (Droba, 1933). How and to what extent the public is aware of an issue can have an impact on how an issue is framed and by whom (Augoustinos et al., 2010, Dannenberg, 2009). Analysis of the five Eurobarometer surveys carried in Ireland from 1996 to 2010 that employed awareness questions shows growth in the number of interviewees stating they had heard of food biotechnology/GM food, from 34% in 1996 to 81% in 2010 (Figure 3.7). A near linear increase in awareness is observed, although in 1999 there was a spike in the number of people having heard of food biotechnology which could be related to the increase in Irish media coverage of agriculture and GM food as during this period field trials of GM sugar beet took place in Ireland.
Knowledge:
Knowledge and its relationship to attitudes has been a key area of research in several fields (e.g. politics, public understanding of science, etc.). The knowledge-attitude nexus within the biotechnology area is one of much contention. Positions range regarding this nexus: some defend the deficit model, stating that low levels of knowledge are correlated with negative attitudes (put simply, understanding biotechnology entails accepting / supporting it); others acknowledge no such relationship between knowledge and acceptance / positive attitudes. Between these poles a range of opinions can be found. These include those who suggest a weak link between knowledge and positive attitudes and those who suggest a fundamentally more complex relationship (for example, in the UK it was found that knowledge of general science is positively correlated with positive attitudes to science in general, while for specific technologies a variety of correlations were found, including a negative one for morally contentious issues) (Durant et al, 2002).
The Eurobarometers that focus on biotechnology employ a range of knowledge testing questions known as the ‘Oxford Scale’ which is a series of factual type closed-ended questions that examine ‘textbook’ knowledge of science. The question set was developed in 1988 via a collaboration between Jon Miller in the US and John Durant and colleagues in the UK (Miller, 1998, Durant et al., 1992).

By examining in a longitudinal manner the results from four knowledge testing questions that were used in the 1996, 1999, 2002 and 2005 biotechnology Eurobarometer surveys administered in Ireland, it is possible to obtain a more granular perspective on the issue of knowledge. The first question analysed here is “is it true of false that ordinary tomatoes do not contain genes, but GM tomatoes do”. Between 1996 and 2005 there is a slight progressive improvement in the number of correct responses from 21% to 31%. The peak of incorrect responses was in 1999 during the peak of media coverage in Ireland on GM foods. Only in 2005 did more people correctly answered the question than not. In all four surveys, the numbers of respondents answering “don’t know” were either the highest or joint highest response level. Since 1999 there has been an increase in the number of “don’t know” responses to this question (Figure 3.8).
The second knowledge testing of Irish Eurobarometer surveys that was used across a few years asked if it was true or false that by eating a GM fruit, a person’s genes could become modified. Across all surveys more respondents answered correctly (false) than incorrectly (true). As in the prior question above, the percentage of incorrect responses (true) peaked in 1999 (25%) and has increased since. The number of “don’t know” responses remained relatively stable over time, with a deviation across the four surveys of ±3 percentile points. Only in 2005 did the number of “don’t know” responses drop below the number of correct answers (Figure 3.9).
Figure 3.9: Irish Responses to the question asking is it true or false that by eating a GM fruit a person’s genes could also become modified (1996-2005)

Another knowledge related question that was suitable for longitudinal analysis over the four surveys was whether it was not possible to transfer genes between species (true or false). As with the prior questions the number of “don’t know” responses was very high and consistently so, with relatively little changes in the levels across the four surveys. Since 1999 the correct answer was more often given than the incorrect answer (Figure 3.10).
Figure 3.10: Irish Responses to the question asking is if the statement that “it is not possible to transfer genes between species” is true or false (1996-2005)

Source: Eurobarometer Surveys 1996-2005

The forth question that longitudinally examined knowledge among Irish respondents in the Eurobarometer surveys asked if it was true or false that GM animals are always bigger than non GM animals. Again a relatively stable “don’t know” response rate was evident across time (Figure 3.11). As in the tomato containing genes question above, only in 2005 did respondents answering correctly outnumber those answering incorrectly.
Figure 3.11: Irish Responses to the question asking is it true or false that GM animals are always bigger than non GM animals (1996-2005)

Overall, Irish responses to the knowledge testing questions in the biotechnology related Eurobarometers that could be measured over time in a longitudinal manner show improvements over time in the correct answers, but relative stability in the percentage of don’t know responses. There is a clear, albeit slow, reduction in incorrect response and increase in correct responses.

Disposition:
One insight into Irish attitudes to modern plant biotechnology that can be measured longitudinally is the Irish public’s disposition to GM technology as reflected by the responses to a number of key Eurobarometer questions that were used consistently across several Eurobarometer surveys.
The first of such questions measures respondents’ optimism towards biotechnology/genetic engineering. The Eurobarometers between 1991 and 2002 inclusively asked respondents if they believed that over the next twenty years biotechnology will improve their way of life. In 2005 and 2010 respondents were asked the same question but with the term ‘genetic engineering’ replacing the term ‘biotechnology’. Over seven Eurobarometer surveys spanning the nineteen year period from 1991 to 2010, Irish respondents have gone from very optimistic in 1991 (66%) to very pessimistic in 1999 (17%), and back to a more optimistic outlook in 2010 (51%) (see Figure 3.12). This dip in optimism in 1999 is during a period of intense media coverage of GM crops in Ireland (the most intense period between 1997 and 2010 – see Chapter 4).

Figure 3.12: Irish Eurobarometer Respondent’s Optimism to Biotechnology

The question of the future effect of GE food/Food biotechnology was also posed to respondents over five Eurobarometer surveys between 1996 and 2010 inclusively. Results show that the 1999 survey had the highest numbers of Irish respondents believing GE food or food biotechnology would make things worse (Figure 3.13). The 1999 survey was also the survey that had the lowest number of respondents believing GE food or food biotechnology would have a positive or improving effect. However, since 2002 there has been an increase of
over 10 percentile points in those respondents believing GE food or food biotechnology will improve life. Noteworthy is the result that depicts the trend that consistently high number of respondents answered “don’t know” to this question.

*Figure 3.13: Irish Responses to the question asking what will the effect of GE food or food biotechnology will be in the future (1996-2010)*

When, between 1996 and 2005, respondents were asked if GM crops are useful, a relatively unstable pattern of responses was found (Figure 3.14). Agreement with the statement that GM crops are useful was at a peak (57%) in 1996, dropping sharply to a low of 32% in 2002, and increasing again to 44% in 2005. For the majority of the nine year time period in question, the number of Irish respondents agreeing that GM crops are useful was never statistically significantly below the number of those who disagreed that GM crops were useful.

*Source: Eurobarometer Surveys 1996-2010*
Another question that has been used in several Eurobarometer surveys (namely in 1996, 1999, 2005, and 2010) is one that asked respondents whether they agreed (or disagreed) that GM crops should be encouraged. Irish respondents’ attitudes changed from a majority (54%) agreeing that GM crops should be encouraged in 1996, to a small minority (22%) in 2010 (Figure 3.15). The large change in attitude occurred in 1999 where a drop in those agreed was replaced by a large change in the number of “don’t know” responses.

Source: Eurobarometer Surveys 1996-2005

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*Figure 3.14: Agreement by Irish respondents that GM crops should be encouraged (1996-2005)*
Examination of the trend in support for GM food by Irish respondents from 1996 to 2010 show that in response to the question if GM foods should be encouraged there has been an overall reduction in those agreeing with the encouragement of GM food (when “don’t know” responses are excluded) (Figure 3.16). The very high levels of don’t know responses from the Irish surveys are noteworthy (for example, in 2010, 42% of Irish respondents (the highest of all countries) answered “don’t know” to this question.

Source: Eurobarometer Surveys 1996-2010
Overall Irish respondents have seen an increase in their optimism towards GM plants and food, while there has been an overall reduction in the number of those Irish respondents agreeing with the encouragement of such technology.

**Trust:**
The source of information is considered an important element in the formation or change of an attitude (Campbell, 1980, Rokeach, 1968, Vaughan and Hogg, 1998, Roguska, 2002, Visser and Mirabile, 2004). Analysis of results from the Eurobarometer question that asks respondents to rate their level of trust in biotechnology information from various sources was carried out to include Irish responses from 1996, 1999, 2002 and 2005. Over these years environmental organisations, the medical profession and consumer organisations had consistent high levels of trust (relative to other sources) as a source of information followed by universities and the media (television and newspapers) (See Figure 3.17). Not all sources were always listed as a choice for respondents (e.g. farmer organisations were not an option to choose in 1996). Over time increases in trust were observed in consumer groups, environmental groups, the medical profession and to a small extent national government bodies. Overall decreases in trust over time were found in the following sources: animal
welfare groups, farmers groups, religious groups, industry stakeholder groups and to a small degree, political parties. Over the same time period levels of trust in universities, TV and newspapers and international institutions remained relatively stable (all had spikes in trust in 2002).

Long term, the public’s evaluation of a source of information as creditable can impact how information from that source is perceived and/or used. To evaluate how credible key actors/source of information are regarding modern biotechnology and genetic engineering, a measure of trust and confidence was used in the Eurobarometer surveys that asked respondents to rate how well such groups are ‘doing a good job for society’. According to the researchers who designed the question saying ‘doing a good job for society’ is likely to express a view that the source of information is both competent and behaves in a socially responsible way (Hogg and Vaughan, 2005). Irish responses to this question in 1999, 2002, 2005 and 2010 when complied together show scientists and doctors consistently having the highest ratings (i.e. ‘university scientists doing research’, ‘medical doctors keeping an eye on the health impacts of biotechnology’ and ‘scientists in industry doing research on biotechnology’) (see Figure 3.18). Environmental groups campaigning against biotechnology and consumer organisations checking products of biotechnology have the next highest rating levels over time. Retailers making sure food is safe and farmers deciding what to group have had consist increases in rating. Noteworthy is that Irish respondents have consistently rated negatively churches giving their points of view on biotechnology. While in 1999 industry developing new products with biotechnology was rated negatively, this has increased dramatically over the years to where respondents now rate industry developing new biotechnology products as positive.
Figure 3.17: Most trusted Sources of Information regarding biotechnology

Source: Eurobarometer Surveys 1996-2005
Figure 3.18: Respondents’ rating of if various groups are 'doing a good job for society'

Source: Eurobarometer Surveys 1996-2010
3.5 Analysis of phone calls to the FSAI Advice line (2000-2010)

3.3.1 Objective
Insights into the public attitudes of modern biotechnology and how concerned the public is with using this technology can be obtained by many methods (qualitative and quantitative surveys, willingness to pay research, etc.). One source of on-going monitoring of public concerns regarding food is the Food Safety Authority of Ireland’s (FSAI) public information/advice line which was created in 2000 and has been in operation since.

3.3.2 Methodology
The 11 full years of data on the volume and nature of food related calls within this data base was sourced directly from the FSAI, transformed into a Microsoft Excel data base and analysed for trends between the years 2000 and 2010 inclusively.

3.3.3 Results:
From 2000 to 2010 inclusively, 97,473 calls were received (annual average of 8,861) by the FSAI advice/info line. Over this time period, GMO/GM food related calls accounted for 0.45% of the total calls received. The highest percentage of GMO related calls reached 0.73% in 2004 (see Table 3.9). This data indicates that the Irish public’s concern with GMO related food safety issues is relatively low compared to other food safety issues.
### Table 3.9: Volume of phone calls to FSAI advice/info line that were GMO related

<table>
<thead>
<tr>
<th>Year</th>
<th>Call Category</th>
<th>Total by category</th>
<th>Total calls per year</th>
<th>% of calls that were GM</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>Info. Request</td>
<td>2,738</td>
<td>6,689</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>GMO</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>Info. Request</td>
<td>2,570</td>
<td>7,274</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>GMO</td>
<td>36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>Info. Request</td>
<td>2,795</td>
<td>7,817</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>GMO</td>
<td>37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>Info. Request</td>
<td>2,777</td>
<td>8,521</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GMO</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>Info. Request</td>
<td>2,890</td>
<td>9,565</td>
<td>0.73</td>
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<td></td>
<td>GMO</td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>Info. Request</td>
<td>2,182</td>
<td>9,913</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>GMO</td>
<td>37</td>
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<td></td>
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<td>2006</td>
<td>Info. Request</td>
<td>1,966</td>
<td>7,686</td>
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<td></td>
<td>GMO</td>
<td>32</td>
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<td></td>
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<tr>
<td>2007</td>
<td>Info. Request</td>
<td>1,711</td>
<td>7,749</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>GMO</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>Pork Dioxin</td>
<td>3,763</td>
<td>12,013</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>GMO</td>
<td>20</td>
<td></td>
<td></td>
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<tr>
<td>2009</td>
<td>Info. Request</td>
<td>2,679</td>
<td>9,345</td>
<td>0.4</td>
</tr>
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<td></td>
<td>GMO</td>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Info. Request</td>
<td>2,358</td>
<td>10,901</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>GMO</td>
<td>19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: FSAI, 2010

### 3.6 Discussion

Results from the longitudinal analysis of the Irish responses to the Eurobarometer surveys allow for the assessment of attitudinal trends within the Irish public concerning modern plant biotechnology (and in particular GM food). The areas of analysis examined in this research are: public awareness, knowledge, disposition and trust.

**Awareness:**

Longitudinal analysis from 1996 to 2010, regarding how aware Irish respondents claim to be of GM food and food biotechnology, shows a steady increase of awareness over time with a spike in 1999. This spike aligns with the peak of Irish media coverage of GM food that occurred in 1999 as described in Chapter 4 and in prior publications (Morris and Adley, 2001). Moreover, the increase in awareness is significant, as it starts at 34% in 1996 and augments to
81% in 2010. This is not surprising, as over time more people would have heard of GM food or food biotechnology which would explain the increase in the number of respondents who state they are aware of the issue.

Knowledge:
While awareness has increased among Irish respondents, the question of knowledge is more complex. Of the four knowledge testing questions that were comparable across multiple Eurobarometers, three showed increases in the number of respondents providing the correct answer in recent years. Responses to the forth question showed a relatively stable level of correct responses over the nine years and in the four separate surveys involved. The two knowledge testing questions that pertained directly to GM food saw peaks of incorrect answers in 1999, which was a key period of media coverage in Ireland on the issue of GM food and crops, a coverage that resulted in a spike in awareness as mentioned above. This is of particular interest, as it demonstrated the absence of correlation between the amount/degree of media coverage and the actual knowledge of the public regarding the material/issues covered by the media. It can be argued that while extensive media coverage indeed impacts the awareness of the public regarding a controversial biotechnology, it does not assist in informing or in educating the public regarding the scientific facts or regarding risks and benefits. This raises possible questions regarding the role of the media in public education regarding science and technology, and in knowledge transfer.

Disposition:
Four questions allowed a longitudinal analysis of results over time and across Eurobarometers in order to gain insights into Irish respondents’ general disposition to modern agri-biotechnology. The first question was a broad non-product specific question that was asked across all seven Eurobarometers. It measured respondents’ belief in the proposition that biotechnology/genetic engineering will improve life in the next 20 years. Irish responses between 1991 and 2010 show that while most Irish people were optimistic in the early 1990’s and most are optimistic today, there was a low point in 1999 where relatively very low numbers (16%) of Irish respondents believed biotechnology/genetic engineering would improve life. The next question analysed from a longitudinal perspective asked respondents if
GM food or food biotechnology will improve life. The Irish public results to this question show very similar trends to the prior question, with a low in respondents’ optimism in 1999, later followed by a marked increase in the belief that the technology in question would improve life.

The next two questions asked respondents if GM crops and GM food should be encouraged. As in the two prior questions, the results concerning GM crops showed a similar but much less pronounced pattern of positive sentiment (i.e. starting in the 1990’s with high levels of encouragement but dropping to a low in 1999 and 2002, only to increase again thereafter). However, when asked about GM food, Irish respondents were decidedly more negative and since 1999 there has been an overall decline in those agreeing that GM food should be encouraged.

These results suggest that while being optimistic that biotechnology/genetic engineering and even GE food/Food biotechnology will improve life, Irish respondents are, at the same time, less willing to encourage GM crops and even less willing to encourage GM food. The progressive change in disposition from positive to negative along a continuum from broad terminology to specific GM products (see Figure 3.15) can be explained by a number of factors. These factors likely include:

- The influence of the NIMBY (Not In My Back Yard) effect
- The concerted stigmatization of GM products over time by anti-GM groups such as the organic farming sector (e.g. IOFGA)
- A lack of understanding of what is included in the broad terms of ‘biotechnology’ and ‘genetic engineering’, which is demonstrated above through the low levels of knowledge that the Irish public had regarding these technologies.

Trust:
The first trust related question asked Irish respondents to rate their levels of trust in different source of information regarding biotechnology. It is evident that environmental and consumer groups have been and still are well trusted by the Irish public. While religious groups, political parties, industry groups and farmer groups are a less trusted source of information, industry
groups and farmer groups have seen increases since 1999 in the number of respondents who believe the groups are doing a good job developing new products of biotechnology and deciding what crops to grow. Over the years that were comparable universities were not some of the most top rated sources of information when compared to other sources. Consistently, universities and the media (specifically T.V. and newspapers) were similarly ranked as each other by the Irish public as a most trusted source of information on biotechnology. These results are noteworthy since they generally show that the Irish public tends to be more suspicious of groups that are perceived as promoting their own interests (e.g. industry, farmers, politicians) as opposed to groups that are perceived as defending or promoting the interests of others (e.g. consumers) (nevertheless, religious groups are consistently ranked low as a source of information on biotechnology which may reflect either the fact they are not specialised in this area or the lack of trust could be reflective of a general lack of confidence in religious institutions). This raises questions regarding levels of policy impact in light of the reality that environmental groups in Ireland have increased political involvement and have gained substantial political power.

The second trust related question asked respondents to rate how well such groups are ‘doing a good job for society’. In this case university scientists doing research were consistently ranked relatively very high followed by the medical profession (keeping an eye on possible impact of biotechnology). The evidence suggests that experts while creditable in general, may not be as trusted as non-experts who claim to represent others or the concerns of ‘civil society’ in a manner that is perceived as selfless. This would suggest that for improved science communication, the structure or approach that improves trust (a key element of communication) is one that combines both expertise and a position of selfless advocacy. This is the model certain environmental groups are already trying to move to by employing experts within their organisations or as aligned coalition partners.

Consistent high number of ‘don’t knows’:
Across all questions and across all areas examined the relatively high number of ‘don’t know’ (DK) responses provided by Irish respondents is a consistent feature. This phenomenon has been highlighted previously in both the official Eurobarometer reports but also in the literature
As pointed out by Brian Trench, the high number of DKs could be a result of the way the surveys were conducted, or a reflection of disinterest or an avoidance technique (interviewees sometimes opt for DK when they are not 100% sure of the answer and are afraid or embarrassed to give an incorrect response) (Trench, 2009). Nonetheless, based on the fact that the high number of DKs has become the hallmark of the Irish Eurobarometer results over 7 surveys spanning nearly two decades, there seems to be only remote likelihood that the primary cause of DKs is the way the surveys were administered. Furthermore, based on more recent research examining the issue of DK responses through knowledge testing survey questions, there is evidence to suggest that the DKs may actually mean the interviewee doesn’t know (i.e. is lacking the knowledge on the particular issue in question) as opposed to the belief held by some that there is so-called ‘hidden knowledge’ behind the ‘don’t know’ response (Luskin and Bullock, 2011).

This consistent high number of DK responses runs contrary to the fact that the Irish Government promotes Ireland as having a high functioning and well respected educational system (Anon, 2011a). This raises questions about the failure of the educational system and the media to inform the public and to engage on a knowledge basis. It also raises the challenge of identifying mechanisms that would allow better knowledge transfer and public education. The optimal functioning of democracies is based on having an educated voting population, where an educated and informed public plays an engaged role in securing support for policies that are evidence-based and that promote a knowledge-based economy. However, it is worth pointing out that in Ireland’s case, support for biotechnology was occurring in the absence of knowledge which could speak to a fundamental cultural aspect of Irish people being inherently more positive towards technology or that they are substituting a narrative or set of heuristics for knowledge that result in a more supportive attitude to biotechnology.

1999: A pivotal year?:

Data derived from the longitudinal analysis of questions that could be compared show that in 1999 there were a number of noteworthy occurrences in the Irish responses, namely:

- A rapid increase (that caused a spike) in the number of respondents indicating they had heard about food biotechnology/GM food.
• Peaks occurred in the level of incorrect answers to the knowledge testing questions relating to GM food.
• Irish Respondents’ optimism to biotechnology fell to an all-time low point.
• An all-time high occurred in the number of Irish respondents believing GE food or food biotechnology would make things worse in the future.
• Rapid and significant drops in the number of Irish respondents believing GM crops and GM food should be encouraged.

In light of the fact that this period was characterised by a peak in media coverage of GM technology etc., a synthetic view of the above points shows that this peak media coverage is strongly correlated with an overall negative impact on the level of knowledge of the public, on the public’s attitude towards GM and on public support or desire to encourage such new technologies.

3.7 Conclusions
This chapter offers insights into the Irish publics’ attitude regarding elements of modern plant biotechnology and the trends that have occurred over time, based on a longitudinal analysis that acknowledges the limitations inherent in any effort to compare and contrast results from different surveys that were carried out at different times. The longitudinal analysis shows that levels of awareness of modern biotechnology in Ireland have grown over time while levels of scientific literacy in the context of GM technologies have been low and improved only slightly since 1996.

In general terms, the Irish remain relatively optimistic about modern biotechnology, while animal cloning and genetically modified food seem to attract little support from the Irish public at the present time. At the same time, this negative attitude is not strong enough and/or not focused enough on safety concerns to lead to information seeking or assurance seeking behaviour, such as contacting government authorities like the FSAI, as suggested by the consistent very low levels of calls to the FSAI concerning GM food (<1% of annual calls). Such behaviour by the public was evident after the 2008 pork dioxin scare that resulted in over 3,700 calls to the FSAI amounting to approx. 28% of all calls received that year.
In addition to the above findings, two key conclusions from a policy perspective can be drawn. First, 1999 was a year that not only saw a large increase in media coverage (Chapter 4) but it also was the year where support, knowledge and optimism regarding biotechnology/genetic engineering (and in particular GM food) was at its lowest. Second, evidence from comparing the levels of GM knowledge with the levels of support for GM technology across time and surveys shows that, contrary to the deficit model, it is possible to have strong support without knowledge (as was the case prior to 1999 in Ireland) and also low support with knowledge (as evident in 2005 and 2010 results).

As shown above, awareness, knowledge, disposition and trust are some of the key elements involved in attitude formation and change/maintenance. While many factors can influence these elements, two of the most important are the media and expert opinion. In the following two chapters the input of both the media (Chapter 4) and an expert group (i.e. Irish university life scientists – Chapter 5) will be examined in the context of understanding the factors that shape policy relating to plant biotechnology risk management in Ireland.
Chapter 4

Modern Plant Biotechnology in Ireland’s National Print Media

“The people will believe what the media tells them they believe”.
George Orwell.


When a new technology enters the public sphere the narratives that accompany it are critical in how that technology is accepted, governed, and risk managed. As a result, the media plays a crucial role in how a technology is framed. During any public discourse the media is used by both the opponents and proponents of a technology platform to set forth their respective arguments. Consequently how the media then presents an issue and how the media presentation evolves is critical in understanding how framing occurs. To date, very little work has been published on the framing of modern plant biotechnology in the Irish news media. This chapter sets out to answer some key questions in how the current Irish print media frames modern plant biotechnology by employing a number of techniques in media content analysis.

4.1 Framing Theory

In modern societies the mass media constitutes an important medium within the public sphere through which information flows. During the process of how public and political attention develops towards an issue, mass media coverage is considered fundamental as it plays a critical role in informing the public (Holliman, 2004). This includes science and technology issues (and the related Government policies) since when the public (i.e. general population) receives information about science/technology issues, it is normally via the news (i.e. material
reported via a specific medium) media (Kepplinger et al., 1991, Gaskell and Bauer, 2001, Nisbet and Lewenstein, 2002, Olausson, 2009, Smith, 2010). As such, the media functions both to explain and legitimise formal policies (‘top-down’) and to signal issues and themes arising from within the public (‘bottom-up’) (Nisbet and Huge, 2006). This process can be envisaged as a “multidirectional circuit” (see Figure 4.1, adapted from (Kjaergaard, 2010)) consisting of pathways of information flow within the public sphere that contains feedback loops. For example, as outlined by Nelkin, the print media not only impacts and effects the body politic, but also the population’s general understanding and opinion of science (Nelkin, 1987a, Nelkin, 1987b), however, as highlighted by Richardson, the media can itself be influenced by those it influences (e.g. the public, politicians and decisions makers, etc.) (Richardson, 2007) thus establishing a multidirectional relationship circuit.

Figure 4.1: Media multidirectional relationship circuit

Results from the published literature have clearly demonstrated that how the public becomes aware of and perceives risk can be influenced by how the media frame and report a risk issue
(Vilella-Vila and Costa-Font, 2008, Miles et al., 1999, McCarthy et al., 2008, Griffith et al., 1994, Lundy and Irani, 2004). This is particularly true regarding, when, how and what the media select to include and/or not include from their coverage of an issue (e.g., their chosen narrative). Moreover, the media is identified as a key actor (and gatekeeper) who aids to construct (Driedger, 2007) and, according to some, solidify the policy agenda by essentially deciding the issues that will obtain public attention and the ones that will not (Brosius and Weimann, 1996, Huck et al., 2009, Scanlon and Whitelegg, 1999, Bammer and Smithson, 2008, Flynn et al., 2001).

Durant et al. note that while most of literature agrees the mass media can be hugely influential, there tends to be far less consensus concerning the exact nature/method of this influence (Durant et al., 1998). Schudson argues that as the media have control of the how the news is selected and framed, the media itself creates a reality to which the public reacts (Schudson, 2002). Gaskell and Bauer note that it is not easy to discern the direct impacts on how the media effects the public’s perception of risk via dramatization (Gaskell and Bauer, 2001). Such an impact could also function differently from the media’s ‘conveyor effect’ (i.e. where the media frames an issue as an ‘on-going debate’, often within a predefined narrative) (Vilella-Vila and Costa-Font, 2008). No matter what the exact process of influence is, it is agreed that the mass media serve to ‘frame’ issues in the public domain (Nisbet and Lewenstein, 2002, Nisbet and Huge, 2006).

Thus, media framing and its impact on the public sphere are clearly functions of a complex set of interactions involving media discourses, policy discourses and public attitudes (Bauer, 2005). According to the literature, the anthropologist Erving Goffman carried the first formal work on framing over five decades ago. Goffman described frames as ‘schemata of interpretation’ that allow individuals to ‘locate, perceive, identify, and label’ issues, events, and topics (Hallahan, 1999, Nisbet, 2008, Tyner, 2009). Entman further explains that to “frame” is to “select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described” (Entman, 1993, p55). Nisbet and Mooney (2007) summarize frames as
“organized central ideas, defining a controversy to resonate with core values and assumptions; [they] pare down complex issues by giving some aspects greater emphasis; [and] allow citizens to rapidly identify why an issue matters, who might be responsible, and what should be done” (Nisbet and Mooney, 2007, p56).

Scheufele and Tewksbury define frames as very important to allow the presentation of complex issues that communicates a concept in an efficient manner that are open to the lay public (Scheufele and Tewksbury, 2007). Thus, exploring the frames through which the media highlights certain points of view, classifies occurrences, and elucidates how they are to be understood (Hornig, 1993) can help to understand how the policy arena is informed and characterised. How an issue is dealt with at a policy level is often defined by how the media reflects and shapes an issue (Sheingate, 2006). As a result the convergence of policy agenda setting and media framing theories can create a better understanding of how a risk issue is managed.

A considerable number of previous publications have used content analysis to explore the framing of biotechnology in the media (Crawley, 2007, Dahinden, 2002, Kohring and Matthes, 2002, Marks et al., 2007, Petersen, 2005, Müller et al., 2010, Bauer and Gaskell, 2002, Nisbet and Lewenstein, 2002, Bauer, 2005, Eyck, 2005, Bonfadelli, 2005, Müller et al., 2010, Bauer and Huge, 2006, Durant et al., 1998). However, little published research is currently available regarding plant biotechnology within the Irish media. References to GM technology in the media can be found in two publications that carried out content analysis within the Irish media (McCarthy et al., 2008, Morris and Adley, 2001) in which the analysis pertaining to plant biotechnology was narrow in scope as it related only to a period in 1999 or earlier. However, related research into the opinions of experts has indicated that Irish life scientists and food safety experts have a negative opinion of how the media has portrayed the issue of GM technology (also Chapter 4) (De Boer et al., 2005, Morris and Adley, 2000b). As a result, such research is both timely and useful from both a policy and science communication perspective.

4.2 Research Design

It was decided to focus the content analysis on the Ireland daily print newspapers as the print media is an important source of representations of issues in the Irish public sphere as 87.8% of
Irish adults state they read a newspaper on a daily basis (Joint National Readership survey, 2009).

The media analysis research of this thesis consists of two sections:

1. Longitudinal media intensity analysis of plant biotechnology articles in the national daily newspaper Irish Times from 1996 to 2010. This was intended to capture (on a long basis) changes in the number of articles in Ireland’s newspaper of record.

2. Content analysis of plant biotechnology articles in the national daily newspapers: Irish Independent, the Irish Times and the Irish Examiner between from 2007 to 2010. This three year time period was chosen as it was the most recent and it spanned a period of time where GM crop policy was formally part of the Irish Governments Program for Government (see Chapter 2).

Section 1 allows for the content analysis section between the years 2007 and 2010 to be put into context. The focus of the content analysis section is on the three daily broadsheet newspaper publications in Ireland, namely the Irish Independent, the Irish Times and the Irish Examiner. These three publications have a combined circulation of 317,038 (i.e. Irish Independent, 152,204 [readership: 555,000]; Irish Times, 114,488 [readership: 364,000] and Irish Examiner 50,346 [readership: 210,000]) (Audit Bureau of Circulations Jan - Jun 2009) which represents 31.9% of the total readership of daily newspapers in Ireland and 47.8% of the ABC1 social class category (Joint National Readership survey, 2009).

Content analysis treats media texts as the ‘objectified’ traces of the complex communication process from senders to receivers. This allows any content analysis study to deliver a systematic and comparable interpretation of these traces (Krippendorff, 2004). While content analysis can logically and systematically dissect a text into constituent parts that can be counted, it can also re-assemble the broken-down elements to allow analysis that identify of which elements co-occur and in different contexts, why they do so, and with what outcomes and impacts. Moreover, as highlighted by Hansen et al. the procedures required in content analysis which are well established allow a much more transparent and repeatable approach to other ‘qualitative’ or ‘interpretative’ approaches (Hansen et al., 1998). The process of content analysis, as put forward by Krippendorff, can be broken down into six related tasks or steps: (1) define the research problem; (2) select media and sample; (3) define analytical categories;
(4) construct a coding schedule; (5) pilot the coding schedule and check reliability; (6) data-preparation and analysis. Derived from these steps are six questions that according to must be addressed in every content analysis, namely:

a. “Which data are analyzed?”
b. “How are they defined?”
c. “What is the population from which they are drawn?”
d. “What is the context relative to which the data are analysed?”
e. “What are the boundaries of the analysis?”
f. “What is the target of the inferences?” (Stemler, 2001, p2)

In the content analysis research presented in this thesis, the analytical model used aligns with that put forward by Riffe et al. (Riffe et al., 2005) and by Krippendorff (Krippendorff, 2004) who have successes examined how media messages in print media. This work also employs key modern content analysis methodological tools and approaches (e.g. adapted coding sheet, use of similar operationalization method and frame sets, etc.) as carried out in other similar studies (for example, McInerney et al., 2004, Nisbet and Huge, 2007, Caulfield et al., 2007, Gaskell and Bauer, 2001). The content analysis time period of three years was chosen to reflect an analysis of the most recent newspaper articles and the fact three years is a reasonable period of time to mitigate the influence of limitation error when compared to other similar research (for example, DeJong and Hoffman, 2000, Semetko and Valkenburg, 2000, Lima and Siegel, 1999, Hind et al., 2011, Johnson et al., 2011, MacPherson and Wadsworth, 2011).

4.3 Longitudinal media intensity analysis of plant biotechnology articles in the Irish Times from 1996 to mid-2010.

3.3.1 Methodology:
Using the Irish Times online archive, a set of key word searches were used to build a data base of articles based on year published. Key words used to identify modern plant biotechnology-related articles included ‘plant biotech’ or ‘plant biotechnology’ or ‘crop biotechnology’ or ‘GM’ or ‘crop biotech’ or ‘food biotech’ or ‘food biotechnology’ or ‘transgenic’ or ‘genetically altered’ or ‘ag biotech’. or ‘agricultural biotechnology’ ‘GM microbe’ or ‘GM organism’ or ‘genetically modified food’ or ‘genetically modified crop’ or ‘genetically
modified agriculture’ or ‘genetically engineered food’ or genetically engineered’ or ‘GE’ or ‘genetically engineered crop’ or ‘genetically engineered agriculture’ or ‘frankenfood’ or ‘GM food’ or ‘GM crop’ or ‘GM agriculture’ or ‘GMO’ or ‘genetically modified organism’ or ‘transgenic crop’ or ‘transgenic agriculture’ or ‘transgenic food’ or ‘genetically altered crop’ or ‘bioengineered food’ or ‘bioengineered crop’ or ‘bioengineered agriculture’

Analysis of the sample of articles was carried out to examine both the level of media attention given to modern plant biotechnology between 1996 and mid-2010 and the prevalence of front page articles that occurred on the topic over this period.

3.3.2 Results

Between January 1, 1996 and June 31, 2010 a total of 1172 articles relating to modern plant biotechnology were published in the Irish Times, peaking in 1999 with 336 articles. Over this period there were a total of 14 articles appearing on the front page with a historic high in 1999 of seven front page articles. Since 2001 there have not been more than 80 articles in any given year (see Figure 4.2 below).
Figure 4.2: Media attention to modern plant biotechnology in the Irish Times between January 1, 1996 and June 31, 2010
During this 14 year time span, the ‘Ireland’ and ‘World’ sections of the Irish Times carried the most articles (495 and 140 respectively) (see Figure 4.3 below).

*Figure 4.3: Sections of the Irish Times (Jan. 1996 to Jun. 2010) that carried GM articles*

Between 1996 and 2009 the ‘Ireland’ carried the most GM articles for all years except for the years 2003, where the ‘World’ section placed first and 2005, where the ‘Health’ section carried the most articles. The ‘World’ section was the next most common section during 1996 and 2009 where is maintained a second place ranking in seven of the 14 years examined (see Figure 4.4 below).
4.4 Content analysis of plant biotechnology articles in the Irish Independent, the Irish Times and the Irish Examiner between from July 7, 2007 to July 31, 2010

4.4.1 Hypotheses

The content analysis research of Irish daily broadsheets from July 7, 2007 to July 31, 2010 tested a number of key hypotheses:

H1: Irish daily broadsheets’ coverage of GM technology between July 7, 2007 and July 31, 2010 was negative in tone.

H2: The same predominant frame occurs in the broadsheet newspapers.

H3: Framing had an effect on article tone.

H4: Risks were more frequently cited in articles than benefits.

H5: The biotechnology industry is the predominant actor in articles sampled.
H6: The presence of the individual terms of ‘feed’, ‘organic’, ‘GM-Free’ and ‘Teagasc’ were more strongly linked to certain frames than others.

These hypotheses were based on discussions with Teagasc and were aimed to meet their needs for insights into the how the Irish print media were framing elements of the debate on modern plant biotechnology.

4.4.2 Methodology:
Access was obtained to a database of news media clippings collected between July 7, 2007 and July 31, 2010 by a commercial media monitoring service, Kantar Media Ireland for their client, Insight Consultants. Insight Consultants is a public relations firm retained by Monsanto Ireland to provide strategic communications services. The news clipping database maintained by Kantar Media Ireland is derived from print and radio sources. As of July 31st, 2010 the database consisted of a total of 2,776 articles (2714 print media and 62 radio). These news articles are collected based on media keyword searches of “genetically modified”, “genetic engineered”, “GM food”, “GM crops”, “Monsanto”, “transgenic”. From this clippings database, all articles sourced from the Irish Times, the Irish Independent and the Irish Examiner were selected. These selected articles were reviewed to ensure relevance and to remove 17 letters to the editor. This resulted in an article sample size of 359.

To mitigate the risk of an incomplete database, online searches of the three newspaper websites were done for articles on 10 random one month periods to test to see if articles were missing. None were found to be outstanding. However, the fact that this content analysis only covered three years could lead to bias when examining changes in framing of issues.

A coding frame was developed based on previously published studies (Nesbitt 2007, Gaskell 2001) which used coding frames that are considered reliable and valid. The coding sheet developed for this study has six sections (see Table 4.1), namely:

1) Basic Information: Basic article information such as the title of the newspaper, date the article appeared and an identification number for the coded article;
2) **Content structure:** Describes the format of the article (e.g. editorial, columnist etc), the section of the newspaper where the article appeared (e.g. farming section, weekend section), the geographic location of the article, if the article was structured as a debate (i.e. opposing arguments presented) and the primary and secondary actors in the article;

3) **Tone of Article:** A judgement rating was used to code the overall tone of the article relative to evaluations, judgment or outlook on modern plant biotechnology (i.e. GM).

4) **Framing:** Categorisation of the coded articles into frames which represent the focus of the article. Both technical frames (TF) (five) and dramatic frames (DF) (four) were used in this study. These nine frames were adopted directly from Nesbitt 2007. These include the following verbatim descriptions:

   a) **“New Research (TF)”**
   
   “Focus on new research released, discovery announced, new scientific application announced, trial results announced (e.g. government study, scientific journal article, scientific meeting paper, science-by-press-conference).”

   b) **“Scientific/Technical Background (TF)”**
   
   “General scientific, technical, or medical background of the issue (e.g. description of previous research, recap of ‘known’ results and findings, description of potential field or medical applications/uses).”

   c) **“Policy/Regulation”**
   
   Focus on regulatory rules for plant biotechnology/framework for regulation/jurisdiction or oversight over research. This includes regulatory approval and oversight in the EU and other countries for field testing, field application, and market introduction. Includes focus on legal decisions in the Ireland, the EU, in other countries, or at the international level. “Focus on rules, enforcement, and technical details of labelling and consumer disclosure. Focus on investigations, fines or penalties paid for violations of regulations. Includes international trade agreements,”
European or other national/trade zone policy or regulation related to ag biotech, such as the International Treaty on Plant Genetic Resources for Food and Agriculture (the “Treaty on PGR”), the Convention on Biological Diversity, and the Cartagena Protocol”.

d) “Marketplace/Economy (TF)”
“Focus on international trade, imports/exports, agricultural commodity prices, company market share, stock prices, company mergers and takeovers, overall growth or health of industry, financial health of farmers, reaction of investors, development/introduction of products for market, implications for domestic economy, global competitiveness, and free/fair trade.”

e) “Patenting/Property Rights (TF)”
“Focus on ownership and control of new research, control and ownership of seeds or field and market products, patenting/patent approval of new crop strains, or discussion of national, international, or cross-national property rights. Also, international agreements, such as Trade-Related Aspects of Intellectual Property Rights (TRIPs).”

f) “Ethics/Morality (DF)”
“Focus on the ethics or morality of GM agricultural practice, focus on environmental perspectives or values, focus on traditional/indigenous perspectives or values, discussion of impeding scientific/medical or social progress, emphasis on ‘hope’ and solution to world hunger, malnutrition, or production of breakthrough medications/treatments, emphasis on ethics of tampering with nature or ‘playing God’”.

g) “Political Strategy/Conflict (DF)”
“Includes the lobbying of interest groups, and the tactics of strategic actors. Focus here is not on specifics of policy, but rather on who is ahead or who is behind in the political conflict and their tactics for gaining an advantage.” Which, in this study, includes a focus on the political strategy, political actions, or political deliberations of political figures, members of Parliament (Irish and European), other elected or nominated EU or state political officials.
**h) “Public Engagement/Education (DF)”**

“Focus on poll results, reporting of public opinion statistics, reference to public/consumer ‘support’, ‘awareness’, ‘concern’, ‘education’, ‘demands’, ‘backlash’, etc. or general reference to ‘public opinion’, ‘public sentiment’, or the ‘battle over public opinion’. Focus on informing the public as a way to either ease their concerns, or to raise alarm. Also includes focus on reaction or opinion specifically from an “average man on the street,” or a non-expert or local community leader. Includes emphasis on personal narrative or testimonial of a farmer, citizen, consumer, or activist.”

**i) “Scientific Uncertainty/Scientific Controversy (DF)”**

“Emphasis on contesting the results of field trials or human health trials. Uncertainty about the ability to reliably sort in harvesting and processing non-GMO and GMO crops, or ensure that food products contain no GMO products.” Which means in this study a focus on scientific uncertainty relative to risks and benefits of agricultural plant biotechnology. Includes focus on the “precautionary principle,” definition of environmental and human health risks, or moving ahead in the face of unknown risks and benefits. Focus on uncertainty over the benefits for sustainable agricultural practice, nutrition, taste, quality, or price.

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5) **A Risk/Benefit analysis:** An analysis of the coded article indicating if a risk or benefit is cited, the type of risk or benefit and the wording of any risk or benefit;

6) **Specific content:** Codes were developed to examine the use of key lexicon that is of particular interest in the public debate. In this case the focus is on the terms: ‘GM-free’, ‘organic’, ‘feed’ and ‘Teagasc’.
Table 4.1: Coding Sheet for Content Analysis

<table>
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<th>Basic Information</th>
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<th>v2</th>
<th>v3</th>
<th>v4</th>
<th>v5</th>
<th>v6</th>
<th>v7</th>
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<tbody>
<tr>
<td>Case id</td>
<td>Newspaper title</td>
<td>Date</td>
<td>Format</td>
<td>Section</td>
<td>Location</td>
<td>Debate present</td>
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<th>v11</th>
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<th>v13</th>
</tr>
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<tbody>
<tr>
<td>Primary Actor</td>
<td>Secondary Actor</td>
<td>New Research</td>
<td>Scientific Background</td>
<td>Policy and/or Regulation</td>
<td>Marketing/Economic</td>
<td></td>
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<tbody>
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<td>Scientific Uncertainty</td>
<td>Political Strategic</td>
<td>Public Engagement</td>
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</table>

<table>
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<th>Risk/Benefit Analysis</th>
<th>v19</th>
<th>v20</th>
<th>v21</th>
<th>v22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk cited</td>
<td>Risk Type</td>
<td>Risk wording</td>
<td>Benefit cited</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specific Content</th>
<th>v23</th>
<th>v24</th>
<th>v25</th>
<th>v26</th>
<th>v27</th>
<th>v28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit Type</td>
<td>Benefit wording</td>
<td>‘Feed’ citation</td>
<td>‘Teagasc’ citation</td>
<td>‘GM-Free’ citation</td>
<td>‘Organic’ citation</td>
<td></td>
</tr>
</tbody>
</table>

| Judgement Rating | V29 | |
|------------------|-----||
| Tone of article  | |

The coded data was inputted electronically and analysis completed using SPSS version 16 (SPSS Inc. (2007). SPSS Base 16.0 for Windows User's Guide. SPSS Inc., Chicago IL). Results are derived from analysis and the employment of several different types of statistical tests.
4.4.3 Results:

1. Basic information:

From July 7, 2007 to July 31, 2010 the number of articles relating to modern plant biotechnology published by the Irish Independent, the Irish Times and the Irish Examiner was 79, 106 and 174 respectively. The Irish Examiner published the highest percentage (48.5%) of total articles (see Figure 4.5 below).

Figure 4.5: Percentage of modern plant biotechnology articles by newspaper examined

Over the 37 months that the sample spans there are three main peaks in the number of articles published occurring in July, 2007 (27 articles), September, 2008 (21 articles) and October 2009 (17 articles) (see Figure 4.6 below).
2. **Content Structure:**

The Irish Examiner and the Irish Independent both have dedicated farming sections that are published on a weekly basis. In both publications these farming sections carried the majority of the plant biotechnology articles (54.6% of Irish Examiner articles and 45.6% of Irish Independent articles) (see Table 4.2). The Irish Times does not carry a dedicated weekly farming section but does have a dedicated agriculture and food correspondent who publishes in the main news section of the paper.
Table 4.2: Distribution of articles between newspaper sections

<table>
<thead>
<tr>
<th>Newspaper section</th>
<th>Newspaper name</th>
<th>Irish Examiner</th>
<th>Irish Independent</th>
<th>Irish Times</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>% within newspaper</td>
<td>Count</td>
<td>% within newspaper</td>
</tr>
<tr>
<td>News section</td>
<td>67</td>
<td>38.5%</td>
<td>30</td>
<td>38.0%</td>
</tr>
<tr>
<td>Farming section</td>
<td>95</td>
<td>54.6%</td>
<td>36</td>
<td>45.6%</td>
</tr>
<tr>
<td>Weekend section</td>
<td>10</td>
<td>5.7%</td>
<td>10</td>
<td>12.7%</td>
</tr>
<tr>
<td>Financial section</td>
<td>2</td>
<td>1.1%</td>
<td>2</td>
<td>2.5%</td>
</tr>
<tr>
<td>Health and well.</td>
<td>0</td>
<td>.0%</td>
<td>1</td>
<td>1.3%</td>
</tr>
</tbody>
</table>

News articles were the most popular article format in all three publications followed by columnist articles, opinion pieces and editorials (See Table 4.3 below). The Irish Independent and the Irish Examiner have near identical percentages of articles occurring in the same format (65.8% and 66.7% respectively in the news format; 25.3% and 24.7% respectively as columnist authored articles; and, 8.9% and 7.5% respectively in opinion pieces). There was no statistically significant relationship between the format of the article and the article tone.

Table 4.3: Format of modern plant biotechnology articles

<table>
<thead>
<tr>
<th>Article Format</th>
<th>Irish Examiner</th>
<th>Irish Independent</th>
<th>Irish Times</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>count</td>
<td>News Article</td>
<td>Opinion Piece</td>
</tr>
<tr>
<td>Irish Examiner</td>
<td>116</td>
<td>66.7%</td>
<td>7.5%</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>1.1%</td>
<td>2</td>
</tr>
<tr>
<td>Irish Independent</td>
<td>52</td>
<td>65.8%</td>
<td>8.9%</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>2.5%</td>
<td>0</td>
</tr>
<tr>
<td>Irish Times</td>
<td>80</td>
<td>75.5%</td>
<td>3.8%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4.0%</td>
<td>1</td>
</tr>
</tbody>
</table>
The majority of articles in the sample cited Ireland as a location (57.9%). The EU and worldwide were cited as locations for 18.4% and 7.8% respectively (see Figure 4.7).

**Figure 4.7: Locations cited in articles examined**

Debate (i.e. have at least two actors take opposing views) occurred in 25.9% of total articles sampled. The Irish Times had the most debate type articles at 28.3% followed by the Irish Examiner (26.4%) and then the Irish Independent (21.5%) (see Figure 4.8 below). There was a relationship found at a statistically significant level between the occurrence of debate in articles and the tone of the article $\chi^2 (2, N = 359) = 11.77, p < .003$. 
The most cited actor overall (derived from combined primary and secondary actors) was an EU body. Politicians that are part of the past Government (Fianna Fail and Green Coalition) were cited five times more frequently than opposition politicians. Anti-GM organisations were more frequently cited than the biotechnology industry at a ratio of 1:1.7 (see Figure 4.9 below).
Articles that cited religious organisations, retailers or the organic industry were the most negative articles while articles citing the feed industry and farming groups were the most positive (see Figure 4.10 below).
3. **Tone of Article:**

Of the total number of articles 27% had a positive tone, 25.6% a negative tone while the remainder were considered neutral or balanced (47.4%). There was no statistically significant difference in the positive and negative tone of articles between the three newspapers. All were very close to a neutral tone (i.e., $\bar{E} = 0.00$) (Irish Examiner tone $\bar{E} = 0.01$; Irish Independent tone $\bar{E} = 0.03$; and the Irish Times tone $\bar{E} = 0.02$). 50.5% of all positive toned articles can be found in the farming section. Results show the tone of articles that were published did differ significantly by newspaper section, $\chi^2 (8, N = 359) = 27.84, p < .001$ but the format of the articles had no observed effect.
4. Framing:

Framing prominence was examined by defining the presence of the frame by ranking it as not present, present or as having the most outstanding focus/lead in the article. This created a ranked variable that was ordinal in nature. Overall, the framing most prominently found in the articles studied was the Market/Economic frame (mean \( \bar{X} = 0.96 \)), followed by the Policy frame (\( \bar{X} = 0.8 \)) and the Political strategy frame (\( \bar{X} = 0.51 \)) (see Figure 3.8 below). The Political strategy frame is also the most prominently found of the dramatic frames (green bars in Figure 4.11 below).

**Figure 4.11: Prominence of frames in newspaper articles**
How frames are used in each newspaper is also important. To this end, the prominence of the frames within each newspaper was measured. A simple weighted frequency count allowed the comparison of frame prominence between publications. In the Irish Examiner and the Irish Independent the Market frame was the most prominent while the Policy and Regulatory frame held primacy of prominence in the Irish Times (see Figure 4.12).

Figure 4.12: Frame Prominence in Newspapers examined

The occurrence of three specific frames (the Market, Policy and Ethical frames) in certain newspapers was statistically significant to a point where both the Market and Policy frames were more likely to be found in the Irish Examiner (Market frame: $\chi^2(4, N = 359) = 35.16$, $p < .001$ and $\gamma = -0.368, p < .001$; Policy Frame: $\chi^2(4, N = 359) = 19.57, p < .001$ and $\gamma = -0.29, p < .001$) while the Ethics frame was moderately related to the Irish Times ($\chi^2(4, N = 359) = 19.57, p < .01$ and $\gamma = 0.32, p < .001$).
The Market/Economic frame is also the most prominent frame found across all article tone types (i.e. positive, negative and neutral toned articles). The Policy frame is found to be the second most frequent framing in all article tone types (see Figure 4.13 below). There was an above moderately significant relationship found between the frame used and the tone of the article in four circumstances, namely when a New Research frame ($\chi^2 (4, N = 359) = 11.67, p \leq 0.002$ and $\gamma = 0.467, p \leq 0.002$), Science Background frame ($\chi^2 (4, N = 359) = 33.99, p < 0.001$ and $\gamma = 0.501, p < 0.001$), Policy/Regulatory frame ($\chi^2 (4, N = 359) = 13.84, p \leq 0.008$ and $\gamma = 0.243, p < .001$) or scientific uncertainty frame ($\chi^2 (4, N = 359) = 12.04, p \leq 0.002$ and $\gamma = -0.267, \leq 0.007$) were used. Only the latter was more likely to be linked to a negative article.

Figure 4.13: Frame occurrence in positive, negative and neutral toned articles
Changes in frame prominence over the time (a three period) were also examined. Results found that the prominence of technical frames (TF) remained relatively stable over the period during which the sampled articles were published (see Figure 4.14). On the other hand, there were considerable changes in the prominence of dramatic frames (DF) (see Figure 4.15).

*Figure 4.14: Change in Technical Frame Prominence over time*
5. Risk/Benefit analysis

Articles containing a cited risk amounted to 32.9% of total articles sampled while benefits were cited in 39.0% of the articles. Articles that cited a risk cited a combination of risks most frequently (26.9% of the time) followed by socio-economic risk (25.2%), health risk (24.4%), environmental risks (16.8%) and ethical risks (6.7%). Articles that cited a benefit cited socio-economic benefits the most frequently (71.2%), after which followed a combination of benefits (14.4%), environmental benefits (7.9%), health benefits (3.6%), and ethical benefits (2.9%). Results indicate there is a statistically significant relationship between an articles citation of a risk and its tone, $\chi^2(2, N = 359) = 27.29, p < .001$. Moreover, statistically testing shows that there exists a moderate association between the citation of a risk and a negative article tone ($\gamma = -.275, p < .001$).
6. Specific content

‘Feed’ citation
Overall the term ‘Feed’ was cited in 34.8% of all articles. Of the articles that cited feed, the Irish Examiner published 67.2%, the Irish Independent published 23.2% and the Irish Times published 9.6%. Moreover, 72% of all articles citing feed were published in farming sections of newspapers. Results show the number of positively toned articles that were published did differ significantly if feed was cited, $\chi^2 (2, N = 359) = 8.16, p \leq .017$. Articles citing ‘feed’ were much more likely to also have Policy and Regulatory frames $\chi^2 (2, N = 359) = 59.14, p < .001$ (very strong relationship $\gamma = 0.588, p < .001$), Market frames $\chi^2 (2, N = 359) = 44.2, p < .001$ (very strong relationship $\gamma = 0.547, p < .001$) and political strategy frames $\chi^2 (2, N = 359) = 22.67, p < .001$ (moderate relationship $\gamma = 0.341, p < .001$).

‘Organic’ citation
The term ‘organic’ is found in 16.4% of the articles sampled. This sub-population of organic citing articles was divided between the newspapers as follows: 50.8% in the Irish Examiner, 27.1% in the Irish Independent and 22.5% in the Irish Times. Analysis shows that the tone of the articles did differ by the citation of the term ‘organic’ in the article, $\chi^2 (2, N = 359) = 38.89, p < .001$. Those articles that cited ‘organic’ had an exceptionally strong likelihood of being negative in tone ($\gamma = -0.641, p < .001$). Articles citing ‘organic’ were much more likely to also have an ethics and morality frame $\chi^2 (2, N = 359) = 19.85.14, p < .001$ (strong relationship $\gamma = 0.479, p < .001$).

‘GM free’ citation
‘GM-free’ was cited in 29.8% of all articles. Within this group of articles 57% appeared in the Irish Examiner, 24.3% in the Irish Independent and 18.7% in the Irish Times. Of these GM-free citing articles, 45.8% appeared in the news section, 43.9% in the farming section, 8.4% in the weekend section and 1.9% in the financial section. Analysis indicates that the tone of the articles did differ by the citation of the term ‘GM-free’ in the article, $\chi^2 (2, N = 359) = 33.26, p < .001$. Articles citing ‘GM-free’ were much more likely to also have Market frames $\chi^2 (2,
N = 359) = 23.98, \( p < .001 \) (strong relationship \( \gamma = 0.401, p < .001 \)), Policy and Regulatory frames \( \chi^2 \) (2, N = 359) = 12.06, \( p < .001 \) (moderate relationship \( \gamma = 0.323, p < .001 \)) and political strategy frames \( \chi^2 \) (2, N = 359) = 13.19, \( p \leq .001 \) (moderate relationship \( \gamma = 0.321, p \leq .002 \)).

‘Teagasc’ citation

The term ‘Teagasc’ occurred in 10.9% of sampled articles. The majority of which were in the Irish Examiner (41%), followed by the Irish Independent (30.8%) and the Irish Times (28.2%). Results show the percentage of positive articles that were published did differ significantly if the term ‘Teagasc’ was cited, \( \chi^2 \) (2, N = 359) = 12.45, \( p < .002 \). In addition, 20.5% of ‘Teagasc’ citing GM related articles in the Irish daily broadsheets between July 7, 2007 and July 31, 2010 appeared in articles relating to the ABIC Conference that was held in UCC in August, 2008. Those articles that cite the term ‘Teagasc’ are much more likely to also have a Science background frame \( \chi^2 \) (2, N = 359) = 13.93, \( p \leq .001 \) (very strong relationship \( \gamma = 0.401, p \leq .001 \)). There is a moderately statistically significant relationship between articles citing ‘Teagasc’ and the Policy and Regulatory frame \( \chi^2 \) (2, N = 359) = 6.32, \( p < .042 \) (moderate relationship \( \gamma = 0.305, p \leq .002 \)), the Market frame \( \chi^2 \) (2, N = 359) = 8.07, \( p < .018 \) and the Public Engagement frame \( \chi^2 \) (2, N = 359) = 8.48, \( p \leq .015 \) (moderate relationship \( \gamma = 0.303, p \leq .076 \)).

4.5 Discussion

The exact manner by which the media can impact public opinion is highly complex and contested. While the media “may not be successful much of the time in telling people what to think (...) it is stunningly successful in telling [people] what to think about” (Cohen, 1963). Moreover, the media can also frame an issue in ways that also tells the public how to think about an issue. As a result, one should attempt to understand how various media outlets are treating the issue of plant biotechnology and to endeavor to understand the overall climate and positioning of the issue as this can have an impact on the policy arena.
By employing longitudinal analysis of the Irish Times it can be seen that in comparison with the 1998-2000 period, modern plant biotechnology has had a lower level of print media attention during the period 1996 to mid-2010. Irish print news coverage of the “GM foods” peaked in 1999 (Morris and Adley, 2001), the same year in which it peaked in the UK (Gaskell, 2003). This similar peaking period is not surprising considering the UK and Ireland’s close geographical and media relationship.

While the main focus of this study was limited to the three daily broadsheet newspapers published in Ireland between mid-2007 and mid 2010 that cover 31.9% of daily readership, several key questions were explored to ascertain the current framing and tone of articles appearing in these ‘elite’ publications. From an article number perspective, three peaks were found over the period in question, namely: July 2007, September 2008 and October 2009. The drivers for these peaks can be linked to key events. For example, July 2007 marked the first month after which the Green Party entered into a coalition Government in Ireland with Fianna Fail. Owing to the change in policy that resulted (i.e. the aim to work towards declaring Ireland a GM-Free zone), much news media debate and analysis occurred at the time. In September 2008 the peak was likely due to the holding in the last week of August a major international agricultural biotechnology conference (ABIC2008) in Ireland (from Aug 25, 2008 to Sept 29, 2008 at least 8 articles made direct reference to the event, the monthly average during the entire period that the articles span was 9.7). The October 2009 peak coincides with the renewal of the coalition Government’s policy program on October 10, 2009 which made reference to prohibiting GM crop cultivation and to the plan to introduce a GM-free label on foods.

A high percentage of total articles were found in the newspapers’ ‘farming’ sections (36.5%). This number accounted for over 45% of all sampled articles from both the Irish Examiner and the Irish Independent. These farming sections occurred as dedicated pull out sections within these newspapers. In all publications news articles were the most popular article format followed by similar percentages in the number of columnist articles, opinion pieces and editorials dealing with modern plant biotechnology.
The testing of a number of hypotheses was carried out based on the data gathered, these included:

**H1:** Irish daily broadsheets’ coverage of GM technology between July 7, 2007 and July 31, 2010 was negative in tone - Rejected

In the UK and elsewhere (e.g. India) several newspapers have launched anti-GM crop campaigns that have been decidedly negative in tone. However, in Ireland this is not the case and based on results obtained, the above first hypothesis (H1) was rejected. Overall, when assessed as a group, the articles examined struck a neutral tone. However, over half of all the positive articles were found in the farming section. It is unclear if this would have an impact on the general public’s perception, as the farming sections are pull-out supplements which may never be read by those not inclined to open the farming section. However, the analysis shows that in general, the perception that the media negatively portrays modern plant biotechnology (Morris and Adley, 2000b) does not hold true for the period between mid-2007 and mid-2010.

**H2:** The same predominant frame occurs in the broadsheet newspapers - Rejected

How a newspaper frames issues is key not only to understanding what is considered important for the newspaper but it is also critical to understanding how the issue is presented to readers. It had been expected that during the examined/studied period of time the same frame would have been predominant in all three newspapers. The Irish Examiner and Irish Independent both had the Market frame and the Policy frame occurring most predominantly, and second most predominantly respectively. However, the Irish Times saw the Ethics frame occur most prominently. Furthermore, it was statistically significantly more likely that the Irish Examiner would use the Market frame and the Irish times the ethics frame. The high number of articles in the farming section of the Irish Examiner pertaining to GM animal feed issues likely accounts for the focus on market issues.

**H3:** Framing had an effect on article tone – Rejected in certain areas

From a theoretical perspective how an article is framed could impact its tone. Results show that in this study there were four frames which were linked to the tone of the article at a moderate or strong statistically significant level. Of the four frames in question only the
Scientific Uncertainty frame was observed to be linked to negatively toned articles. The remaining three frames were linked to positively toned articles in the following descending order of strength: Scientific Background frame, New Research frame and Policy and Regulatory frame. Such a strong relationship between the Scientific Background frame and positive tone indicates that when the time is taken to provide a science background in an article, there is a greater likelihood that the article will be positive in tone towards modern plant biotechnology. An equally interesting finding is the observation that scientific uncertainty presented in articles tends to be more frequently linked to negatively toned articles.

**H4: Risks were more frequently cited in articles than benefits - Rejected**

In the articles analyzed the citation of risk (32.9%) occurred slightly less frequently than the citation of benefits (39%). However, when risks were cited, the majority of time they were cited together in combination with other risks. This was in stark contrast to how benefits were cited, where the majority of cited benefits were socio-economic in nature. This indicates the use of a multi-issuing style argument when describing risks of modern plant biotechnology. This can be very difficult to counter by proponents as there is a tendency to try and separate the risks into isolated arguments, a strategy that often fails as it becomes too technical and too complex.

**H5: The biotechnology industry is the predominant actor in articles - Rejected**

Results indicate that this hypothesis should be rejected as the biotechnology industry was only the seventh most prominent actor in the articles studied, while EU bodies were the most prominent. Preceding the biotechnology industry in prominence (in descending order from the most prominent) were EU bodies, anti-GM NGOs and Government bodies (equal level of prominence), Government politicians, universities and the feed industry. The predominance of EU bodies is indicative of the location of debate concerning approvals which has had a direct impact on the Irish feed industry. Of note is the fact that the feed industry is also the actor most frequently found in positively toned articles.
H6: The presence of the individual terms of ‘feed’, ‘organic’, ‘GM-Free’ and ‘Teagasc’ were more strongly linked to certain frames than others. – Failed to Reject

Statistical testing provides evidence that does not allow rejection of the hypothesis that the terms ‘feed’, ‘organic’, ‘GM-Free’ and ‘Teagasc’ were more strongly linked to certain frames than others. The greater frequency of the terms in certain frames at statically significant levels allows one to construct a view of how key terms and concepts are used in the framing of certain articles. As such, the greater likelihood of ‘feed’ occurring in the Policy and Regulatory frame, the Market frames and the Political Strategy frame is reflective of the Irish feed industry’s efforts to tackle the issue of illegal adventitious presence in feed imports which they have taken to the political level both in Ireland and in the EU in a proactive manner. Similarly, the term “GM-Free” is linked to the Market frame, the Policy and Regulatory frame and the political strategy frames as it is a term that forms a base of a political campaign. Logically, the term ‘organic’ has a statistically significant relationship with the Ethics and moral frame as organic farming is a value-laden form of agricultural production. Of interest is the fact that the term ‘Teagasc’ is very strongly linked to the Science Background frame and moderately linked to the Policy and Regulatory frame, the Market frame and the Public Engagement frame. This reflects well the elements of the advisory mandate of Teagasc.

While this study was constrained to a content analysis of the three national broadsheet newspapers in Ireland, it has provided a snapshot of the debate within a key element of the Irish media between mid-2007 and mid-2010. Within this window it is clear that the Irish media debate surrounding modern plant biotechnology is now clearly dominated by issues relating to GM feed in the Irish market and the location of this debate is firmly within the farming sections of the media. Furthermore, it is clear that during this period a political discourse was taking place that nearly exclusively involved politicians and NGO’s and feed industry stakeholders acting at both the national level and the EU level.

Result from this analysis lends support to the concept that at the Irish science–policy interface concerning modern plant biotechnology there has been an intense focus on feed issues in recent years. This has been primarily driven by the feed industry to combat uncertainty in the policy and regulatory arena pertaining to the importation of feed material derived from GM
sources. The media, while striking an overall balanced representation of the issues, placed the debate surrounding GM feed into the farming segments of their publications. This has tended to streamline the narrative of the debate. In addition, there is evidence that the politicization of the GM issue, by its inclusion in the coalition’s Program for Government in Ireland, brought media attention to the issue. Overall, the Irish daily broadsheets still (and will likely continue) to play an important role as a risk communication medium in the discourse on modern plant biotechnology and an arena in which the debate occurs.

4.6 Conclusions
This chapter examines the role of a large proportion of the Irish daily print media in the policy process pertaining to modern plant biotechnology between mid-2007 and mid-2010. As the literature review shows, the media plays a very important role in this process which can include framing issues, setting the policy agenda, connecting actors and sectors of the policy arena and/or the public sphere, etc. As such, it was important to examine how the media presents modern plant biotechnology in Ireland and how it has evolved over time. To do this, research was carried out by employing an intensity analysis of the number of modern plant and agri-biotechnology related articles occurring in the Irish Times from 1996 to mid-2010 and a content analysis, covering reports on agri-biotechnology in Ireland’s top three daily newsprint publications between 2007 and 2010. Analysis from the Irish Times intensity shows that the number of articles covering this issue has significantly reduced from a peak in 1999 (a period when there was a significant shift in public attitudes and EU policy regarding GM food and plants) and has in 2009 and 2010 reached its lowest levels over the period analysed (1996 to 2010). The content analysis of the three main daily newspapers shows that the majority of articles were found to be neutral or balanced (47.4%), while 27% had a positive tone and 25.6% had a negative tone. The citing of risk in the articles examined occurred less frequently (32.9%) than the citing of benefit (39%). While issues regarding animal feed were the most frequently cited topic in the articles examined there was evidence that the politicisation of the GM issue was a key driver. EU bodies, anti-GM NGOs and Government bodies occupied the position of the top three actors cited. It was also found that different newspapers employed different framing. The articles published by the Irish Times had a more ethical frame as opposed to the market and policy framing employed by the Irish Examiner and the Irish
Independent. Overall, it is clear that the media is still interesting in modern plant biotechnology, albeit at a less intense level than before. The Irish media is relatively balance in its current approach to GM issues and opportunity exists for all actors to use the media to influence the policy process regarding risk management of modern plant biotechnology.

This chapter allows insights into one of the sectors of the Irish media (daily print media) which illuminates how certain key policy questions and factors are framed. This provides for a greater understanding to the formation and changes to Irish policy pertaining modern plant biotechnology (see Chapter 2). It also allows in an understanding of the framing of plant biotechnology directly preceding the administration of the most recent Eurobarometer survey carried out in 2010 (see Chapter 3).
Chapter 5

Irish University Life Scientists’ Risk Perceptions and Attitudes to Modern Plant Biotechnology

“When, however, the lay public rallies round an idea that is denounced by distinguished but elderly scientists and supports that idea with great fervour and emotion - the distinguished but elderly scientists are then, after all, probably right”.

Isaac Asimov, 
*Quasar, Quasar, Burning Bright*, 1978

**Notation:** Elements of this chapter are taken from the paper below where S. Morris researched and wrote all elements used:


5.1 Why Scientists’ attitudes?

Across the world, a variety of concerns regarding health, environmental, socio-economic and ethical issues have been raised regarding GM crops/foods. Within a technology innovation value chain, academic scientists in semi-public sector institutions such as universities are key actors that can inform both public discourse and the development of policy. Such expert opinion can be used to legitimise policy or to create uncertainty. Academic experts played a role in the policy advice process in all industrial democracies (Parsons, 1995). While debate
exists in the literature about what the exact role of the academic/expert scientist is in the policy making process (Pielke, 2007), it is clear they are often referred to and relied on for input and comment (see Chapter 2).

From the point of view of decision-makers, experts (e.g. academic scientists) can be a source of information and add legitimacy to a decision (Jasanoff, 1990). Using expert advice, governments or interest groups can argue that their policies are based on ‘independent’ evidence, or that their policy decisions meet with experts’ seal of approval (Parsons, 1995, pg. 393). Consequently, this chapter examines the attitudes of Irish university-based life scientists regarding key issues in the public debate on modern plant biotechnology.

Two surveys are employed to assess the opinions of Irish university-based life scientists, one survey conducted in 1999 and the other in 2008. Within the published literature, no previous study had examined university scientists’ attitudes to GM technology by employing the same survey tool at two different points in time (in this case, almost a decade apart). In doing so, this work hopes to explore respondents’ attitudes to GM technology not only at one moment in time but over a period of time. This would illuminate what shifts in respondents’ attitudes, if any, have occurred during what is now a multi-decade old public debate that continues to this day. This chapter is divided into three main sections: section 1 presents the results of the survey carried out in 1999, section 2 presents the one of 2008, and section 3 compares the results of the two.

As outlined previously (in Chapter 2), experts can play an important role in the policy arena as decision makers often rely on experts’ input about risks to make policy decisions (Corley et al., 2009). In this context, scientific experts’ perceptions and opinions regarding GM technology (GM plant technology in particular) are worth understanding. In general, risk perception theory is a complex and evolving area and in general terms a number of key drivers of risk perceptions exist (Ropeik, 2011) (see Chapter 4).

With regards to experts’ perception of risk, the traditionally dominant theory has been that they differ from those of the public (Slovic et al., 1995, Kraus et al., 1992, Slovic et al., 1979,
Savadori et al., 1998). This difference between expert and lay perceptions of risk, had been termed the “objective perceived risk dichotomy” (Cross, 1992, Slovic, 1997). It has been suggested that the perceptions of the lay public regarding risk are formulated in a very different way than the perceptions of experts, since experts tend to attach different meanings to risk while judging, prioritizing and responding to risks in a different way than the lay public (Slovic et al., 1979, Slovic, 1997, Slovic et al., 1995, Kraus et al., 1992). Furthermore, expert risk perceptions were considered to be grounded in information of technical and analytical nature, that is generated from an objective process of risk assessment that is not affected to the same extent by key psychometric elements that impacted public perceptions of risk (e.g. social, cultural, political and personal factors) (Slovic, 1997). This difference between public and experts formed the basis of the ‘deficit model’ of risk communication according to which it is only a matter of informing the public about the facts so they can be educated to think about risk in the same way as experts (McCarthy and Brennan, 2009).

However, more recent literature has challenged these assertions and suggested expert risk perceptions were more multidimensional in nature and that comparisons of lay risk perceptions and expert risk assessments focused too easily on differences in and expertise knowledge, but ignored differences that are equally valid such as individual motives, values and contexts (Bostrom, 1997). Sjöberg analysed nine studies that looked at expert and lay judgments of risk. His analysis suggested that too many sociological possibilities could have been at play to conclusively conclude that lay people and experts have different perceptions of risk (Sjöberg, 2002). These possibilities included:

- Different risk definitions: The focus by experts on probability differs from the public’s focus on consequences.
- Realism: The public may be misinformed and experts’ risk assessments may be realistic.
- Self-selection: scientists, by their educational and professional choices, are more likely to share common interests and approaches to problems than the public.
- General political ideology: An individual’s overall political ideology can be generally a powerful factor in shaping risk perception.
- Familiarly with the issue: long experience in a certain risk area can habituate scientists to risks in that area.
- Professional and institutional role: Socialization of values in professional training and conformity pressures can influence risk perceptions.
- Media contents: The media, that can be ideologically or commercially driven, can exert influence on experts.

Other research has found little empirical evidence that experts evaluate risk differently than the public or that experts are more correct/accurate in their risk assessments (Rowe and Wright, 2001). Furthermore, it has been argued that the validity of expert judgement of risk is prone to global biases similar to those found in the public’s perception of risk (Wright et al., 2002).

Nevertheless, more recent work still shows evidence of differences in the risk perceptions between experts and the public (Krystallis et al., 2007, Savadori et al., 2004, Kugo et al., 2005, De Boer et al., 2005, Verbeke et al., 2007, Hansen et al., 2003, Blok et al., 2008, Priest and Gillespie, 2000, Hagemann and Scholderer, 2009, Deckers, 2005, Falchetti et al., 2007, Februhartanty et al., 2007, Gamble and Kassardjian, 2008, Garvin, 2001, Macer et al., 2002, Scheufele et al., 2007, Besley et al., 2008, Devos et al., 2008b, Small, 2009, Hagemann and Scholderer, 2007, Van Kleef et al., 2006). Specifically Savadori et al (Savadori et al., 2004), noted that in their study comparing experts and lay attitudes towards biotechnology there were keys differences in the two groups’ risk perceptions included the facts that:

- Experts significantly and systematically perceived risk as lower for all of the seven biotechnological applications.
- Experts perceived food applications as more useful and less harmful.
- Experts perceived medical applications as less new and less harmful, but on the other hand, better known to science, and more useful.
- When estimating the risk of applying biotechnological developments to food, the public expressed concerns not only regarding potential harm and potential benefits, but also regarding the amount of scientific knowledge and their perception of the product, while experts were only concerned with how harmful and useful the product is.
When evaluating the risk of applying biotechnology in the medical field, the public was concerned with how useful and how harmful the application could be, while experts considered factors as well, such as the number and type of people who would be potentially affected by a large-scale introduction of the application into medicine and the level of scientific knowledge about the technology (Savadori et al., 2004).

Added to this are studies that suggest experts judge risks to be smaller when they are in their own area of expertise (Siegrist et al., 2007) and that experts’ perception of risk is not homogenous. Rather, they are as likely as the lay public to hold a spectrum of different risk perceptions (Wright et al., 2002). These studies did not disaggregate experts according to their depth of expertise within any particular domain of scientific enquiry. Moreover, experts tend to define risk and benefit in terms of cause and effect relationships, where they see detailed causal chains between variables that can be clearly defined and clearly measured, while the lay public holds more abstract and holistic reasoning concerning biological processes (Hagemann and Scholderer, 2009). Other results have shown that when personal risk was studied, and factors such as ‘severity of consequences’, ‘morality’ and ‘interfering with nature’ were considered, the risk ratings of experts were characterized similarly to those of the public (Sjöberg, 2008). Overall, the recent literature indicates that differences do exist between expert and public perception of risk. While studies show that experts/scientists often rely on rules of thumb or social norms to justify policy decisions just as the public does, (Carr and Levidow, 2000, Silva and Jenkins-Smith, 2007, Young and Matthews, 2007) they do so to a lesser degree than the public (Ho et al., 2010).

5.2 Review Surveys examining Experts attitudes to GM foods and crops

While in general terms there have been many studies that have examined the difference in risk perceptions between experts and the lay public, there have been a limited number of studies that have examined expert opinions on the issue of GM crops or food. The following will review 19 studies in the chronological order of their publication, from 1995 to date (Table 5.1).
Table 5.1: Overview of studies examining experts’ attitudes to GM technology

<table>
<thead>
<tr>
<th>Publication</th>
<th>Location</th>
<th>Sample size (n=x)</th>
<th>Method Type</th>
<th>Data type</th>
<th>Expert/Public &amp; Expert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rabino 1998</td>
<td>US</td>
<td>1257</td>
<td>Mail Questionnaire</td>
<td>Quantitative</td>
<td>Expert</td>
</tr>
<tr>
<td>Scholderer, Balderjahn et al. 1999</td>
<td>Denmark, Germany, Italy &amp; UK</td>
<td>48</td>
<td>Focus groups</td>
<td>Qualitative</td>
<td>Expert</td>
</tr>
<tr>
<td>Gunter, Kinderlerer et al. 1999</td>
<td>UK</td>
<td>30</td>
<td>Interview</td>
<td>Quantitative</td>
<td>Expert and Journalist</td>
</tr>
<tr>
<td>Ng, Takeda et al. 2000</td>
<td>Japan</td>
<td>370</td>
<td>Mail Questionnaire</td>
<td>Quantitative</td>
<td>Experts and Non-expert</td>
</tr>
<tr>
<td>Frewer, Hunt et al. 2001</td>
<td>UK</td>
<td>33</td>
<td>Interview and Questionnaire</td>
<td>Qualitative and Quantitative</td>
<td>Expert</td>
</tr>
<tr>
<td>Wilkins, Kraak et al. 2001</td>
<td>US</td>
<td>215</td>
<td>Survey (Q methodology)</td>
<td>Quantitative</td>
<td>Expert</td>
</tr>
<tr>
<td>Cook, Pieri et al. 2004</td>
<td>UK</td>
<td>18</td>
<td>Interview</td>
<td>Qualitative</td>
<td>Expert</td>
</tr>
<tr>
<td>Ruth, Telg et al. 2004</td>
<td>US</td>
<td>62</td>
<td>Web-based Questionnaire</td>
<td>Quantitative</td>
<td>Experts</td>
</tr>
<tr>
<td>Savadori, Savio et al. 2004</td>
<td>Italy</td>
<td>58</td>
<td>Survey</td>
<td>Quantitative</td>
<td>Experts and Non-experts</td>
</tr>
<tr>
<td>De Boer, McCarthy et al. 2005</td>
<td>Ireland</td>
<td>143</td>
<td>Survey</td>
<td>Quantitative</td>
<td>Expert</td>
</tr>
<tr>
<td>Roberts, Boyle Struble et al. 2006</td>
<td>US</td>
<td>256</td>
<td>Survey</td>
<td>Quantitative</td>
<td>Expert</td>
</tr>
<tr>
<td>Van Kleef, Frewer et al. 2006</td>
<td>Denmark, Germany, Greece, Slovenia, UK</td>
<td>62</td>
<td>Focus groups</td>
<td>Qualitative</td>
<td>Expert</td>
</tr>
<tr>
<td>Februhartanty, Widyastuti et al. 2007</td>
<td>Indonesia</td>
<td>400</td>
<td>face-to-face interview</td>
<td>Quantitative</td>
<td>Expert</td>
</tr>
</tbody>
</table>
In 1995 members of the American Society for Microbiology were surveyed on various aspects concerning biotechnology (n=1,257) (Rabino, 1998). Most respondents agreed that agricultural biotechnologies, if misused, could be ecologically risky (such as Bt crops) while a significant 4:1 ratio of respondents favoured continued research and development in this area. Two-thirds of respondents recognized a serious threat to biodiversity from bioengineered crops. When it came to mandatory labelling of GM food products, a majority (almost 2:1) were opposed, considering it as unnecessary, costly, confusing to the public, and giving in to anti science hysteria. Respondents were in agreement that openness is important and the public needs to be educated about biotechnology.

In November 1997 four expert focus groups were conducted in Denmark, Germany, Italy, and the United Kingdom (UK) to explore experts’ opinions regarding the risks and benefits of genetically modified food products (n=48) (Scholderer et al., 1999). Results found that perceptual incongruities between experts and consumers existed. The same attributes that are considered key benefits by the experts are considered risks by the consumers. Respondents asked why genetic engineering was so special, arguing that from a competitiveness point of view, it was unfair to impose strong safety requirements only on genetic engineering techniques and not on other methods of breeding and food processing. Respondents also

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Sample Size</th>
<th>Methodology</th>
<th>Data Type</th>
<th>Expertise Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kvakkestad, Gillund et al. 2007</td>
<td>Scandinavia</td>
<td>62</td>
<td>Survey (Q-methodology)</td>
<td>Quantitative</td>
<td>Expert</td>
</tr>
<tr>
<td>Wheeler 2007 &amp; 2009</td>
<td>Australia</td>
<td>185</td>
<td>Mail Survey</td>
<td>Quantitative</td>
<td>Expert</td>
</tr>
<tr>
<td>Gamble and Kassardjian 2008</td>
<td>New Zealand</td>
<td>17</td>
<td>Focus group</td>
<td>Quantitative</td>
<td>Expert and non-expert</td>
</tr>
<tr>
<td>Sjöberg 2008</td>
<td>Sweden</td>
<td>49</td>
<td>Mail Questionnaire</td>
<td>Quantitative</td>
<td>Expert and non-expert</td>
</tr>
<tr>
<td>Gardner and Jones 2010</td>
<td>US</td>
<td>91</td>
<td>Mail and Interview (questionnaire and card sort)</td>
<td>Quantitative</td>
<td>Expert</td>
</tr>
</tbody>
</table>
blamed environmental and consumer organizations for the public outrage relating to GM food as they believed these groups had established a stable association between genetic engineering and risk, that was not based on fact and that the media readily picked up such counterfactual messages and even multiplied them.

In a study published in 1999, scientists (n=30) and journalists (n=31) in the UK were asked their opinion regarding the media coverage of biotechnology (Gunter et al., 1999). The majority of scientists had a negative opinion of the media’s coverage of GM crops which was considered too sensational, overly focused on risks, and failing to provide scientific accuracy or balance. Most scientists who responded also believed that scientists distrusted journalists. However, the low number of respondents in this study is important to note when considering the results.

A Japanese study in 2000 that surveyed 370 scientists (randomly selected from lists of Japanese researchers) found that those biotechnology applications that were deemed risky by the public are viewed as the least risky by scientists (Ng et al., 2000). Interestingly, 62% of respondents agreed with the suggestion that GM crops contribute to destroying biodiversity. 40% of respondents agreed that biotechnology would substantially reduce world hunger (41.9% disagreed and 18.1% didn’t know). Over half (52%) of the scientists surveyed would not buy GM fruits if they tasted better and most disagreed (65.7%) with the statement that ‘it is not worth putting special labels on genetically modified foods’. A key issue with this study is the fact that it surveyed scientists who were from a broad range of expertise areas and only 4.2% were employed in University/research while 23.4% were in employed in industry and 14.9% were still students (although 80% had postgraduate degrees).

In a study published in 2001 that examined the views of 33 UK scientific experts related to food (working in universities, the civil service, industry and research bodies) on how the public conceptualises uncertainty, the majority of respondents supported the representation of the public as unable to understand the scientific process, or ‘scientific rationality’ (Frewer et al., 2001). Moreover, respondents suggested that information about scientific uncertainty had
and will have a negative impact on the public trust of scientists, science and scientific institutions.

A 2001 study in the US that surveyed 215 land grant university employees (Wilkins et al., 2001) revealed three distinct points of view regarding GE foods and crops within this sample that was relatively well-educated and scientifically-literate. One group expressed a ‘precautionary’ point of view, a second group expressed a ‘promoting’ point of view, and a much smaller group expressed a ‘cautiously supportive’ point of view that had similarities to each of the other two groups. The basis for these viewpoints stemmed from the fact that respondents were divergent on several social, political, economic, health, ethical and environmental aspects of agricultural genetic engineering. The two major opposing viewpoints (i.e. precautionary vs. promoting) do not appear to take opposite sides on the same set of statements pertaining to GM crops and food, but rather they tended to reflect strong reactions to different sets of statements. However, the fact that all the survey respondents were employed by the same institution was a limiting factor to this study.

Results from a qualitative study of 18 UK based GM scientists’ perceptions of the GM food discourse published in 2004 showed that the respondents frequently characterized the public as ignorant of GM science and attributed opposition mainly to a lack of knowledge (Cook et al., 2004). The respondents in this study considered that the opposition to GM food stemmed from individuals and organizations that are self-interested and have an influence on a passive and impressionable public, rather than from the public itself. The main sources of opposition are perceived as campaigning NGOs, the media as well as supermarkets and politicians (thought to a lesser degree). All are seen as acting in their own interests and judged as making decisions on the public’s behalf without having the authority to do so. However, the study had a several critical weaknesses ranging from the low number of scientists interviewed and the fact they were all from one institution.

A 2004 US study examined 62 agricultural scientists’ (51% of which were either an associate or full university professor) perceptions regarding whether coverage in the news media represents science and agriculture fairly and accurately (Ruth et al., 2004). The study found
that respondents were more negative towards national news coverage of general scientific topics and towards topics from their own agricultural disciplines. Results also suggested that agricultural scientists hold neutral to negative perceptions of all news media, including national news media, while having a more positive perception about local and agricultural news media. This study had the weakness of a low sample number that had a limited scope owing to its very regional focus (i.e., the southern US).

Another study published in 2004 compared Italian lay and expert perception of risk from biotechnology (Savadori et al., 2004). A total of 116 persons, 58 experts and 58 non-experts, took part in the research. Experts were professors or Ph.D. students in biology at a north-eastern Italian university while the non-experts were residents of the local community adjacent to the university. Seven biotechnology applications where used to elicit the respondents’ opinions. Of the seven applications four were food related. Respondents were also asked to express their levels of trust in various sources of information on the topic of biotechnology. Experts consistently considered the food biotechnology applications less risky and more useful than the public. The expert and public samples were found to agree regarding the level of trustworthiness of all sources. Environmental groups, however, were trusted by the public more than by the experts in a significant way. A key weakness in this study was the fact that all expert respondents were from the same institution and all non-expert respondents were from one region.

Results from a survey of food safety experts (n=143) in Ireland published in 2005 found food safety experts believed that there is a significant over-assessment of the risk associated with GM foods by the public, relative to other food (De Boer et al., 2005). Respondents also believed the public had a very low understanding of biotechnological issues relating to GMOs. Respondents were clearly of the opinion that the Irish public were over-assessing certain risks (such as GM food) that from a scientific perspective are much less grave than other risks (e.g. food microbiological risks). There was also a general perception among respondents that the public reacts to novel risks rather than to established ones.
In 2006 a study was published examining US dietetics professionals’ viewpoints on genetically engineered foods and crops (Roberts et al., 2006). From the input of the 256 respondents who replied, three divergent viewpoints on genetically engineered foods and crops were established (i.e. precautionary, discerning supporter, and promoting). All three viewpoints agreed that consumers have a right to know whether the foods they are buying contains genetically engineered ingredients. They also agreed that the role of professional societies should be in promoting critical thinking and in leading thoughtful dialogues about different aspects of integrating genetically engineered foods and crops into the food system. The weakness in this study is the fact that respondents came from one area of expertise.

A 2006 publication that explored differences and similarities in perceptions and attitudes related to practices of food risk management held by consumers and experts employed a total of fifteen expert focus group discussions held in five different countries (i.e. Denmark, Germany, Greece, Slovenia and the United Kingdom) (n=62) (Van Kleef et al., 2006). While the research examined food safety issues in general, results relating to GM food found that expert respondents held the opinion that consumers lack essential knowledge about a variety of food-related risk issues and believed that GM food was not a high concern.

In 2007 a study was published that reported the results of a 2003 survey examining the attitudes of Indonesian agricultural scientists towards genetically modified foods (n=400) (Februhartanty et al., 2007). 73% of those surveyed indicated that they supported GM food developments, 15% were neutral, and only 12% were opposed. The majority (78.3%) stated that if offered GM food they would try it while over 90% respondents indicated that there should be some form of labelling to distinguish food containing GM ingredients from non-GM foods. The scientists’ attitudes were significantly shaped by willingness to try GM foods if offered, agreement with restrictions on GM foods, and exposure to media reports about the pros and cons of GM foods. However, this study took place in only one research institute leading to possible occurrence of institutional bias.

A study exploring the perceptions of 62 Scandinavian scientists regarding the deliberate release of GM crops was published in 2007 (Kvakkestad et al., 2007). The study examined
respondents’ agreement with 36 different statements which allowed subsequent factor analysis to suggest the existence of two different perspectives (Perspective 1: the environmental effects of releasing GM crops are unpredictable, and Perspective 2: GM crops are useful and present no unique risks). Results found that no ecologists were associated with Perspective 2, while all the scientists employed in the GM-industry were associated with Perspective 2. The low number of respondents and the limited regional coverage should suggest caution in generalising the results.

A study published in 2007 that identified the beliefs of agricultural professionals employed in the Australian public sector (n=185) towards organic agriculture and genetic engineering (Wheeler, 2007) showed that more respondents believed in the positive net benefits of genetic engineering than those who believed in the positive net benefits of organic agriculture. Respondents also indicated that:

“genetic engineering will play a vital role in influencing the sustainability of Australian agriculture in the future, namely by increasing production and improving pest and disease management. However, professionals voiced concerns about the potential costs of genetic engineering, with many citing risk and uncertainty issues and the lack of long-term testing” (Wheeler, 2007, p1389).

Further analysis from this survey was published in 2009 (Wheeler, 2009) indicating that some of the significant key influences on overall beliefs regarding GM technology were: age; research relevance; ethnicity; farm background; information and occupational effects; attitudes towards the current sustainability of conventional agriculture; attitudes towards agricultural research issues; and attitudes towards the individual aspects of genetic engineering.

In 2008 a study was published that reported on focus group research that was carried out in 2003 in New Zealand (Gamble and Kassardjian, 2008) that examined the social, cultural and spiritual dimensions of biotechnology through an analysis of five selected community groups (total n = 68): scientists (n=17), Buddhists, business people, mothers with young children and the environmentally active. The scientists interviewed were all from the same institution (i.e. the Horticulture and Food Research Institute of New Zealand). Results found that of the five
groups interviewed, scientists were the most knowledgeable about biotechnology and genetic modification. They were also the only group that did not perceive biotechnology to be “unnatural”. While the scientists in this study were the most supportive of biotechnology, they indicated a feeling of powerlessness in their perception that they were not listened to by lay people (whose minds were already set) or politicians (with different agendas). The two main weaknesses with this study were the facts that a very small sample of respondents was used and that all the scientists were from the same institution.

Research published in 2008 which examined the difference in attitudes to GM food between experts (n=49) and non-experts (n=469) that were sampled in Sweden in 2004 and 2003 respectively (Sjöberg, 2008) found that experts were overall much more positive towards GM food than non-experts. However, the attitudes and risk perceptions of experts were found to share dynamic properties similar to those found in the non-exert group. More specifically, experts’ perceptions of risk and benefits of GM food, while considerably different than the non-expert sample, showed similar ratings regarding personal risk related to GM food.

Results from a survey of 90 scientists that were located in the US and Canada (60 were university based, 10 were government based and 20 worked in private institutions) that were published in 2009 (Strauss et al., 2009) indicated that large majority of respondents believed that transgenic tree regulations, in particular containment requirements (71.6%) and regulatory costs/uncertainties at the commercial release level (65.7%) have an adverse impact on the continued research and pose significant obstacles to development. Respondents indicated that the priorities for forest biotechnology research were the development of gene containment methods and field studies of wood and abiotic stress modification.

In 2010 research was published that examined the risk perceptions of biotechnology applications among a range of US science educators that consisted of four sub-samples (total n=91): pre-service science teachers (n=31), in-service science teachers (n=20), biology graduate teaching assistants (n=23), and university biology professors (n=17) (Gardner and Jones, 2010). Results found that the teacher groups were similar in many areas of risk perception; however university professors were more likely to view the more “grey areas”
between biotechnology risks. The low number of respondents in addition to the fact two of the
cohorts came from the same campus are key weaknesses to this study.

As seen from this review of the literature, most studies of experts’ opinions demonstrate a
positive attitude towards GM food and crops. The studies that compared experts’ opinions
directly to lay persons show a clear difference of opinion between experts and non-experts and
a difference in the factors influencing the opinions in each group. In addition, most studies
suffer from weaknesses/limitations such as small number of participants or a sample from only
one location or one institution. Furthermore, no study was ever repeated to allow for an
analysis of change in respondents’ opinions over time.

5.3 A 1999 Survey of the attitudes of Irish University based Life Scientists
This first section outlines the findings of a 1999 quantitative study exploring the attitudes of
Irish University based life scientists to GM technology. Up to the point of this 1999 study the
Irish Government had not officially made clear its GM food policy (see Chapter 2). To aid
public input into the policy formulation process, the Irish Government at the time ran a unique
type of public consultation process which was carried out under the auspices of the
Department of Environment and Local Government (DOE) (Dempsey, 1998). This
consultation process allowed for a panel of stakeholder representatives to partake in debate
sessions held in public. The stakeholder panels consisted of two representatives, two from
each industry, the academic science community and the NGOs/pressure group community.
These representatives where picked from those who had responded to the previously
advertised Government call for submissions on the issue of GMOs and the environment. On
close of submissions (30th September, 1998) only ten submissions were made by academic
This was the lowest response rate of any of the three stakeholder groups presenting at the
public debate. During the consultation process the two academic science representatives took a
pro-GM stance. However, the public consultation process subsequently came under criticism
from pressure groups, which resulted in a boycott on the final day of the two-day debate by the
vast majority of the anti-GM Non-Government Organisations (NGOs) pressure groups. A
concluding report by the independent chairing panel was subsequently issued (O’Donnell,
1999a), which the Government (via the Minister of Environment and Local Government) accepted (Coleman, 1999).

5.3.1 The justification and importance of this survey
An examination, at the time, of the perceptions and attitudes of university-based life scientists regarding GM food was deemed important for several reasons outlined below.

I. Representatives from the Irish academic science community took a pro-GM position in the Governments national consultation process:
The initial hypothesis that the scientists representing the academic panel at the National Consultation Process hearings were wrong to present a pro-GM stance was tested in this study. To do so the survey investigated if the majority of university based scientists held similar pro-GM attitudes as the two scientists who represented the Irish academic scientists at the consultation hearings.

II. The role of expert advice in serving / assisting decision makers:
In the Irish debate on GM technology there are several key groups who play important roles. One such key group are university-based scientists, who are consulted as an objective source of information, knowledge and expert advice, by governments, journalists, industry, policy makers and pressure groups. From this perspective, it is important to examine their opinion and attitudes as a group.

III. To allow scientists to voice opinion/concerns:
In a prior Irish study, it was noted that individuals from citizen and religious groups believed that ‘dissident’ scientists are reluctant to speak out on the topic of GM food for fear of losing funding (Barbagallo and Trench, 1999, p.59). The 1999 survey allowed such scientists to voice their opinion in a confidential manner.

IV. The role of academic scientists as educators:
A further reason for sampling academic scientists is that they are involved in an educational role within third level institutions. Making future decisions regarding advancements in the
areas of pharmacogenomics, genetically modified foods, cloning will be critical for the next
generation and their attitudes toward biotechnology are likely to affect their participation in
the public discourse as well as their behaviours as citizens (Bal et al., 2007). To this end,
teaching can play an important role in attitude formulation of students and thus it was hoped to
gain an insight into the educators’ attitudes towards issues relating to GM food via this survey.

V. Assessment of the claims used in the GM discourse:
Within the public debate on GM technology, both the anti- and pro-GM food stakeholders
have made several claims. The 1999 survey examined respondents’ acceptance of the
assertions made by both sides of the GM debate. The two specific claims investigated were:
(a) GM crops will cause a reduction in pesticide use.
(b) GM crops will reduce world hunger.

VI. Assessment of the existence / extent of division of opinion within the science community:
A division (or a claimed/alleged division) in scientific opinion within the scientific world can
often create the perception that there is extensive uncertainty within the science community.
Moreover, the media’s common (and blunt-ended) approach to reflect balance in individual
news report generally leads to equal time and space being given to both sides of a scientific
argument on a particular issue. Disputes among (scientific) experts may become a major
source of confusion for policy-makers and for the public (Mazur, 1973, Keller, 2009). This,
over time, can leave the public with the impression that there is a greater divide in scientific
opinion than there is in reality. It is for this reason it was decided to quantitatively assess any
actual division of opinion within university based scientists on the issue of GM technology.

It should be noted that disagreement over the interpretation of discoveries and new data is not
new to the scientific world, “...uncertainties are not unusual in a scientific context; it is
uncertainty that drives all of science. In fact all scientific results are only provisional, subject
to better data, better methods and better frameworks” (Leiss and Chociolko, 1994, pg. 137).
However, persistent expert/scientific disagreement becomes a problem when it becomes
divisive on a frequent basis within a given subject area, as it makes public trust variable and
conditional at best (Lidskog, 1996, Beck, 1992). Frequent heated discourse within a scientific
field over a long period of time can destroy the credibility of the scientific community as a whole in the eyes of the general public who perceive scientific discourse very differently. The observing public may conclude that perhaps the scientists/experts, in fact, ‘do not know what they are talking about’ or cannot even agree amongst themselves. Conflict between scientists highlights their fallibility, demystifies their special expertise and calls attention to non-technical and political assumptions that influence technical advice (Nelkin, 1975, Sarewitz, 2004). The public may form the attitude that in case of serious scientific doubt, the safest route is prudence. This attitude may in turn “lead to or reinforce an aversion to risk” (to any degree) where a certain science and technology is concerned (Von Wartburg and Liew, 1999, p. 36). Furthermore, the concept of ‘outrage’ within the public can be amplified when experts disagree (Sandman, 1988).

VII. The role of trust:
It has been suggested that in an ever increasingly complex world, where everyone (including scientists) is dependent upon the special expertise of others, trust becomes a functional substitute for knowledge (Luhmann, 1979). Increasing attention has been paid to the issue of trust as a crucial element in the public perception of science and technology (Renn and Levine, 1990, Renn, 2008b, Poortinga and Pidgeon, 2005). Scientists, like any other group within the debate surrounding GM food, must obtain, assess and form an opinion on issues of contention. Trust can become an important factor in this process. In organisational communications trust rests on two essential elements: the information itself and its source. Both must be “reliable and credible” (Von Wartburg and Liew, 1999, p. 32). However, information sets within science are rarely absolute and can be open to debate within the science community. As a result, it is worth examining where the scientists, as experts, place their trust in terms of sources of information.

VIII. The relationship between the media and the Irish science community:
In 1999, the intensity of the GM debate was reflected in the fact that there had been a steady growth in the print media coverage of GM related issues. From January to June 1999, a total of 283 articles were published on GM food issues in the three main daily broad-sheets in Ireland (Morris and Adley, 2001). Irish academic scientists, as a group, within the GM
discourse largely failed to make their collective views known in the print media (or other media forms) at the time. Rather, their attitudes and opinions remained relatively unknown and unexplored. This was aided by the fact that there was no formally organised group representing Irish scientists involved in the Irish GM debate. This becomes relevant when considering the university based scientist’s attitudes towards the handling of GM food issues by the media.

Furthermore, up to 1999, the Irish media has covered GM food not just as a scientific issue but rather as a social problem. One definition suggests a social problem tends to exist in the political sense when it affects and threatens some other group (Spector and Kitsuse, 2001, Henshel, 1990). Under this definition the issue of GM foods has become a social problem within Ireland which attracted considerable media coverage. The dissemination of problems in the media has a major part to play in constructing and framing social problem issues, their placing on the political agenda and responses to such issues. As a result a relationship can exist between the mass media and the science community on which traditional science communication is built (which some have argued has been far from perfect (Gunter et al., 1999)). Little previous work has been carried out on the relationship between the media and the science community in Ireland, from the perspective of the scientist. This work wished to explore this domain.

The role of the media in the agenda setting process is an important factor to consider in the construction of social problems (Nisbet and Huge, 2006) (see Chapter 3). There is general agreement that the media is enormously influential but much less agreement about the exact nature of this influence. It is variously argued that the mass media serve to ‘frame’ issues in the public domain, and that they play an ‘agenda-setting’ role and/or that they serve to lead and even shape public opinion (Durant et al., 1998). In the 1960s and 1970s the main difference in evaluation, quantification and framing of a problem was that professionals, experts, technocrats, bureaucrats were doing the calculations and evaluations. However in the 1990s one could argue that the power has shifted towards the four M’s: markets, managers, moralists and the media (Parsons, 1995). This has continued to be the case up to current day albeit with the broadening of the definition to include electronic online media and social
networking. It is the last of the four M’s, the media, which this work investigated by examining the relationship between the media and Irish university based life scientists.

5.3.2 Methodology:
The primary hypothesis investigated in this study is that the academic representatives were justified in their pro-GM stance at the 1999 national consultation process since it was a true reflection of the academic science community that they claimed to represent.

Several other aims were addressed by this survey, namely:
1. Exploration of concerns held by respondents regarding GM food
2. Levels of acceptability of the genetic modification of different organisms
3. Approval of different GM applications
4. Respondents’ willingness to buy GM food
5. Support by respondents for a complete ban on GM food
6. Agreement with GM crop field trials
7. The investigation of the acceptability of claims made by both sides of the argument
8. Level of trust in information from different sources
9. Respondents’ attitudes to the reporting of GM food by the media

A quantitative survey in the form of a questionnaire was designed using both novel questions and questions previously used in similar research ((Gaskell et al., 1998, Macer, 1992a). The population selection criteria involved the selection of scientists from academic staff lists from the seven universities within the Republic of Ireland. These were National University of Ireland, Galway (NUIGalway), National University of Ireland, Cork (UCC), University College Dublin (UCD), University of Limerick (UL), Trinity College Dublin (TCD), Dublin City University (DCU), and the National University of Ireland, Maynooth (NUIM).

Surveys were administered to those on faculty lists received from the universities who were working in biological/life science related areas. In total this numbered 257 and all names on the received lists were surveyed. The respondents were full time academic staff working in diverse areas such as food science, botany, ecology, microbiology, genetics, environmental
science and more (due to the structure of medical education in Ireland in 1999, where key medical training school were outside the university system, medical departments within the university system were not surveyed directly. However, in many cases, academics with positions in university medical departments also had cross appointments in non-medical departments).

The survey instrument was a 25 question self-administered questionnaire conducted by post with a pre-stamped return addressed envelope. A cover letter was included which outlined the confidential and secure nature of the survey. A charity donation incentive to return the completed questionnaire was included. This guaranteed at least £1 (one Irish pound) to charity (from a list of five) for each returned survey. The questionnaires were sent by post on July 16\textsuperscript{th}, 1999. Follow up reminder emails were sent to all survey recipients three weeks later. 118 questionnaires were returned, four of which were unusable (no data responses include), and this resulted in 114 valid returned questionnaires, which reflected a 46.6% response rate. This response rate exceeded the normal response rate to a mailed survey of approximately 33\% (Fowler, 2008). This survey carries a 6.9\% margin of error, at a 95\% confidence level.

\textbf{Question design:}

The questionnaire was designed to elicit information to allow hypothesis testing and investigation of the key aims. During development the questionnaire was piloted and revised appropriately. A number of different question types were used to develop attitude scaling, these included open and closed questions; ranking; Likert scales (5-point) (Oppenheim, 1998).

\textbf{Open/Closed questions:}

Open-ended questions are best suited when respondents are able to give their answers verbally rather than in writing (De Vaus, 1996). As a result the majority of the questions were closed-ended. A section at the end of the questionnaire gave ample room for comment on any issue regarding the GM food debate to be added.

\textbf{Ranking:}
Ranking allowed to obtain information regarding the degree of importance or the priorities that respondents gave to different objects of concern (Frankfort-Nachmias and Nachmias, 1992). Certain questions in the questionnaire gave respondents a list of alternative answers, but rather than selecting between them, respondents were asked to rank their importance. Scores were assigned to an item depending on how the respondent ranked it within the list.

**Likert scale construction:**
A scale consists of answers to a number of questions. For each question respondents receive a particular score depending on their answer (Frankfort-Nachmias and Nachmias, 1992). The score is allocated to particular answers depending on how favourable the answer is to the attitude being measured. The scores for each question are then added together to provide each respondent with an overall score for that set of questions (scale score). The scale score is then taken to indicate a person’s ‘position’ on the abstract dimension, which the individual questions are intended to explore (De Vaus, 1996). A Likert scale (five-point) was used to develop a measure of the respondents’ attitude to the use of GM technology in food crops. A correlation matrix was obtained to establish if the questions belonged together in the scale (De Vaus, 1996). After piloting and refining the scale the best questions were selected. Tests for unidimensionality and reliability were performed. Consequently, eight statements (seven favourable and one unfavourable) were decided upon and positioned throughout the questionnaire. Further tests for unidimensionality and reliability were carried out on the data collected. Using the resulting data, the process of dividing a variable into three collapsed groups (low, medium and high) was performed.

Most of the questions used in this survey instrument were taken directly from prior surveys or modified slightly to fit within the Irish context (Macer, 1992a, Macer, 1992b, Ng et al., 2000, Eurobarometer, 1996).

**5.3.3 Results:**
The collected survey response data was coded and analysed. Analysis was carried out using SPSS for Windows (SPSS, 1995). Within the study, several different types of statistical tests were employed. Various methods of analysis were adopted which incorporated univariate
analysis (e.g. frequency distribution), bivariate analysis (e.g. correlation coefficient determination and factor analysis) and multivariate analysis (e.g. cluster analysis). The outcomes of which are reported below.

Profile of Respondents:
The majority of respondents were male 75.0%, while 25.0% were female. This imbalance was not surprising as it was also reflected in the employment lists obtained from the universities. The age profile of respondents was as follows: 18.1% were between 20-34yrs inclusively; 41.4% between 35-45yrs inclusively; 38.8% between 46-64yrs inclusively and 1.7% was 65yrs and over. The sample mean was (SD = 8.53: ranging from 23 to 68). The qualifications of the respondents included a total of 94.0% who held a Doctorate (Ph.D.) degree (and 20.4% of the sample held a Professorship, including associate professorships). Of the remainder, 4.3% had a Masters degree and 1.7% held a bachelors degree.

Exploration of concerns regarding GM food:
Respondents were asked if they had any concerns regarding GM food. 13.3% of respondents had no concerns while 86.7% had some concerns (see Figure 5.1). Those who had concerns were asked to indicate the nature of their concerns. This was achieved by ranking concern types (i.e., health, socio-economic, environmental, ethical and ‘other’ concerns). Scores were assigned to a response depending on how the respondent ranked their concerns within the list. This resulted in environmental concerns emerging at the forefront by those who had some concern regarding GM Food (see Figure 5.1). Health concerns were next, narrowly followed by socio-economic concerns. Ethical concerns were deemed to be of least importance regarding GM food.
Of note is that the primary concern of university life scientists in Ireland on the topic of GM food is not health related, but environmental. This is further supported by the responses obtained in another question, which asked, when it comes to the safety of food they buy nowadays to eat, how concerned are they about the genetic engineering of food. Only 32.7% of respondents were concerned about the genetic engineering of the food they eat (Figure 5.1).

A common topic of debate within the GM food discourse concerns the strength of regulations surrounding GM foods that protect the public from any supposed health risks. The GM industry claim that EU regulations are currently sufficient, while the pressure groups demand a tightening of such health related regulations. Respondents were asked if they agree with the statement, “current regulations are sufficient to protect people from any supposed health risks linked to GM foods”. A total of 43.0% agreed that the current regulations suffice, however 33.2% of those surveyed disagreed and 22.8% were not sure. Testing by using gamma (a coefficient used for measuring the association between ordinal variables), it was shown that there was a relatively strong relationship between respondents who agree with the statement that current regulations are sufficient to protect people from any supposed health risks linked to GM foods and those who are not at all concerned about genetic engineering as a food safety issue. Gamma = -0.597 at 99% confidence level (P≤0.01).
Levels of acceptability of genetic manipulation in different organisms:
Manipulation of genetic material in microbes was unacceptable to 5.5% of the 1999 respondents. This unacceptability level increased to 7.2% in plants and 10.9% in animals and reached a peak of 23.2% when considering genetic manipulation of human cells with 76.8% still approving of such manipulation (Table 5.2).

Table 5.2: Acceptability of genetic manipulation in different organisms

<table>
<thead>
<tr>
<th>Organism</th>
<th>Acceptable (%)</th>
<th>Unacceptable (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbes</td>
<td>94.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Plants</td>
<td>92.8</td>
<td>7.2</td>
</tr>
<tr>
<td>Animals</td>
<td>89.1</td>
<td>10.9</td>
</tr>
<tr>
<td>Human Cells</td>
<td>76.8</td>
<td>23.2</td>
</tr>
</tbody>
</table>

Approval of GM applications and uses:
Medical applications in which GM technology is used received high levels of approval (over 90%). The use of GM technology in bioremediation, specifically the use of GM bacteria to help clean up oil spills, also received high approval (91.2% approved). Food and agricultural related applications received lower approval ratings, but with application dependent differences (see Figure 5.2). The lowest level of approval (at 38.4%) was given to new types of genetically modified grass that requires cutting less frequently. The continuum of acceptability of GM applications and uses is reflected in Figure 5.2.
Figure 5.2: Approval of GM applications and uses

1. Hormones like insulin to help diabetics: **97.3% approved**
2. New drugs to cure human disease: **94.6% approved**
3. Bacteria to help clean up oil spills: **91.2% approved**
4. Fruits and Vegetables with extra resistance to disease: **69.4% approved**
5. Fruits and Vegetables with longer shelf life: **61.9% approved**
6. Better tasting fruits and vegetables: **56.9% approved**
7. Crops that are herbicide resistance: **45.5% approved**
8. New types of grass that won’t have to be as cut as often: **38.4% approved**
Willingness of scientists to buy GM food:
In the 1999 survey, respondents were asked how willing they would be to buy certain types of genetically engineered food if they were at the same price as similar non-GM products. The axiom that those buying the food would do so to consume it was drawn. 60.4% of respondents would buy genetically modified food items if they were the same price as non-GM food with the notable exception of baby food (that 41.4% would buy; 45% would not; 13.6% not sure) (See Table 5.3). T-tests carried out showed that when the means were compared, the drop in willingness to buy GM baby food was statistically significant (P≤0.01). This drop is an interesting insight into risk perception of the scientist and its dynamic nature as it shows context is an important element of how risk is perceived.

Table 5.3: How willing would you be to buy the genetically engineered foods below if they were at the same price as similar products?

<table>
<thead>
<tr>
<th>GM Product</th>
<th>YES (%)</th>
<th>NO (%)</th>
<th>Not Sure (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread</td>
<td>61.3</td>
<td>27.9</td>
<td>10.8</td>
</tr>
<tr>
<td>Cheese</td>
<td>62.5</td>
<td>27.7</td>
<td>9.8</td>
</tr>
<tr>
<td>Beer</td>
<td>60.0</td>
<td>30.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Baby-food</td>
<td>41.4</td>
<td>45.0</td>
<td>13.6</td>
</tr>
<tr>
<td>Sugar</td>
<td>60.4</td>
<td>28.8</td>
<td>10.8</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>58.6</td>
<td>29.7</td>
<td>11.7</td>
</tr>
</tbody>
</table>

Support for a Complete Ban on GM foods:
The goal of several pressure groups opposed to GM food is to implement a complete ban on GM foods. To examine to what degree university based life scientists agreed with this proposed policy, respondents were asked if there should be an immediate complete ban on all GM foods and their production. An overwhelming majority (79.1%) stated no, while 12.2% responded yes and 8.7% stated they don’t know (see Figure 5.3). Respondents were also asked
if they believed that within the next twenty years there would be a complete public rejection of GM foods. 18.1% deemed it likely, while 60.3% felt it was unlikely that a complete public rejection would occur (Figure 5.4).

**Figure 5.3: Respondents approval of a complete ban on GM foods**

![Graph showing respondents' approval of a complete ban on GM foods.](image)

**Figure 5.4: Respondents’ belief that there will be rejection of GM food**

![Graph showing respondents' belief in complete public rejection of GM foods.](image)
Whether respondents’ area of speciality had a bearing on their support for a ban on GM food was investigated (see Figure 5.5). Respondents in all areas of speciality disagreed with a complete immediate ban on GM foods. However, respondents who specialise in environmental science had the highest level (42%) of support for a ban.
Figure 5.5: Respondents support for an immediate complete ban of all GM foods and their production by speciality.
Agreement with GM crops field trials:

Many of the various different actors within the GM debate in Ireland hold different attitudes toward experimental field trials of GM crops. The attitudes of Irish academic life scientists toward field trials had never been investigated previously. To factor in the ‘Not In My Back Yard’ (NIMBY) effect, respondents were specifically asked whether they agreed with the experimental plant field trials of genetically modified sugar beet in Ireland (GM sugar beet field trials had been carried out in Ireland from 1997-1999 – see Chapter 2). The majority of respondents (77.0%) agreed with the trials while 16.2% disagreed and 6.8% didn’t know (see Figure 5.6).

Using a Likert scale, respondents were further asked if they agree with the destruction of Government licensed experimental GM crop trials by activists. In total, 84.6% of respondents disagreed with such actions (76.0% strongly disagree; 8.6% somewhat disagree) while 12.0% of respondents agreed with the actions (6.0% strongly agree; 6.0% somewhat agree) (see Figure 5.6).

Figure 5.6: Support for experimental plant field trials of GM Sugar Beet
Analysis of whether respondents’ area of speciality had a bearing on their support for GM field trials was carried out. Figure 5.7 (overleaf) demonstrates that the majority of respondents in all areas agreed with the GM trials. However, disagreement with the trials was more likely to occur in respondents whose area of speciality was environmental science (p≤0.02).
Figure 5.7: Support for GM field trials by respondents are of specialty

Support for experimental plant field trials of GM sugar beet in Ireland by respondents in different areas of speciality

Area of Speciality

<table>
<thead>
<tr>
<th>Area of Speciality</th>
<th>Support for Experimental Plant Field Trials of GM Sugar Beet in Ireland by Respondents in Different Areas of Speciality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did Not Specify</td>
<td>73</td>
</tr>
<tr>
<td>Environmental Science</td>
<td>47 (Yes: 38, No: 15)</td>
</tr>
<tr>
<td>Food Science</td>
<td>63 (Yes: 18, No: 19)</td>
</tr>
<tr>
<td>Life Science</td>
<td>84 (Yes: 10, No: 6)</td>
</tr>
<tr>
<td>Plant Science</td>
<td>100</td>
</tr>
</tbody>
</table>

Did Not Specify: 0%  Environmental Science: 27%  Food Science: 40%  Life Science: 57%  Plant Science: 100%
Investigation of the acceptability of claims made by both sides of the argument:
Throughout the GM public debate both the anti- and pro GM food actors have made several claims regarding benefits and threats. As a result it was decided upon to examine some of these claims to assess what degree of acceptance the respondents attributed to such assertions. The results below examine two such claims.

(a) GM crops will cause a reduction in pesticide use:
One major claim by advocates of GM crops is that by genetically engineering certain traits into crop plants to induce herbicide tolerance or insect resistance, a reduction in the amount of agri-chemicals applied to the crop will occur. Respondents were asked two separate questions in relation to this subject. First, when asked whether genetically engineered plants will help Irish farmers use less chemical herbicides, 58.1% agreed (see Table 5.4). The second question, which featured later in the survey, asked their opinion on the likelihood of a reduction in herbicide use due to modern biotechnology, in the next twenty years. 58.9% of respondents agreed with this statement (see Table 5.4). These results would suggest that there is a consistent majority amongst respondents who agree with the claim that GM crops will help reduce certain agri-chemical inputs (namely pesticides) in crop cultivation.

Table 5.4: Will GM crops cause a reduction in pesticide use

<table>
<thead>
<tr>
<th>Question</th>
<th>Agree</th>
<th>Disagree</th>
<th>Not Sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetically engineered plants will help Irish farmers use less chemical</td>
<td>58.1%</td>
<td>23.0%</td>
<td>18.9%</td>
</tr>
<tr>
<td>herbicides.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within the next 20 years there will be reduced herbicide and insecticide</td>
<td>58.3%</td>
<td>32.2%</td>
<td>9.5%</td>
</tr>
<tr>
<td>usage due to GM crops</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.4: Will GM crops cause a reduction in pesticide use

<table>
<thead>
<tr>
<th>Likely</th>
<th>Unlikely</th>
<th>Don’t Know</th>
</tr>
</thead>
</table>

58.1% | 23.0% | 18.9% |
58.3% | 32.2% | 9.5%  |
(b) GM crops will reduce World hunger:
Respondents were also asked about their opinion on the likelihood that within the next 20 years, due to developments within modern biotechnology, a substantial reduction in world hunger would occur. Only 21.1% of respondents stated it would be likely while 70.1% believed it to be unlikely. This result suggests that the respondents have not readily accepted this claim.

*Level of trust in information from different sources:*
Respondent’s levels of trust in information from various groups a propos GM crops showed that universities were the most trusted (Figure 5.8). The medical profession then followed; high levels of trust in the regulatory authorities of both the European Union and Government agencies were observed. Both the media and the biotechnology industry had relatively low trust levels. Concern/pressure groups were even less trusted than religious organisations.

*Figure 5.8: Levels of trust in information from various groups*
Attitudes towards the Media:

The number of GM related stories appearing in the Irish press media from 1997 to June 1999 had dramatically increased (see Figure 5.9 and Chapter 4). As a result, an exploration of the attitudes of Irish university based life scientists regarding how the media handled the issues related to GM food/crops and science and technology in general was carried out.

Figure 5.9: Number of GM articles in Irish daily broadsheet newspapers from January 1997 to June 1999

Two types of media related questions were asked in the questionnaire, the first dealt with the specific question of GM foods and the media, the second dealt with the media and general science and technology. In terms of the media coverage of GM, 50.8% of respondents thought it has been unfair, while the remainder thought it was fair or neutral. In addition, the largest portion (50.0%) felt that on balance the widespread public attention to genetic engineering had been harmful to progress in the field, while 20.2% believed the public attention to be beneficial. 65.1% of respondents stated they would like to see journalistic rules introduced to ensure all experimental research is peer-reviewed before any results enter the media/popular press. The majority of respondents (77.3%) agreed with the statement that Irish scientists have
mostly left it to others to communicate science to the public. Nevertheless, 44.7% of respondents rated as average the quality of science and technology reporting that they had seen/heard in Ireland. Only 33.3% and 3.6% of respondents stated it was good and excellent respectively. However, less again rated it as poor (17.5%) and very poor (0.9%) (see Table 5.5).

Table 5.5: Quality of science and technology reporting in Ireland according to Irish university based life scientists.

<table>
<thead>
<tr>
<th>The quality of science and technology reporting that you have seen/heard in Ireland?</th>
<th>Excellent (%)</th>
<th>Good (%)</th>
<th>Average (%)</th>
<th>Poor (%)</th>
<th>Very Poor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.6</td>
<td>33.3</td>
<td>44.7</td>
<td>17.5</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>

When asked if they had ever contacted the national media to complain about coverage of a science issue, a total of 24.0% responded yes (10.3% yes, once; 13.7% stated yes more than once) but 76.0% had never complained (see Table 5.6).

Table 5.6: Percentage of respondents who have contacted the national media to complain about coverage of a science issue.

<table>
<thead>
<tr>
<th>Have you ever contacted national media to complain about coverage of a science issue?</th>
<th>Yes, More than once</th>
<th>Yes, once</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.7%</td>
<td>10.3%</td>
<td>76.0%</td>
<td></td>
</tr>
</tbody>
</table>

Results also show that 58.4% of respondents had been contacted by the national media within the last two years in relation to their research. However, 77.9% of respondents agreed with the statement: “Scientists do not trust journalists to reflect their views correctly and fear that the journalist will twist the scientist’s words”. Figure 5.10 illustrates that there is a moderate association between those who have had contact with the media and an increasing agreement with the statement that scientists do not trust journalists to reflect their views correctly and fear that the journalists will twist the scientist’s words (Gamma = -0.307 at 98% confidence
level (P≤0.02)). One can extract from this that contact with the media does not allay such fears but may actually increase them to an extent (Figure 5.10).

Figure 5.10: Cluster Graph showing Cross-Tabulation of respondents who had been “contacted by the national media within the last two years in relation to their research” and those who agreed with the statement that “Scientists do not trust journalists to reflect their views correctly and fear that the journalist will twist the scientist’s words”
Irish University-based scientists’ attitudes to GM applications in food products:

As outlined in the methodology, a Likert scale was developed with the aim of establishing the attitudes of the respondents to GM food. The questions used and the resulting correlation matrix is shown in Table 5.7 overleaf. The overall level of support for GM food applications when respondents’ scale score were calculated was found to be positive as illustrated in Figure 5.11.
### Table 5.7: Likert Scale Correlation Matrix

<table>
<thead>
<tr>
<th>Correlation Matrix</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Q8(b): Better tasting fruits and Vegetables due to GM</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Q8(c): Fruits and vegetables with longer shelf life due to GM</td>
<td>0.7707</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Q8(d): Crops that are herbicide resistant due to GM</td>
<td>0.5487</td>
<td>0.6191</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Q8(I): Fruits and vegetables with extra resistance to disease due to GM</td>
<td>0.6258</td>
<td>0.6668</td>
<td>0.5540</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Q9: When it comes to the safety of food, how concerned are you about the genetic engineering of food?</td>
<td>-0.444</td>
<td>-0.519</td>
<td>-0.438</td>
<td>-0.446</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Q13(a): Agree that GM foods are safe; if not safer than non-GM foods</td>
<td>0.4634</td>
<td>0.6198</td>
<td>0.5859</td>
<td>0.5125</td>
<td>-0.669</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Q13(g): Agree that genetically engineering plants will help Irish farmers use less chemical herbicides.</td>
<td>0.4609</td>
<td>0.4530</td>
<td>0.6772</td>
<td>0.4781</td>
<td>-0.557</td>
<td>0.6920</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>8 Q15(e): Agree that current regulations are sufficient to protect people from any supposed health risks linked to GM foods</td>
<td>0.5277</td>
<td>0.6048</td>
<td>0.6106</td>
<td>0.5353</td>
<td>-0.630</td>
<td>0.6831</td>
<td>0.5876</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Reliability Coefficients: \( \text{ALPHA} = 0.7698 \)  
Standardised Item Alpha: \( \text{ALPHA} = 0.7800 \)
5.3.4: Discussion:
The initial hypothesis that the scientists representing the academic panel at the National Consultation Process hearings were wrong to present a pro-GM stance has to be rejected on the basis of these results (Table 5.8 and Figure 5.11). This is based on the evidence emerging from the survey, which allows one to conclude that the majority of university based scientists would take a similar pro-GM food standpoint as the two scientists who represented Irish academic scientists at the public consultation hearings on GM. The other findings of the 1999 survey are discussed below:

**Exploration of concerns held regarding GM technology:**
As outlined in Figure 5.1 the majority of respondents had concerns over GM food. This result reflects previously published data where people who have high familiarity with gene technologies, for example scientists and high school teachers, are also shown to be concerned about such technologies (Macer, 1992b). However, when these concerns were explored it was found the primary concern held by Irish university life scientists was not health related but
rather environmental. This is noteworthy when one considers that the majority of previous public opinion surveys have indicated that human health concerns are of primary concern to the general public. (Macer, 1992b, Gaskell et al., 1998, Morris and Adley, 2001, Hoban, 1997). The results from this survey indicate a difference in opinion between the Irish science respondents and the general public on what to be more concerned about regarding GM food.

Levels of acceptability of the genetic modification of different organisms:
Higher unacceptability of genetic manipulation (GM) in higher organisms was found compared to that of GM in lower organisms (see Table 5.2). This trend is similar to findings in other public opinion surveys (Gaskell et al., 1998, Einsiedel, 1998, Gaskell et al., 2003b)

Approval of different GM applications:
A trend emerged in the survey responses where medical applications received substantially higher approval, than food related GM applications (see Figure 5.2). GM fruits and vegetables with extra resistance to disease received a higher approval than better tasting GM fruits and vegetables. This is indicative of previous research (Hallman, 1996, Durant et al., 1998, Macer, 1992a) and appears that approval of possible uses of GM technology is context dependent.

Willingness to buy GM food:
“The proof of the pudding is in the eating”, is an old but relevant phrase. The results shown in Table 5.2 suggest that the majority of scientists would buy GM food. However, it is clear that willingness to buy GM baby-food is significantly lower than respondents’ willingness to buy other GM food products. This result has interesting considerations for risk perception theory. It may be the case that even scientists apply different risk assessment criteria when considering buying GM baby food for babies compared to buying GM food for themselves.

Support for a complete ban on GM food:
The fact that 79.1% of Irish university based scientists reject the proposal for an immediate complete ban of all GM foods and their production (see Figure 5.3) should be beneficial to national policy makers as it serves as a national sounding of scientific expert opinion. It also raises some questions within the food industry. For example, are bans on GM foods by certain
large retailers science based or merely marketing ploys? In addition, if the ban is consumer choice driven, why then do such retailers not give customers a real ‘choice’ by making shelf available for GM products as well as non-GM products? It is also worth noting that 60.3% of respondents believe it “unlikely” that, within the next twenty years, a complete public rejection of GM food will occur (see Figure 5.4). The largest proportions of respondents, within all the speciality areas, disagree with a ban (see Figure 5.5). Support for such a ban is highest among those specialising in environmental science.

Agreement with GM crop field trials:
Results show strong agreement (77%) with the experimental plant field trials of GM sugar beet in Ireland (see Figure 5.6). This result also provides a wide base of scientific expert opinion to policy makers and legislators. It also indicates that a call by pressure groups for the suspension/ban for such field trials only has limited support (16.2%) among the Irish university life science community. Respondents from all areas of speciality agree with experimental field trials of GM crops (see Figure 5.7). It is worth noting (in context of the previous section regarding support for a ban of GM food), that respondents from the area of environmental science had the highest negative result towards GM crop trials.

The investigation of the acceptability of claims made by both sides of the argument:
Certain claims have come to the fore in the debate between those who are pro-GM and anti-GM food. The results shed light on the opinions of university scientists concerning two such claims.

(a) GM crops will cause a reduction in pesticide use:
There is consistent support in the belief that GM crops will cause a reduction in pesticide use (see Table 5.4). Interestingly, 56% of scientists surveyed by Macer (Macer, 1992a) agreed that genetically engineered plants would help Japanese farmers use less chemical herbicides.

(b) GM crops will reduce world hunger:
The proposition that GM technology will substantially reduce world hunger has in the past been a pivotal argument for some companies promoting of GM foods (Monsanto, 2000). The
debate on this particular point has been heated and in-depth. However, 70.1% of Irish university based life scientists do not believe that developments in modern biotechnology, within the next twenty years, will bring a substantial reduction in world hunger. When the exact same question was posed to 1003 respondents (multi-stage, random sample) in Ireland in 1996 (Eurobarometer, 1996) it elicited a very different response, 43.7% thought it likely that modern biotechnology would substantially reduce world hunger, while only 44.7% believed it unlikely.

Level of trust in information on GM crops from different sources:
Respondents had the highest level of trust in information on GM crops provided by universities (see Figure 5.8). This is worth noting as it suggests a certain degree of insular attitude formulation. Results show a collapse in trust in information from concern/pressure groups. This could have a detrimental effect on the long-term creditability of certain pressure groups. Trust in Government agencies and the EU is relatively high (ranked third), higher than general public’s trust in this group (which was ranked fifth) (Durant et al., 1998).

Respondents’ attitudes towards the Media:
A third of respondents believed the reporting of science and technology was good, 44.1% believed it was average (see Table 5.5). When asked the same question, Japanese scientists rated media coverage of science and technology in Japan in the following manner; 44.7% rated it as average, 20.2% as good, 1.3% as excellent, 23.4% and 10.3% as poor and very poor respectively (Macer, 1992b). Of interest is that 50% of respondents felt that the widespread public attention to genetic engineering has been harmful to progress in this field. It was also found that 77.9% of respondents agreed with the statement that, “Scientists do not trust journalists to reflect their views correctly and fear that the journalist will twist the scientists words”. This result was unexpected and it was postulated that lack of direct contact/experience with the media explained such a negative attitude. A statistical test (gamma) was carried out to investigate if prior contact with the media in the past two years had an influence on responses. It was found that there was a moderate association between those who have had direct contact/experience with media and agreement with the above statement. One can extract from these results (see Figure 5.10) that contact with the media
does not allay such fears but may actually increase them. These results, coupled with the fact that 65.1% of respondents would like to see journalistic rules to ensure all experimental research is peer-reviewed before results enter the media/popular press, send a strong discontented message to the journalistic world.

5.3.5 Conclusions from 1999 Survey:
The results from this study show that scientists who claimed to represent the community of Irish university based scientist at the National Consultation process were justified in their pro-GM stance as a reflection of attitudes held by their peers. They also show that environmental scientists are less supportive/more cautious towards agri-biotechnology than other scientists but are not opposed to it. Overall, Irish university based scientists surveyed tend not to have a very comfortable relationship with journalists and media. This is something that could possibly be addressed in the long term within third level science education by both equipping science graduates with the skills and knowledge to interact with the media and improving training of journalism students to communicate with scientists.

The results obtained support the proposition that knowledge and understanding of GM technology does not automatically induce a more positive attitude but that it can simply polarise already existing attitudes. Scientists have different attitudes towards GM technologies than the general public. It is also clear that the Irish public’s response to the risks of GM food and crops is qualitatively different from Irish scientific experts, a result that is in agreement with results of prior studies examining the differences between experts perceptions of risk and those of the lay public (Sjöberg, 2008, Savadori et al., 2004, Gamble and Kassardjian, 2008).

5.4 A 2008 Survey of the attitudes of Irish University based Life Scientists
The 2008 Irish scientists’ survey was designed and administered with the aim of comparing responses obtained to those of 1999, thus allowing Irish university based scientists’ opinions and attitudes regarding GM food/crops to be examined over time. The primary hypothesis of the 2008 study was that the Irish Government’s 2008 GM food/crops policy was not supported by a majority of life scientists employed in Irish universities.
5.4.1 Methodology
The population selection criteria in the 2008 survey involved the use of university faculty lists from the seven universities in the Republic of Ireland which contained 461 faculty scientists working in a broad range of life science based departments. Medical departments were excluded again in 2008 (as they were in 1999) to ensure samples were as similar as possible in scope to allow their comparison. A quantitative 26 question online survey (see Appendix A) was administered, via email, using the online survey tool Survey Monkey (Survey Monkey, 2008) on June 22, 2008. Three follow up reminder emails were sent over the next several weeks as there was a technical problem with the first email containing the survey. A charity donation incentive to complete the questionnaire was included. This guaranteed that 5 Euro for each valid survey returned would be donated to a charity that was selected by the respondent (from a list of five). A response rate of 29.2% was achieved (132 valid responses from a total of 461 surveys administered of which 9 emails bounced/failed to deliver). This survey carries a 7.2% margin of error, at a 95% confidence level. Quantitative analysis of the responses obtained was carried out using SPSS version 18.0 for Windows (known as PASW Statistics 18.0) (SPSS, 2008). For analysis of the survey’s open ended questions, the qualitative data analysis software DiscoverText™ (DiscoverText.com, Texifter, LLC, Amherst, Massachusetts, USA) was used. For this, qualitative responses were reviewed and cleaned (e.g. spelling errors corrected, etc.) to establish a dataset to examine. This dataset was then coded and analysed.

Question design
The majority of questions in the 2008 survey were identical to the 1999 survey. Six additions were made in the 2008 survey. These included:

1. The application of blight resistant potato crop was added to the list of plant technologies in the question where respondents were asked rate their approval of genetic engineering applications.
2. In the willingness to buy question, potatoes were added to a list of genetically engineered foods that respondents could choose from.
3. Blight resistant genetically modified potatoes replaced genetically modified sugar beet as the plant biotechnology example used to measure respondents’ agreement with experimental field trials.

4. A new question that measured respondents’ awareness of the Irish Government’s current GM food/crop policy was added.

5. A set of GM food/crop policy elements for which respondents were asked to indicated their level of agreement were added.

6. An open ended question was added that asked respondents what advice they would give to Irish politicians regarding genetically modified crops.

5.4.2 Results of the 2008 survey

Profile of Respondents:
The majority of respondents in the 2008 survey were male 65.2%, while 34.8% were female. The age profile of respondents was as follows: 18.2% were between 20-34yrs inclusively; 43.2% between 35-45yrs inclusively; 37.9% between 46-64yrs inclusively and 0.7% was 65yrs and over. The sample mean was 43.69 (SD = 9.48: ranging from 23 to 65). The qualifications of the respondents included a total of 96.2% who held a Doctorate (Ph.D.) degree, 1.5% had a Master’s degree and 2.3% held a bachelor’s degree. 94.7% of respondents were employed as university faculty.

Concerns regarding GM food:
The majority of respondents (58.5%) had no concerns regarding genetically modified (GM/GE) food (i.e. food produced using recombinant DNA technology). Respondents that had a concern ranked environmental concerns as the highest followed by socio-economic concerns, health concerns and then ethical concerns.

Levels of acceptability of genetic manipulation in different organisms:
In the 2008 survey the manipulation of genetic material in plants was unacceptable to 5.65% of respondents. This increased to 8.1% for microbes and 17.9% for animals and reached a peak of 27.2% when considering genetic manipulation of human cells with 65% still approving of such manipulation (see Table 5.8).
Table 5.8: Acceptability of genetic manipulation in different organisms

<table>
<thead>
<tr>
<th>Organism</th>
<th>Very acceptable (%)</th>
<th>Somewhat acceptable (%)</th>
<th>Neither (%)</th>
<th>Somewhat unacceptable (%)</th>
<th>Very unacceptable (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbes</td>
<td>68.5</td>
<td>21.8</td>
<td>1.6</td>
<td>4.8</td>
<td>3.2</td>
</tr>
<tr>
<td>Plants</td>
<td>49.2</td>
<td>41.1</td>
<td>4.0</td>
<td>4.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Animals</td>
<td>28.5</td>
<td>48.8</td>
<td>4.9</td>
<td>12.2</td>
<td>5.7</td>
</tr>
<tr>
<td>Human cells</td>
<td>29.3</td>
<td>35.8</td>
<td>7.3%</td>
<td>15.4</td>
<td>12.2</td>
</tr>
</tbody>
</table>

Approvals of GM applications:

Over 90% of respondents approved of using GM technology to produce insulin and new drugs to cure human disease while 67.8% approved putting vaccines into foods so medicines can be administered more easily (see Table 5.9). The use of GM bacteria to clean up oil spills was approved by 88.3% of respondents. Disease resistant crops received approval from 80% or over of respondents (blight resistant potatoes: 84%, and fruits and vegetables with extra resistance to disease: 80%). Agronomic GM applications applied to fruits and vegetables (traits making such crops less expensive or having a longer shelf life) received an average of 64.4% approval. 62.5% of respondents approved of better tasting fruits and vegetables while 46.2% approved of new types of grass that won't have to be cut as often.
**Table 5.9: Approval of genetic manipulation applications**

<table>
<thead>
<tr>
<th>Application</th>
<th>Approve (%)</th>
<th>Not Sure (%)</th>
<th>Disapprove (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hormones like insulin to help diabetics</td>
<td>95</td>
<td>1.7</td>
<td>3.3</td>
</tr>
<tr>
<td>New drugs to cure human disease</td>
<td>92.4</td>
<td>5.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Bacteria to help clean up oil spills</td>
<td>88.3</td>
<td>5.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Potatoes that are resistant to blight</td>
<td>84</td>
<td>6.7</td>
<td>9.3</td>
</tr>
<tr>
<td>Fruits and vegetables with extra resistance to disease</td>
<td>80</td>
<td>9.1</td>
<td>10.9</td>
</tr>
<tr>
<td>Putting vaccines into foods so medicines can be administered more easily</td>
<td>67.8</td>
<td>9.9</td>
<td>22.3</td>
</tr>
<tr>
<td>Fruits and vegetables with longer shelf life.</td>
<td>65.8</td>
<td>8.3</td>
<td>25.9</td>
</tr>
<tr>
<td>Fruits and vegetables made less expensive</td>
<td>63</td>
<td>14.3</td>
<td>22.7</td>
</tr>
<tr>
<td>Better tasting fruits and vegetables</td>
<td>62.5</td>
<td>11.7</td>
<td>25.8</td>
</tr>
<tr>
<td>New types of grass that won't have to be cut as often</td>
<td>46.2</td>
<td>17.7</td>
<td>36.1</td>
</tr>
</tbody>
</table>

**Willingness to buy GM food products:**

Respondents were asked how willing they would be to buy certain types of genetically engineered food if they were at the same price as similar non-GM products. As in the 1999 survey, the axiom that those buying food would do so to consume it was drawn. With the exception of beer and baby food, over 60% of respondents would buy genetically modified food items if they were the same price as non-GM food (see Table 5.10). A majority of respondents would buy GM beer (58.3%) while only a minority would buy GM baby food (32.5% would buy; 42.5% would not; 25% were not sure). T-tests carried out showed that when the means were compared, the drop in willingness to buy GM baby food when compared to other GM products was statistically significant (P≤0.01) (see Table 5.11). In addition, analysis showed that there was a moderately significant relationship between female respondents and those not willing to buy GM baby food (gamma = -.385 at P≤0.01).
Table 5.10: Willingness of respondents to buy certain GM food products if they were at the same price as similar products

<table>
<thead>
<tr>
<th>GM Products</th>
<th>YES (%)</th>
<th>NO (%)</th>
<th>Not Sure (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread</td>
<td>62.5</td>
<td>19.2</td>
<td>18.3</td>
</tr>
<tr>
<td>Cheese</td>
<td>60.5</td>
<td>21.7</td>
<td>18.3</td>
</tr>
<tr>
<td>Beer</td>
<td>58.3</td>
<td>22.5</td>
<td>19.2</td>
</tr>
<tr>
<td>Baby-food</td>
<td>32.5</td>
<td>42.5</td>
<td>25.0</td>
</tr>
<tr>
<td>Sugar</td>
<td>65.8</td>
<td>18.3</td>
<td>15.8</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>62.5</td>
<td>17.5</td>
<td>20.0</td>
</tr>
<tr>
<td>Potatoes</td>
<td>64.2</td>
<td>18.3</td>
<td>17.5</td>
</tr>
</tbody>
</table>

Table 5.11: Paired Samples Test between willingness to buy GM baby food and other GM food products

<table>
<thead>
<tr>
<th>GM Products</th>
<th>Paired Differences</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% CI</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babyfood /Bread</td>
<td>-.53333</td>
<td>.77712</td>
<td>.07094</td>
<td>-67380</td>
<td>-.39286</td>
<td>-7.518</td>
<td>119</td>
</tr>
<tr>
<td>Babyfood /Cheese</td>
<td>-.48333</td>
<td>.76678</td>
<td>.07000</td>
<td>-62194</td>
<td>-.34473</td>
<td>-6.905</td>
<td>119</td>
</tr>
<tr>
<td>Babyfood /Beer</td>
<td>-.45833</td>
<td>.80852</td>
<td>.07381</td>
<td>-60448</td>
<td>-.31219</td>
<td>-6.210</td>
<td>119</td>
</tr>
<tr>
<td>Babyfood /Sugar</td>
<td>-.57500</td>
<td>.82668</td>
<td>.07547</td>
<td>-72443</td>
<td>-.42557</td>
<td>-7.619</td>
<td>119</td>
</tr>
<tr>
<td>Babyfood /Tomatoes</td>
<td>-.55000</td>
<td>.78697</td>
<td>.07184</td>
<td>-69225</td>
<td>-.40775</td>
<td>-7.656</td>
<td>119</td>
</tr>
<tr>
<td>Babyfood /Potatoes</td>
<td>-.55833</td>
<td>.81782</td>
<td>.07466</td>
<td>-70616</td>
<td>-.41051</td>
<td>-7.479</td>
<td>119</td>
</tr>
</tbody>
</table>

Support for a Complete Ban on GM foods:
In 2008, support for an immediate complete ban on GM foods and their production in Ireland was minimal with 11.7% of respondents in agreement with such a ban. A large majority of 84.2% disagreed with a ban while 4.2% stated they don’t know. In terms of the future, 65.8%
of respondents believed it unlikely that a complete public rejection of GM foods would occur within the next twenty years while 9.2% felt it was likely.

**Agreement with GM crop field trials:**
A number of questions examined respondents’ opinions concerning field trials of GM crops. In response to the broader question regarding whether they are in agreement with the Irish Government’s policy of banning experimental GM crop trials, 80.7% disagreed while 12.6% agreed and 6.7% neither agreed or disagreed. More specifically, 70.8% of respondents agreed with experimental field trials of blight resistant GM potatoes in Ireland while 11.7% disagreed and 17.5% didn’t know. Only 3.3% agreed with the destruction of GM field trials by activists with a clear majority of 93.4% in disagreement (89.2% strongly disagree and 4.2% somewhat disagree).

**Claims used in the debate regarding GM crops:**
a) GM crops will cause a reduction in pesticide use
As in the 1999 survey, the 2008 survey examined respondents’ opinions on the claim that GM crops would reduce pesticide use via two questions. The first question asked if genetically engineered crops can help Irish farmers use less chemical herbicide: 78.3% of respondents agreed (27.5% strongly agreed, 50.8% somewhat agreed) and 10.8% disagreed (5% strongly agreed, 5.8% somewhat disagreed) while 10.8% were not sure. The second question asked respondents how likely it is, in their opinion, that within the next twenty years there will be reduced herbicide and insecticide usage due to GM crops. 50.8% believed it would be likely while 22.5% believed it unlikely and 26.7% responded that they didn’t know.

b) GM crops will reduce World hunger
Since 1999 the claim that GM crops can help reduce world hunger has remained a point of debate in the discourse on GM technology. As a result, the opinions of respondents on the likelihood that within the next twenty years developments in GM technology will have a substantial role in reducing world hunger was elicited. 58.3% of respondents felt it was likely, 17.5% were not sure and 24.2% held the opinion it was unlikely.
Trust in information from different sources:
The levels of trust in information from various groups a propos GM crop cultivation showed that universities were found to be the most trusted by respondents followed by the medical profession and the European Union. Concern/Pressure groups were the least trusted source of information (see Figure 5.12).

Figure 5.12: Levels of trust by respondents in information from certain sources

Scientists and the media:
In 2008, 45.4% of respondents indicated that they had been contacted by the national media in relation to their research within the last two years. In addition, the majority (42%) of respondents described the quality of science and technology media reporting (via newspapers and TV) as average while 23.5% described the reporting as good and 0.8% described the quality of reporting as excellent. However, on the other end of the spectrum, 28.6% described it as poor and 5% as very poor. 15.1% of respondents indicated they had contacted the national
media to complain about the coverage of a science issue (10.1% claimed to have done so once and 5% claimed to have done so more than once). When asked if they agreed with the statement: “Scientists do not trust journalists to reflect their views correctly and fear that the journalist will twist the scientist’s words” 68.9% of respondents answered in the affirmative while 15.9% disagreed and 15.1% neither agreed nor disagreed. Statistical testing showed that in 2008 there was no significant relationship between those respondents who had been contacted by the media concerning their research within the last two years and those respondents who didn’t trust journalists to reflect their view correctly.

Scientists’ opinion on Irish Government’s Policy regarding GM crops:
When respondents were asked if they were aware of the Irish Government’s current GM food/crop policy 29.2% of respondents replied yes and the reminder (70.8%) replied no. When asked to express their level of agreement with certain key elements of the Irish Government policy on GM crops, a majority of respondents disagreed with bans on both experimental (80.7%) and commercials planting (59.3%) of crops and agreed with the import of GM animal feed (58.8%) (see Table 5.12).

<table>
<thead>
<tr>
<th>Policy</th>
<th>Agree (%)</th>
<th>Neither Agree or Disagree (%)</th>
<th>Disagree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ban on commercial GM crop production</td>
<td>26.3</td>
<td>14.4</td>
<td>59.3</td>
</tr>
<tr>
<td>Allow import of GM animal feed</td>
<td>58.8</td>
<td>16.0</td>
<td>25.2</td>
</tr>
<tr>
<td>Ban on experiment GM crop trials</td>
<td>12.6</td>
<td>6.7</td>
<td>80.7</td>
</tr>
</tbody>
</table>

Scientific advice offered by respondents to Irish politicians regarding GM crops:
As scientific advice plays an important role in policy formulation, those surveyed where asked (via an open ended question) what advice they would give to an Irish politician regarding GM crops. Overall, 66 comments were obtained (See Appendix B). 36.4% of these open ended
responses were actively supportive of GM technology, 53% contained advice that was neutral in nature and 10.6% was negative towards GM technology. 31.8% of the advice given urged the use of independent expert advice. 16.6% of the advice cited GM field trials in a positive manner. Pressure groups were cited in 10.6% of the responses and industry groups in 13.6%. In those responses that cited industry, two thirds (66%) were negative in nature (i.e. warning of industry), a third (33%) neutral and none were positive. The majority of comments citing pressure groups did so in a negative way (73.4%). Using a “wordle tool” (a graphic that gives greater prominence to words that appear more frequently in the source text) the comments received can be displayed to show which words occurred more frequently (see Figure 5.13).

Figure 5.13: Wordle presentation of respondents’ advice to Irish politicians on GM crops
5.4.3 Conclusion:
The responses to the 2008 survey provided evidence that the majority of Irish university based life scientists did not support Government policy regarding GM food/crops. More specifically, respondents gave strong support for experimental GM crop field trials and the vast majority strongly disagreed with the destruction of GM field trials by activists. The majority of respondents (58.5%) did not have any concerns in regards to GM food and of the 41.5% who did have a concern; their primary concern was environmental in nature. These results indicate that university based scientists have a considerably different view of GM crops than the public, the majority of which would appear to have concerns that are health related in nature (Eurobarometer, 1996, Gaskell et al., 2003b, Gaskell et al., 1998, Hohl and Gaskell, 2008, Pardo and Calvo, 2004, Priest et al., 2003).

In terms of buying GM food products, the majority of respondents would be willing to buy a broad range of food products. A notable exception is that of GM baby food which the majority would not buy. This greater cautiousness regarding their children could be a function of the risk outrage phenomenon (Sandman, 1988) in the fact that risks to vulnerable populations like children arouse more outrage. But one could also consider it as a sensible judgment that children are more vulnerable and that they have more of their lives left to live – and that on both counts the hazard is simply higher when children are exposed.

Evidence from the 2008 data shows that majority of respondents support the two GM crop claims examined (i.e. GM crops would help Irish farmers use less chemical herbicide and also likely help substantially reduce world hunger within the next 20 years). The minority of respondents had a positive view of the quality of science and technology media reporting they saw or heard in Ireland. Moreover, a majority of respondents didn’t trust journalists to reflect their views correctly. This indicates a relationship with the media that is far from ideal.
5.5 Comparison of 1999 and 2008 surveys of Irish University based Life Scientists

Both the 1999 and 2008 surveys of Irish university based life scientists allow understanding of attitudes to GM technology held by respondents in each of the years they were carried out. However, a comparison of results between the two surveys allows the production of novel data and insights. By taking advantage of the fact that the survey tool that was administered in both years contains a large proportion of the same questions, responses obtained in 1999 can thus be directly compared to those obtained in 2008.

Comparison of Respondents profiles:
The percentage of female respondents was found to be higher in the 2008 survey than in 1999 survey (see Table 5.13). The ratio of males to females in 2008 was 3:1 as compared to 4:1 in 1999.

Table 5.13: Gender comparison of respondents in 1999 and 2008

<table>
<thead>
<tr>
<th>Gender</th>
<th>1999</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (%)</td>
<td>75</td>
<td>65.2</td>
</tr>
<tr>
<td>Female (%)</td>
<td>25</td>
<td>34.8</td>
</tr>
</tbody>
</table>

The comparison between the age profiles of respondents in each of the surveys showed no significant change (see Table 5.13). In addition, the qualification levels of respondents did not significantly change from 1999 (94% had a doctorate degree) to 2008 (96.2% had a doctorate degree).
Comparisons of concerns regarding GM food:
The number of respondents who said they had concerns regarding GM food dropped by half in 2008 to 41.5% from 86.7% in 1999 while those respondents indicating they had no concern rose from 13.3% in 1999 to 58.5% in 2008. In addition to this significant drop in concern that respondents had regarding GM food, there was also a change in the ranking of types of concerns listed. In 2008, while environmental concerns still ranked as the primary concern cited by respondents, socio-economic concerns replaced health concerns as the second highest ranked concern listed by respondents when compared with the 1999 survey. In the responses obtained in 2008, health concerns were ranked third, followed by ethical concerns as the least ranked concern type.

Comparison of levels of acceptability of genetic manipulation in different organism:
The numbers of respondents who found the use of the genetic manipulation acceptable across a range of organism did not change significantly in regards to the fours organism types (i.e., micro-organisms, plants, animals and humans)(see Table 5.14).
Table 5.14: Comparison of levels of acceptability of GM organism types

<table>
<thead>
<tr>
<th>Organism</th>
<th>Acceptable (%)</th>
<th>Unacceptable (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbes</td>
<td>94.5</td>
<td>90.3</td>
</tr>
<tr>
<td>Plants</td>
<td>92.8</td>
<td>90.3</td>
</tr>
<tr>
<td>Animals</td>
<td>89.1</td>
<td>77.24</td>
</tr>
<tr>
<td>Human Cells</td>
<td>76.8</td>
<td>65.04</td>
</tr>
</tbody>
</table>

Comparison of GM application approvals:
In both the 1999 and 2008 survey’s respondents were asked to indicate their level of acceptance of seven different GM applications. This list of seven applications remained the same in both surveys. The ranked order of acceptability for all seven applications by respondents did not change between surveys (see Figure 5.15 below).
In both surveys there was also a GM crop application included in the acceptability rating question. In 1999 it was ‘Crops that are herbicide tolerant’ which 45.5% of respondents approved and in 2008 it was ‘Potatoes that are resistant to blight’ which 84% of respondents approved of.

**Comparison of willingness of respondents to buy GM food:**

In the 2008 survey, respondents’ willingness to buy a range of GM food (i.e. bread, cheese, beer, sugar, and tomatoes) if at the same price as similar non-GM food showed no significant change (remaining at approx. 60%) when compared with the 1999 survey (i.e. there has been no significant increase in those willing to buy GM products). However, the percentage of those responding ‘not sure’ did increase significantly while the percentage of respondents who would not buy GM products fell across all products types in the 2008 survey (see Table 5.15).
Table 5.15: Comparison of respondents’ willingness to buy certain GM products

<table>
<thead>
<tr>
<th>GM Product</th>
<th>YES (%)</th>
<th>NO (%)</th>
<th>Not Sure (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread</td>
<td>61.3</td>
<td>62.5</td>
<td>27.9</td>
</tr>
<tr>
<td>Cheese</td>
<td>62.5</td>
<td>60.5</td>
<td>27.7</td>
</tr>
<tr>
<td>Beer</td>
<td>60.0</td>
<td>58.3</td>
<td>30.0</td>
</tr>
<tr>
<td>Baby-food</td>
<td>41.4</td>
<td>32.5</td>
<td>45.0</td>
</tr>
<tr>
<td>Sugar</td>
<td>60.4</td>
<td>65.8</td>
<td>28.8</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>58.6</td>
<td>62.5</td>
<td>29.7</td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td>64.2</td>
<td>18.3</td>
</tr>
</tbody>
</table>

As with the 1999 survey respondents, the percentage of 2008 respondents willing to buy GM baby food was significantly lower when compared to their willingness to buy the other GM products (p≤0.01). This is interesting because one would expect experts’ opinions/attitudes to be even more informed as time goes by and as information is disseminated via the scientific literature about these technologies. However, the opposite result is emerging and this may be explained by the influence of key psychometric factors.

Comparison of support for a complete ban on GM foods:
Both of the surveys contained two questions to measure respondents’ attitudes and perceptions regarding a complete ban on GM foods. The first question examined respondent’s agreement with an immediate complete ban on GM foods and their production in Ireland. There was no significant change difference in the 2008 responses to this question when compared to those in the 1999 survey (see Figure 5.16).
The second question pertaining to GM food acceptance asked how likely it was in their opinion that within the next 20 years a complete public rejection of GM foods would occur. A small difference in opinion was evident between 1999 and 2008 (see Figure 5.17).

Figure 5.17: Comparison of 1999 and 2008 responses to the likelihood of a complete rejection of GM food within the next 20 years
Comparison of agreement with GM crop field trials:
Two questions in both the 1999 and 2008 surveys measured respondents’ attitudes towards GM field trials in Ireland. The first asked respondents to rate their agreement with the destruction of GM field trials by activists. There was a significant reduction in those who agreed with such actions in the 2008 survey when compared to the 1999 survey (see Table 5.16).

Table 5.16: Comparison of levels of agreement with the destruction of GM field trials

<table>
<thead>
<tr>
<th>Do you agree with the destruction of GM field trials by activists?</th>
<th>1999</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agree (%)</td>
<td>12.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Disagree (%)</td>
<td>84.6</td>
<td>93.4</td>
</tr>
<tr>
<td>Don’t know (%)</td>
<td>3.5</td>
<td>3.3</td>
</tr>
</tbody>
</table>

In the 1999 survey, a question was posed to examine if respondents agreed with experimental field trials of GM sugar beet in Ireland while in the 2008 survey, respondents were asked if they agreed with experimental field trials of blight resistant GM potatoes in Ireland. The reason for the difference between the two questions is that in 1997 GM sugar beet trial licenses had been granted and were at the centre of media coverage during this period while in 2006 licenses where granted for field trials of blight resistant GM potatoes in Ireland. While the questions are not identical, a comparison of results is nevertheless worthwhile. Results show no significant change in the percentage of respondents who disagreed with the trials. However, changes did occur at a significant level in regards to the percentage of respondents replying ‘don’t know’ (see Table 5.17).
Comparisons of respondent’s attitudes to claims regarding GM foods:
The first claim examined is that GM crop use will lead to a reduction in pesticide use. A comparison of respondents’ attitudes to this claim between the 1999 and the 2008 surveys was done by examining the results of two pesticide related questions. There was a significant increase (20.1 percentage point different) in the number respondents in 2008 who agreed with the statement that “Genetically engineered crops can help Irish farmers use less chemical herbicides” when compared to the response to the same question in the 1999 survey (see Figure 5.18).

Table 5.17: Comparison of levels of agreement with GM field trials of certain crops

<table>
<thead>
<tr>
<th>Do you agree with experimental field trials</th>
<th>1999 (Sugar beet)</th>
<th>2008 (potatoes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes (%)</td>
<td>77.0</td>
<td>70.8</td>
</tr>
<tr>
<td>No (%)</td>
<td>16.2</td>
<td>11.7</td>
</tr>
<tr>
<td>Don’t know (%)</td>
<td>6.8</td>
<td>17.5</td>
</tr>
</tbody>
</table>
The second question asked respondents how likely they believed it would be that within the next 20 years there will be reduced herbicide and insecticide usage due to GM crops. A comparative analysis of the responses in the 1999 and the 2008 surveys shows a drop in both those believing it to be likely and unlikely. However, a significant increase was found in the percentage of respondent’s stating that they didn’t know (p≤0.02) (see Table 5.18).

Table 5.18: Comparison of respondents’ opinions on the likelihood of GM crop usage reducing herbicide and insecticide use within the next 20 years.

<table>
<thead>
<tr>
<th>Within the next 20 years there will be reduced herbicide and insecticide usage due to GM crops?</th>
<th>1999</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Likely (%)</td>
<td>58.3</td>
<td>50.8</td>
</tr>
<tr>
<td>Unlikely (%)</td>
<td>32.2</td>
<td>22.5</td>
</tr>
<tr>
<td>Don’t know</td>
<td>9.5</td>
<td>26.7</td>
</tr>
</tbody>
</table>
The second claim examined was that GM crops will substantially reduce World hunger. Respondents in both surveys were asked their opinion on the likelihood GM crops will have a substantial role in reducing world hunger. Comparing the results, it is evident that a significant difference exists between the 1999 and 2008 results (p≤001). In 1999, 70.1% believed it unlikely that GM food would reduce world hunger; however in 2008, this fell to 24.2% while the converse change in those believing it was likely, increased from 21.1% in 1999 to 58.3% in 2008 (see Figure 5.19).

Figure 5.19: Comparison of 1999 and 2008 responses to the likelihood that GM technology will play a substantial role in reducing world hunger within the next 20 years

Comparison of trust in information from different sources:

In both surveys (1999 and 2008) respondents were asked to rank different sources of information on GM crops by how much they trusted each of the sources. When the resulting trust levels for each group were compared, results show very similar findings between the two surveys (see Figure 5.20). Universities were considered the most trusted source of information by respondents in both surveys.
Comparison of attitudes towards media:
In both the 1999 and the 2008 surveys a number of questions were used to elicit respondents’ attitudes to the Irish media regarding science issues. A comparison of the responses to the question that asked respondents to describe the quality of science and technology reporting that they have seen/heard in Ireland showed no significant change between the surveys (see Table 5.19). When the quality ratings were scored from one to five (where one is very poor and five is excellent) the total quality score received in 1999 is 321.2 while in 2008 it is lower at 286.2.
Table 5.19: Comparison of respondents’ opinion on the quality of science and technology reporting in the Irish media

<table>
<thead>
<tr>
<th>The quality of science and technology reporting that you have seen/heard in Ireland?</th>
<th>Excellent (%)</th>
<th>Good (%)</th>
<th>Average (%)</th>
<th>Poor (%)</th>
<th>Very Poor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>3.6</td>
<td>33.3</td>
<td>44.7</td>
<td>17.5</td>
<td>0.9</td>
</tr>
<tr>
<td>2008</td>
<td>0.8</td>
<td>23.5</td>
<td>42.0</td>
<td>28.6</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Also occurring in both surveys was a question asking respondents if they have contacted the media to complain about coverage of a science issue. When responses to this question in both the 1999 survey and 2008 survey were compared an overall reduction in the percentage of respondents contacting the media was evident (see Table 5.20).

Table 5.20: Percentage of respondents who have contacted the national media to complain about coverage of a science issue

<table>
<thead>
<tr>
<th>Have you ever contacted national the media to complain about coverage of a science issue?</th>
<th>Yes, More than once (%)</th>
<th>Yes, once (%)</th>
<th>No (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>13.7</td>
<td>10.3</td>
<td>76.0</td>
</tr>
<tr>
<td>2008</td>
<td>5.0</td>
<td>10.1</td>
<td>84.9</td>
</tr>
</tbody>
</table>

Besides contact with the media to complain about an issue of science coverage respondents in both surveys were asked if, within the last two years, they had been contacted by the national media in relation to their research. Comparing the response to this question obtained in 1999 to those in 2008, it was found that there was no significant difference between the two sets of responses (see Table 5.21)
Table 5.21: Comparison of the percentage of respondents who has been contacted by the national media concerning their research within the prior two years.

<table>
<thead>
<tr>
<th>Within the last two years have you been contacted by the national media in relation to your research?</th>
<th>Yes (%)</th>
<th>No (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>41.6</td>
<td>45.4</td>
</tr>
<tr>
<td>2008</td>
<td>58.4</td>
<td>54.6</td>
</tr>
</tbody>
</table>

The last question that both surveys posed concerning the media asked respondents to indicate their agreement with the suggestion that scientists do not trust journalists to reflect their views correctly and fear the journalist will twist their words. When the results are compared in both the 1999 and 2008 surveys it can be seen there is only a small change between the two sets of results (see Table 5.22).

Table 5.22: Comparison of the percentage of respondents who do agree scientists don’t trust journalists to reflect their views correctly

<table>
<thead>
<tr>
<th>“Scientists do not trust journalists to reflect their view correctly and fear the journalist will twist the scientists words”</th>
<th>1999</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agree (%)</td>
<td>77.9</td>
<td>68.9</td>
</tr>
<tr>
<td>Disagree (%)</td>
<td>11.5</td>
<td>15.9</td>
</tr>
<tr>
<td>Don’t know (%)</td>
<td>10.6</td>
<td>15.1</td>
</tr>
</tbody>
</table>

Further statistical analysis of the 1999 data showed that contact with the media did not allay mistrust in the media but results show that those who had had contact more likely to have the fear that a journalist would not correctly reflect their views. Similar analysis of the 2008 results showed that no significant relation existed between those respondents who had been contacted by the media regarding their work and their belief that a journalist would misrepresent their views. However, analysis did show that those respondents who had
contacted the media to complain about the coverage of a science issue were more likely not to trust journalists to reflect their views correctly ($p \leq 0.01$).

5.6 Conclusions
The results of this longitudinal study examining the attitudes of Irish academic based life scientists towards GM technology allow insights into this important policy actor group at two distinct points in time. Moreover, the research results presented here can shed light on the areas of where change in attitudes have occurred and areas where attitudes remain consistent on certain issues over time. Overall, evidence from this study supports the previous research that while generally positive towards GM food and crop production, the attitudes and risk perceptions of scientific experts still showed dynamic properties similar to those found in the data from the public (Sjöberg, 2008).

A key area of change that reflects a shift in respondents’ attitudes includes the reduction in respondent’s levels of health concerns regarding GM food. This is likely a result of the lack of published negative impacts of GM food on consumer’s health and an on-going familiarisation with commercial GM food applications in the market. From an acceptability of application perspective there was no significant change in the other of levels of acceptability of GM organism types. However, there was a drop in the levels of acceptability of GM animals and human cells by respondents in 2008. This could be as a result of more recent advances in GM applications in this area that have become publicized in contemporary media compared to in 1999.

While the overall order of acceptability of certain GM applications did not change between the two surveys, in both surveys the consistent citing of medical application of GM technology as the most acceptable application of GM technology and the citing of GM grass that doesn’t require as frequent mowing as the least acceptable suggests respondents scale acceptability more on the basis of benefits than of risks. Highly beneficial GM applications merit support despite the risks, while less beneficial ones merit caution because of the risks. This theme is reinforced by the fact that a specific application relating to blight resistant GM potatoes
received significantly more support than the generic broad GM application of herbicide tolerant crops.

The two sets of results show that scientists do not have a simple pro- or anti- attitude to GM technology but it is very much context dependent and varies widely depending on application. However, this is a concept that can work both ways as the causality flows both ways. While one’s independent assessment of the risk and the benefit of a technology can determine their judgment about that technology’s risk/benefit trade-off, one’s judgment about the risk/benefit trade-off also inevitably influences their assessment of the two components. This leads to the situation where once a person decides that the benefits exceed the risks, they thereafter tend to underestimate risks and overestimate benefits (Sandman, 2008, personal communication).

Results pertaining to Irish scientists’ willingness to buy GM food products show that while there was no significant increase in willingness to buy such products between the two surveys there was a significant decrease in those not willing to buy GM food products (with the exception of GM baby food) and a corresponding increase in those responding ‘don’t know’. This shows evidence of a shift in attitudes where respondents are moving from a negative perception of GM food products to a more considered perspective. Respondents are clearly not seeing the risk of GM foods as zero (or so close to zero that they treat it as zero). They are distinguishing applications of GM technology they want to see benefit in and to adopt and applications they want to avoid. Respondent’s unwillingness to buy GM baby food reflects this sophisticated approach and provides evidence that there are key psychometric factors at play. In this case elements such as the specific fear/dread (Sjöberg, 2000), the lack of experience/knowledge (Barnett and Breakwell, 2001) and the involuntary risk they would subject others to (Fischhoff et al., 1978) by the use of GM baby food might all be relevant.

While most results showed little change between surveys (e.g., age, trust levels in sources of information, acceptability of applications, levels of agreement that an immediate complete ban on all GM foods and their production in Ireland would occur, etc.), a key dramatically significant change in attitude over time emerged in respondents suggesting it was likely that
GM technology will play a substantial role in reducing world hunger within the next 20 years (see Figure 5.19).

Another key result was the worsening of scientists’ opinions regarding the quality of science and technology reporting that they have seen/heard in Ireland. This is an interesting result considering the increasing efforts of science communication in Ireland at many levels that have occurred between 1999 and 2008 (e.g. the Irish Times [a daily broadsheet newspaper] has instituted a weekly science page, etc.). It is clear that improving science reporting and communication via approaches taken in Ireland between 1999 and 2008 (often based on the deficit model) has not improved the quality of science reporting in the Irish media in the eyes of respondents.

Overall results show that respondents have a relatively weak knowledge of policy related to modern plant biotechnology. This could result from the fact there is no organised group in Ireland that represents Irish life scientists on this issue thus there is no formal window for engagement in the policy process and no vehicle of policy information flow. As a key stakeholder group within the public discourse Irish university based scientists may need to examine options to organise themselves to allow formal interaction with the policy process. This is of growing importance considering the fact there has been five formal Irish government consultation processes concerning GM technology since 1997 (namely consultations on two field trial license applications, a GMO public consultation, a GM co-existence consultation and a GM crop risk/benefit consultation administered by the Irish Government on behalf of the EU Commission).

In summary this longitudinal research shows that Irish university life scientist’s attitudes to GM technology are context dependent but very supportive of continued research into this area. Their attitudes towards the quality of media coverage of GM related issues continue to be negative and they tend to trust their own peer group. However, Irish life scientists’ attitudes, like those of the public, can be influenced strongly by core psychometric factors that shows expert opinion is dynamic in nature and is not uniquely different to public opinion in term of
what can influence it. However, while such influences can be shown to exist, their exact level of impact and how such impact levels differ to the public is still not fully known.
Chapter 6

Modern Plant Biotechnology and the Irish Feed Industry

"It is the framework which changes with each new technology and not just the picture within the frame.”

Herbert Marshall McLuhan (1955) 

Essential McLuhan, Routledge, New York, 1997

The impacts that a new technology has on the innovation chain (from conception to consumer) are of critical importance in determining its success. How stakeholders, consumers and regulators react cannot only make or break a particular technology but can also set precedents for how future technologies are treated. Consequently, a study of how modern plant biotechnology impacted the Irish animal feed industry was undertaken. The aim of this chapter is to examine the responses and opinions of the Irish feed industry as a key sector in the value chain that have had to respond to the impacts and changes brought about by the introduction of new plant biotechnologies.

6.1 Irish Feed Industry: Background

The agri-food sector in Ireland is an important element of the Irish economy as it is responsible for approx. 8% of Irish GDP with primary agriculture directly accounting for 3% of GDP (Teagasc, 2010). Irish agriculture is highly dependent on animal production. The beef and dairy sectors combined are responsible for approximately 60% of Irish agricultural output based on producer prices (ibid). This heavy reliance on animals (in particular cattle) places
animal feed in the position of the largest input segment into Irish agriculture (see Figure 6.1) (Central Statistics Office, 2011).

Figure 6.1: Inputs into Irish Agriculture, 2005

Illustrating this point is the fact that approximately 80% (3.36 million hectares [ha]) of Irish agricultural land is used for grass production for animal feed use (i.e., pasture, hay, and silage), 11% (0.46 million ha) is used for rough grazing while only the remaining ~9% (0.38 million ha) is devoted to the production of crops. Furthermore, 3.75 million metric tonnes (MT) of compound feed was used in Ireland in 2010 (including cattle feed: 2.3 million MT, swine feed: 0.58 million MT and poultry feed: 0.47 million MT – all of which were similar to previous years’ levels [see Figure 6.2]) (Bouxin, 2010) representing one of the highest rates of compound feed use per head of capita in the EU.
As an integral part of Irish agriculture the feed industry plays a key role in the agri-food value chain and is the major cross point between the plant based supply chain and animal based supply chain (see Figure 6.3). Furthermore, the feed industry has many connections with key players all along the food chain and with associated industries.
While overall in Europe the independent feed supplier model remain the most prevalent form in Europe and tends to employ a transactional supply chain configuration (Bröring 2009), the Irish feed industry is dominated by co-operatives, several of which are integrated into large multinational food businesses (e.g. Kerry Group plc.).

The Irish Grain and Feed Association (IGFA) is the representative body of the grain and feed industry and is recognized by the Irish Government as the official voice of the industry. The Association has members that fall into four main categories:

- Animal compound feed manufacturers (47 - covering 90% of the industry)
6.1.1 Sources of Irish Animal Feed Components:

While grass and its direct products (e.g. grass silage) form the basis for most ruminant production systems in Ireland, it fails to fully supply the needed protein-carbohydrate ratios for commercial cattle production (McGee, 2000). Consequently, the availability of high protein animal feed is crucial for the Irish beef, pig and poultry sectors (and Irish agriculture as a whole). Thus, the sourcing, importing and processing of suitable feed components is required because Ireland only produces a fraction of the feed components it requires. This feed component production deficit situation has been exacerbated since the BSE crisis when in 2001 a prohibition on the usage of bovine protein was implemented in the EU via Article 4 of Council Decision 2000/766/EC (2000). To replace this protein source, the EU feed industry has had to use an extra 3 million MT of soy meal per annum (Webb, 2011). Consequently, the volumes of EU imports of soybeans and soybean meal have grown steadily since the late 1990s and have stabilized in recent years at approx. 34 million MTs (2007) and (USDA, 2011c). This has led to a situation where several key agri-food producing countries in the EU are heavily dependent on feed imports. According to Hughes’s analysis for the feed market, Ireland is 52% reliant on feed imports as opposed to the UK which is only 36% dependent, France is 19% dependent, and Germany is 26% reliant on feed imports (Hughes, 2008). Sourcing feed raw materials for import is increasingly difficult and expensive due to a number of key factors such as increasing freight costs, instability in money markets (e.g. currency fluctuations), currency, energy prices, etc.

The key feed elements of soybean and maize products (e.g. distillers dried grain [DDG], maize gluten feed) [MGF] are normally imported from the US, Brazil and Argentina to meet the animal feed needs of Irish agriculture. Soya bean meal is the most popular vegetable protein feed used in the production of animal feed as it has a comparatively high protein content
DDG and MGF are used as a very cost effective and high-performing animal feed source as both are high in protein, energy and phosphorus (Klopfenstein et al., 2007; Stein and Shurson, 2009). DDG is a co-product of the dry milling industry that focuses on converting the starch from the maize to sugar which is then fermented to produce ethanol while MGF is a co-product of the wet maize milling industry that extracts the starch, which is then further processed to make fructose, or fermented to produce ethanol.

More specifically, according to the Irish Government, “over 90 per cent of the protein feed for Ireland’s livestock comes from soya and maize gluten imported from North and South America, practically all of which contains GM varieties sown in those countries” (Department of Agriculture Food and Fisheries, 2011). Soya bean meal and the maize (including its by-products DDG and gluten) combined have, year on year, constituted the main segments of imported feedstuffs into Ireland (see Table 6.1).

Table 6.1: Imports of feedstuffs into Ireland 2004 to 2008 (’000s of MT)

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cereals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>363,401</td>
<td>494,171</td>
<td>465,055</td>
<td>432,111</td>
<td>343,639</td>
<td>400,893</td>
<td>294,116</td>
</tr>
<tr>
<td>Barley</td>
<td>81,823</td>
<td>15,072</td>
<td>149,433</td>
<td>114,368</td>
<td>70,586</td>
<td>234,509</td>
<td>299,811</td>
</tr>
<tr>
<td>Oats</td>
<td>613</td>
<td>1,976</td>
<td>6,927</td>
<td>2,634</td>
<td>1,436</td>
<td>215</td>
<td>1,948</td>
</tr>
<tr>
<td>Sorghum</td>
<td></td>
<td></td>
<td>68,000</td>
<td>21,930</td>
<td>11</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>180,611</td>
<td>159,395</td>
<td>201,343</td>
<td>272,415</td>
<td>409,281</td>
<td>354,099</td>
<td>350,685</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>626,448</td>
<td>670,614</td>
<td>822,758</td>
<td>889,528</td>
<td>846,872</td>
<td>989,727</td>
<td>946,771</td>
</tr>
<tr>
<td><strong>Proteins</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soyabean</td>
<td>56,590</td>
<td>50,611</td>
<td>52,318</td>
<td>83,673</td>
<td>30,116</td>
<td>24,106</td>
<td>24,903</td>
</tr>
<tr>
<td>Soyabean meal</td>
<td>14,250</td>
<td>15,140</td>
<td>14,014</td>
<td>19,854</td>
<td>22,848</td>
<td>27,174</td>
<td>37,326</td>
</tr>
<tr>
<td>Soyabean meal</td>
<td>307,876</td>
<td>433,789</td>
<td>337,650</td>
<td>319,386</td>
<td>281,409</td>
<td>385,583</td>
<td>402,526</td>
</tr>
<tr>
<td>Soya Hulls</td>
<td>100,727</td>
<td>193,198</td>
<td>119,472</td>
<td>184,856</td>
<td>231,831</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Quantity 1</td>
<td>Quantity 2</td>
<td>Quantity 3</td>
<td>Quantity 4</td>
<td>Quantity 5</td>
<td>Quantity 6</td>
<td>Quantity 7</td>
</tr>
<tr>
<td>-------------------------</td>
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</tr>
<tr>
<td>Cotton</td>
<td>22,644</td>
<td>12,587</td>
<td>14,349</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>Linseed</td>
<td>1,533</td>
<td>5,705</td>
<td>1,819</td>
<td>1,373</td>
<td>1,005</td>
<td>2,149</td>
<td>1,159</td>
</tr>
<tr>
<td>Sunflower</td>
<td>93,267</td>
<td>82,762</td>
<td>138,764</td>
<td>117,615</td>
<td>63,076</td>
<td>94,868</td>
<td>92,129</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>110,520</td>
<td>107,803</td>
<td>105,841</td>
<td>158,563</td>
<td>245,693</td>
<td>218,601</td>
<td>256,499</td>
</tr>
<tr>
<td>Copra</td>
<td>5,290</td>
<td>37</td>
<td>3</td>
<td>8</td>
<td>9</td>
<td>1,508</td>
<td>4</td>
</tr>
<tr>
<td>Palm Kernel</td>
<td>103,393</td>
<td>78,347</td>
<td>165,590</td>
<td>112,594</td>
<td>98,932</td>
<td>170,745</td>
<td>119,573</td>
</tr>
<tr>
<td>Poultry Offal Meal</td>
<td>1,917</td>
<td>2,752</td>
<td>2,195</td>
<td>946</td>
<td>2,559</td>
<td>1,816</td>
<td>4,211</td>
</tr>
<tr>
<td>Fishmeal</td>
<td>4,246</td>
<td>6,691</td>
<td>8,720</td>
<td>6,478</td>
<td>5,297</td>
<td>4,168</td>
<td>3,814</td>
</tr>
<tr>
<td>Maize Gluten Feed</td>
<td>625,903</td>
<td>365,382</td>
<td>464,024</td>
<td>229,396</td>
<td>44,688</td>
<td>88,620</td>
<td>212,048</td>
</tr>
<tr>
<td>Peas</td>
<td>9,686</td>
<td>16,737</td>
<td>11,617</td>
<td>3,860</td>
<td>1,740</td>
<td>3,870</td>
<td>2,435</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,357,115</strong></td>
<td><strong>1,178,343</strong></td>
<td><strong>1,417,631</strong></td>
<td><strong>1,246,944</strong></td>
<td><strong>916,850</strong></td>
<td><strong>1,208,064</strong></td>
<td><strong>1,388,508</strong></td>
</tr>
<tr>
<td><strong>Other Materials</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize Distillers</td>
<td>175,614</td>
<td>230,800</td>
<td>246,437</td>
<td>196,414</td>
<td>108,994</td>
<td>253,191</td>
<td>389,700</td>
</tr>
<tr>
<td>Maize Screenings</td>
<td>36,650</td>
<td>44,122</td>
<td>30,108</td>
<td>38,542</td>
<td>20,758</td>
<td>18,039</td>
<td>23,651</td>
</tr>
<tr>
<td>Rice Bran</td>
<td>27,701</td>
<td>29,952</td>
<td>25,244</td>
<td>2,877</td>
<td>21,255</td>
<td>10,670</td>
<td>0</td>
</tr>
<tr>
<td>Wheat Bran</td>
<td>94,979</td>
<td>56,919</td>
<td>105,893</td>
<td>133,386</td>
<td>125,982</td>
<td>127,846</td>
<td>145,811</td>
</tr>
<tr>
<td>Screenings</td>
<td>3,877</td>
<td>2,477</td>
<td>2,096</td>
<td>1,781</td>
<td>5,114</td>
<td>19,761</td>
<td>14,091</td>
</tr>
<tr>
<td>Molasses</td>
<td>223,240</td>
<td>229,236</td>
<td>134,507</td>
<td>148,098</td>
<td>115,349</td>
<td>132,398</td>
<td>116,327</td>
</tr>
<tr>
<td>Citrus Pulp</td>
<td>232,121</td>
<td>309,238</td>
<td>255,777</td>
<td>322,715</td>
<td>205,458</td>
<td>294,772</td>
<td>373,765</td>
</tr>
<tr>
<td>Beet Pulp By Products</td>
<td>54,321</td>
<td>14,831</td>
<td>0</td>
<td>0</td>
<td>1,270</td>
<td>12,254</td>
<td>18,314</td>
</tr>
<tr>
<td>Beet Pulp Molasses</td>
<td>2,054</td>
<td>1,896</td>
<td>949</td>
<td>183</td>
<td>548</td>
<td>520</td>
<td>97</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>2,964</td>
<td>9,061</td>
<td>6,910</td>
<td>19,174</td>
<td>6,428</td>
<td>5,820</td>
<td>4,273</td>
</tr>
<tr>
<td>Compound</td>
<td>85,719</td>
<td>82,260</td>
<td>79,926</td>
<td>82,703</td>
<td>67,192</td>
<td>88,199</td>
<td>113,148</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Other</td>
<td>422</td>
<td>566</td>
<td>423</td>
<td>513</td>
<td>829</td>
<td>845</td>
<td>455</td>
</tr>
<tr>
<td>Total</td>
<td>939,662</td>
<td>1,011,358</td>
<td>888,270</td>
<td>946,386</td>
<td>679,177</td>
<td>964,315</td>
<td>1,199,632</td>
</tr>
</tbody>
</table>

Source: IGFA, 2011

Soya sources:

Global cultivation of soya bean is currently at a level of 250 million tonnes per year. Three countries, the US, Brazil and Argentina, make up approximately 82% of the global production base of soya bean (Nábrádi and Popp, 2011). Approximately 85% of all soya beans globally produced are processed/crushed every year to make soya bean meal and oil. According to an important industry source, Soyatech, “ninety eight percent of the soybean meal that is crushed is further processed into animal feed with the two percent balance used to make soy flour and proteins” (Soyatech, 2010, pg. 1). One of the primary pressure points for the Irish feed industry is the continued increase of price for soya bean meal which has increased in Ireland by 46.5% since 2005 (see Table 6.2).

Table 6.2: Price of soya bean meal in Ireland (Euro per MT)

<table>
<thead>
<tr>
<th>Soya bean meal (MT)</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>278.18</td>
<td>286.86</td>
<td>316.02</td>
<td>386.15</td>
<td>394.92</td>
<td>407.51</td>
</tr>
</tbody>
</table>

Source: CSO Ireland, 2011

The 2010 price of soya bean meal in Ireland reflects the trend found globally where the average price of soya protein meal on the global markets has more than doubled since 1999/2000 to reach over $400 per MT (see Figure 6.4).
Figure 6.4: Average Global Price of Soya Protein Meal

(Average Global price is based on the following four price sources used by the USDA: Decatur, Average Wholesale 48% Protein; USDA. Rio Grande, Brazil FOB; Bulk Rate 45-46% Protein; Reuters. Argentina Pellets, FOB Up River; Reuters; Hamburg FOB Ex-Mill; Oil World)

This increase in price has occurred despite the increased global production of soya (Figure 6.5) and increased soya meal exports from the top exporting countries (Figure 6.6)
Figure 6.5: Global Soya bean production

Source: (USDA, 2011b)

Figure 6.6: Levels of soya meal exports from main source countries

Source: (USDA, 2011c)
GM technology in soya:

The adoption of GM technology in soya bean production has been very rapid since its first introduction in 1996 (See Figure 6.7 and Figure 6.12). 81% of all soya beans grown are now GM varieties (James, 2010), of which the vast majority contain herbicide tolerant traits. Of all the major commodity crops produced the adoption of GM technology has been the most rapid in soya bean production (see Figure 6.7). By 2010, 94% of soya planted in the U.S. was GM herbicide tolerant. In Brazil, approximately 68% of soya beans grown in 2010/11 were transgenic and it is estimated that 75% will be transgenic in 2011/12 (Enrique M. Traver, 2011). In Argentina, approximately 98% of soya produced is GM (Nábrádi and Popp, 2011) and the last non-GM soybean variety was registered in 2006 (Milanesi et al., 2009).

Figure 6.7: Global adoption of GM technology in main commodity crops

Maize Sources:

Total global maize production per year is currently at approx. 813 million tonnes (USDA, 2011d). Forty percent of this is grown by the U.S. as the largest global producer of maize. The feed industry in the U.S. accounts for 40% of total U.S. maize use (Nábrádi and Popp, 2011).
While the U.S. only exports one fifth of its production, it still remains the world’s largest exporter of maize (Figure 6.8). In combination, three countries (the U.S., Argentina and Brazil) account for over 80% of the global maize trade (USDA, 2011d, Toepfer International, 2010). As the U.S. both produces and exports the most maize globally, U.S. maize prices form the basis of the global market price for maize.

*Figure 6.8: Leading Exporters of Corn*

![Leading world exporters of corn](source)

*Source: (USDA, 2011d)*

The price of maize in the U.S. has increased significantly since 2005 without a reduction in yield in the U.S. This has led to the maintenance of higher prices for maize and maize by-products across the globe (Figure 6.9).
However, since 1998 there has been no maize exported to the EU-15 from the U.S. Consequently, the supply of maize into the EU market has since been from Brazil, Argentina and the Ukraine. Nevertheless a rapid increase (~100%) in the price of maize imported into the EU was observed from 2006 to 2008 (see Figure 6.10).
This price rise has also been reflected in Irish prices for maize meal over the same period. The price of maize meal in Ireland has been over €250 per MT since 2006 (CSO, 2011) but peaked in 2008 at over €330 per MT (see Table 6.3).

Table 6.3: Price of Maize meal in Ireland (Euros per MT)

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize meal</td>
<td>238.80</td>
<td>251.44</td>
<td>303.00</td>
<td>334.98</td>
<td>269.55</td>
<td>264.01</td>
</tr>
</tbody>
</table>

Source: CSO, 2011

Adding upward pressure to this price increase in maize meal were the changes in supply of imported maize meal from the U.S. to Ireland. From 2004 to 2006 maize meal imports from the U.S. dropped by over 50% from 204,200 MT to only 66,400 MT before rapidly increasing
again, by over double, to 201,300 MT in 2009 (see Figure 6.11) (USDA, 2011). This large drop in 2006, 2007 and 2008 can be attributed to the risk of low level presence of non-approved GM feed components which led to the near stoppage of imports of DDG from the U.S. because importers feared rejection of such shipments.

*Figure 6.11: U.S. Exports of DDG to the EU and Ireland*

![US Exports of Distillers Grain to EU and Ireland](image)

*Source: USDA, 2011*

**GM technology in maize:**

GM maize was first introduced in 1996 in the U.S. The adoption of GM technology in U.S. maize production has since increased to a level where 88% of all corn produced in the U.S. in 2011 was GM (see Figure 6.12). There are now three broad trait sets available in U.S. commercial maize production: insect resistant traits, herbicide tolerant traits and the combination of IR and HT traits ‘stacked’ in the same cultivar. The technologies of IR (via Bt) and HT are both reviewed in Chapter 1.
6.2 EU GM Feed Regulation

On April 19, 2004 the EU enacted a renewed regulatory framework regarding the usage of GM products in feed and food stuffs. Both European Regulation EC No 1829/2003 (European Council, 2003a) (regarding placing on the market of either GMOs for food and feed use or for food and feed containing, consisting or produced from GMOs) and EC No 1830/2003 (European Council, 2003b) (dealing with GMO admission, labelling and traceability) both have the stated aim of allowing freedom of choice in the market while avoiding environmental and health risks of GM food or feed. These regulations had set out that GM food and feed products must be labeled as containing GMOs when they contained GM material over a 0.9 % threshold that had an EU authorization and 0.5 % for unauthorized GM material if they had already received a favorable EU risk assessment (Grossman, 2005, Holst-Jensen et al., 2006).
Specifically, Regulation 1829/2003 established an approval system within the EU where the European Food Safety Authority (EFSA) carried out independent risk assessments based on which the EU Commission makes a final approval decision. To apply for an approval to place GM food or feed on the market, an applicant must submit the appropriate documentation to either a member state’s competent authority or directly to EFSA where submission summaries are then published online. Next, the application is sent to both the EU Commission and the EU Member states for review and comment. In theory, EFSA must develop an opinion on the submission within six months. However, the clock can be stopped if a request for more information is sought. Along with the opinion from EFSA, the independent scientific opinion from EFSA’s GMO Panel can be appended concerning any special requirements or considerations. In addition to the EFSA review, the EU Commission’s Joint Research Centre (JRC), acting in its role as the EU’s reference laboratory, verifies the detection method submitted by the applicant for the GM in question. This verification made public by publication on the JRC website. After the above steps are complete, the Commission submits a draft Decision to the Standing Committee of Food Chain and Animal Health (SCoFCAH) for approval consideration within three months of receiving the EFSA opinion (Viju et al., 2011)

To date the following 38 transgenic events have been approved for use in the EU as a GM feed or food (EU Commission, 2011):

1. Cotton (MON1445)
2. Cotton (MON15985)
3. Cotton (MON15985 x MON1445)
4. Cotton (MON531)
5. Cotton (MON531 x MON1445)
6. Cotton (LLCotton25)
7. Cotton (GHB614)
8. Maize (DAS1507)
9. Maize (GA21)
10. Maize (MON810)
11. Maize (MON863)
12. Maize (MON863 x NK603)
13. Maize (MON863 x MON810)
14. Maize (NK603)
15. Maize (NK603 x MON810)
16. Maize (T25)
17. Maize (DAS59122)
18. Maize (DAS1507xNK603)
19. Maize (MON89034)
20. Maize (MON88017)
21. Maize (59122xNK603)
22. Maize (MIR604)
23. Maize (MON863xMON810xNK603)
24. Maize (Bt11)
25. Maize (Bt11xGA21)
26. Maize (MON88017xMON810)
27. Maize (MON89034 xNK603)
28. Maize (59122x1507xNK603)
29. Maize (1507x59122)
30. Maize (MON89034 xMON88017)
31. Oilseed rape (GT73)
32. Swede-rape (MS8, RF3, MS8xRF3)
33. Oilseed rape (T45)
34. Starch potato (EH92-527-1)
35. Soybean (MON40-3-2)
36. Soybean (A2704-12)
37. Soybean (MON89788)
38. Sugar beet (H7-1)

However, in the past, delays in the approval process caused by both applicant issues (incomplete submissions, etc.) and lack of political will to make approval decisions at the level of SCoFCAH have caused a situation whereby certain GM events in feed and food were approved in an exporting country but not in the EU which was importing the feed stuffs and food products in question (Nábrádi and Popp, 2011, Zapilko et al., 2009). This resulted in asynchronous approvals occurring between a GM feed/food exporting jurisdiction and importing jurisdictions. Between when the regulation was introduced (in 2003) and 2009 there have only been nine approvals of GM events completed by the EU. This has led to a situation where asynchrony existed between EU approvals and U.S. approvals in 10 different GM events in 2009 (see Table 6.4)
Table 6.4: Approvals of key GM varieties in the U.S. and EU – Year and Delay

<table>
<thead>
<tr>
<th>GM crop</th>
<th>USA</th>
<th>EU</th>
<th>Delay (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundup Ready soy (MON 40-3-2), Monsanto</td>
<td>1994</td>
<td>1996</td>
<td>2</td>
</tr>
<tr>
<td>Bollgard cotton (MON531), Monsanto</td>
<td>1995</td>
<td>1997</td>
<td>2</td>
</tr>
<tr>
<td>Roundup Ready cotton (MON1445), Monsanto</td>
<td>1995</td>
<td>1997</td>
<td>2</td>
</tr>
<tr>
<td>NaturGard KnockOut maize (Bt176), Syngenta</td>
<td>1995</td>
<td>1997*</td>
<td>2</td>
</tr>
<tr>
<td>LibertyLink maize (T25), Bayer</td>
<td>1995</td>
<td>1998</td>
<td>3</td>
</tr>
<tr>
<td>YieldGard CB maize (MON810), Monsanto</td>
<td>1996</td>
<td>1998</td>
<td>2</td>
</tr>
<tr>
<td>Agrisure CB maize (Bt11), Syngenta</td>
<td>1996</td>
<td>1998</td>
<td>2</td>
</tr>
<tr>
<td>Agrisure GT maize (GA21), Syngenta</td>
<td>1997</td>
<td>2005</td>
<td>8</td>
</tr>
<tr>
<td>LibertyLink canola (T45), Bayer</td>
<td>1998</td>
<td>1998</td>
<td>0</td>
</tr>
<tr>
<td>LibertyLink soy (A2704-12), Bayer</td>
<td>1998</td>
<td>2008</td>
<td>10</td>
</tr>
<tr>
<td>Roundup Ready canola (GT73), Monsanto</td>
<td>1999</td>
<td>1996</td>
<td>-3</td>
</tr>
<tr>
<td>InVigor canola (MS8xRF3), Bayer</td>
<td>1999</td>
<td>1999</td>
<td>0</td>
</tr>
<tr>
<td>LibertyLink rice (LLRICE62), Bayer</td>
<td>2000</td>
<td>Assessment</td>
<td>Current AA</td>
</tr>
<tr>
<td>SeedLink canola (MS1xRF1), Bayer</td>
<td>2002</td>
<td>1996*</td>
<td>-6</td>
</tr>
<tr>
<td>SeedLink canola (MS1xRF2), Bayer</td>
<td>2002</td>
<td>1997*</td>
<td>-5</td>
</tr>
<tr>
<td>TOPAS19/2 canola (HCN92), Bayer</td>
<td>2002</td>
<td>1998*</td>
<td>-4</td>
</tr>
<tr>
<td>Roundup Ready 2 maize (NK603), Monsanto</td>
<td>2000</td>
<td>2005</td>
<td>5</td>
</tr>
<tr>
<td>Herculex I maize (1507), Dow/Pioneer</td>
<td>2001</td>
<td>2006</td>
<td>5</td>
</tr>
<tr>
<td>Bollgard II cotton (MON15985), Monsanto</td>
<td>2002</td>
<td>2003</td>
<td>1</td>
</tr>
<tr>
<td>YieldGard RW maize (MON863), Monsanto</td>
<td>2002</td>
<td>2006</td>
<td>4</td>
</tr>
<tr>
<td>LibertyLink cotton (LLCotton25), Bayer</td>
<td>2003</td>
<td>2008</td>
<td>5</td>
</tr>
<tr>
<td>Widestrike cotton (210-23x24-236), Dow</td>
<td>2004</td>
<td>Assessment</td>
<td>Current AA</td>
</tr>
<tr>
<td>Herculex RW maize (59122), Dow/Pioneer</td>
<td>2005</td>
<td>2007</td>
<td>2</td>
</tr>
<tr>
<td>Roundup Ready sugar beet (H7-1), KWS/Monsanto</td>
<td>2005</td>
<td>2007</td>
<td>2</td>
</tr>
<tr>
<td>YieldGard VT maize (MON88017), Monsanto</td>
<td>2005</td>
<td>Assessment</td>
<td>Current AA</td>
</tr>
<tr>
<td>Roundup Ready Flex cotton (MON88913), Monsanto</td>
<td>2005</td>
<td>Assessment</td>
<td>Current AA</td>
</tr>
<tr>
<td>Mavera High Value maize (LY038) Renessen/Monsanto</td>
<td>2006</td>
<td>Assessment</td>
<td>Current AA</td>
</tr>
<tr>
<td>Roundup Ready 2 soy (MON 89788), Monsanto</td>
<td>2007</td>
<td>2008</td>
<td>1</td>
</tr>
<tr>
<td>Agrisure RW maize (MIR604), Syngenta</td>
<td>2007</td>
<td>Assessment</td>
<td>Current AA</td>
</tr>
<tr>
<td>Amylase maize (3272), Syngenta</td>
<td>2007</td>
<td>Assessment</td>
<td>Current AA</td>
</tr>
<tr>
<td>YieldGard WT PRO maize (MON89034), Monsanto</td>
<td>2008</td>
<td>Assessment</td>
<td>Current AA</td>
</tr>
<tr>
<td>Optimum GAT maize (98140), Pioneer</td>
<td>2008</td>
<td>Assessment</td>
<td>Current AA</td>
</tr>
<tr>
<td>Optimum GAT soy (356043), Pioneer</td>
<td>2008</td>
<td>Assessment</td>
<td>Current AA</td>
</tr>
<tr>
<td>3 events in soy and cotton</td>
<td>Submitted</td>
<td>Submitted</td>
<td>(0)</td>
</tr>
<tr>
<td>1 event in potato (BASF’s amiflora)</td>
<td>Not submitted</td>
<td>Approved</td>
<td></td>
</tr>
<tr>
<td>7 events in maize, soy, cotton, and alfalfa</td>
<td>Submitted</td>
<td>Not submitted</td>
<td>Isolated foreign approvals</td>
</tr>
<tr>
<td>&gt;60 events in maize, soy, cotton, canola, potato, rice, and sugar beet</td>
<td>Approved</td>
<td>Not submitted</td>
<td></td>
</tr>
</tbody>
</table>

Source: Stein and Rodríguez-Cerezo, 2009; Nábrádi and Popp, 2011
There are three types of asynchronous approvals (Stein and Rodriguez-Cerezo, 2010):

1. ‘Time delayed approval’ where a cultivating country has authorized a GM crop while an importing country has not yet finished the approval process of the GM crop in question.

2. ‘Isolated foreign approval’ where a cultivating country has approved the GM crop but the developers/owners of the technology/GM crop have not sought its approval in the importing jurisdiction.

3. ‘Low level presence/adventitious presence’ of non-approved GM events (e.g. events undergoing research field trials) can occur as a result of accidental release into the seed or feed chain.

Such situations, combined with the EU’s zero-tolerance policy for unapproved events in imported product, have led to a number of inspection/enforcement actions by EU authorities and resulting notifications in EU’s Rapid Alert System for Food and Feed (RASFF). The RASFF was,

"established to provide food and feed control authorities with an effective tool to exchange information about measures taken in response to serious risks detected in relation to food or feed. This exchange of information helps EU countries to act more rapidly and in a coordinated manner in response to a health threat caused by food or feed" (EU European Commission, 2011, last accessed on December 15, 2011).

Since 2004 a total of 456 GM notifications have been made via the RASFF by 24 participant jurisdictions (see Figure 6.13). Germany and Austria have made the most GM notifications at 135 and 64 respectively. While Germany is a large importer of food and feed it is expected that it would have a high number of notifications. In contrast, the high number of notifications for Austria is noteworthy and may be reflective of their national anti-GM policy stance.
The sources of the GM feed and food that caused the notifications to the RASFF are primarily from outside the EU. The U.S., China and Canada are the sources of the vast majority of RASFF GM notifications together accounting for 91.2% of all such notifications to date (see Figure 6.14 below).

Source: RASFF Database, 2011
Analysis of the GM notifications to the RASFF shows that there was a very large increase in GM notifications from 2006 onwards. In addition, the data shows that 12% of all GM notifications from 2002 to 2010 were feed related (see Figure 6.15).

Figure 6.15: GM Notifications to RASFF (2002-2010) – All Notifications vs. Feed

Source: RASFF Database, 2011

From 2004 onwards, the difficulty of segregating GM feed components from non-GM material (Gryson et al., 2007) combined with the risk of finding unapproved GM events, made importing food or feed a very high risk activity that put importers in the situation of having the threat of a shipment of feed or food barred from entry into the EU. This was potentially a very costly situation as to have a cargo of feed refused entry into the EU at the border often required the entire bulk shipment to be returned to its country of origin or to attempt to find a non-EU port willing to accept GM feed. While costly to the shippers/carriers and importers, such a situation was also very expensive to those further along the feed value chain (such as feed manufacturers and farmers). For example, feed manufacturers had to change formulations, forego orders, source new materials and suppliers, etc. Industry analysis suggests that the “EU’s zero tolerance policy has had significant impacts on profitability of the EU livestock..."
sector with approximately 17% of the extra total feed costs” for the fiscal year 2006/2007 (i.e. €2.55 billion) can be attributed to the policy (Cardy-Brown & Co. Ltd., 2008, p3).

Several studies have examined the potential impacts on the EU agri-food chain caused by reduction in availability of GM feed as a result of import restrictions (Philippidis, 2010, DG-Agri, 2007). In most scenarios examined, a negative impact on EU meat production was found with pork producers bearing the largest impact. This was echoed by an Irish study published in 2008 by Lawor and Walsh (Lawor and Walsh, 2009) that examined the potential impact of GM issues on Irish pig production. The study highlighted concerns regarding the related financial impact of sourcing non-GM ingredients and replacing GM ingredients with other protein and energy sources. Of note is that the study stated: “while GM maize by-products are not used to a great extent in pig diets, the effect of using more wheat and barley as substitutes in cattle diets would make such cereals scarcer thus increasing their cost of inclusion in GM-free pig diets” (Lawor and Walsh, 2009, p26).

In 2011 the EU changed its regulations to allow a new threshold of 0.1% for unapproved GM events in feed as long as the trait had been approved in another jurisdiction (Viju et al., 2011). This removed the ‘zero tolerance’ for unapproved GM material in feed that had caused disruption to feed imports into the EU and effectively allowed the issue of unapproved events at trace levels to be circumnavigated from a trade impact perspective.

6.3 Objective of Survey of the Irish Feed Industry
The overall aim of this chapter is to investigate the impact of the introduction of GM plant technology into the Irish feed chain by interviewing a panel of Irish feed producers using qualitative methods. This research identifies and explores the issues, impacts and attitudes arising from the introduction of GM plant material in the Irish animal feed system. The data gathered was gleaned from a group of respondents who have been subject to little prior study.
6.4 Methodology

A list of feed producers was obtained from the Irish Grain and Feed Association (IGFA). From this list 10 feed companies were randomly selected to be invited to participate in the study. Seven companies (see Table 6.5) accepted and took part in a qualitative semi-structured interview via telephone (Skype). The sample size, while small in number, represented 14.8% of the IGFA feed manufacturers (approx. 9% of all licensed compound feed manufacturers in Ireland) and was large enough that those interviewed were responsible for over 30% of compound feed produced on the island of Ireland. The method used for data collection was a semi-structured in-depth interview (IDI), which featured questions relating to five major themes, namely: historic background, business impacts, policy responses, future of the GM feed issue and company specific information (see Appendix C). The interviews took place between March 8 and March 24, 2011. The interviews were digitally recorded and transcribed verbatim. One interview recording failed and transcription was not possible, however, responses were recorded by hand via written notes taken during the interview in question. Qualitative analysis of the interviews were carried out using Atlas.Ti software (Atlas.Ti, 2010) with examination for content pertaining to the study’s objectives. This analysis consisted of cleaning and coding the data. The coded data was then examined to connect relevant data segments with each other, shaping categories and connection patterns for deeper analysis via memoing. Memoing was carried out to allow reflective assessment on the data. Connections were made between the data and memos via Atlas.Ti to allow relationships in the data to be confirmed and grouped.
Table 6.5: Interviewee’s company details

<table>
<thead>
<tr>
<th>Feed Company</th>
<th>Number of Employees</th>
<th>Product Production level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Company 1</td>
<td>120</td>
<td>feed ingredients in ~35% of all Irish feed.</td>
</tr>
<tr>
<td>Feed Company 2</td>
<td>undisclosed</td>
<td>undisclosed</td>
</tr>
<tr>
<td>Feed Company 3</td>
<td>10</td>
<td>undisclosed</td>
</tr>
<tr>
<td>Feed Company 4</td>
<td>125</td>
<td>undisclosed</td>
</tr>
<tr>
<td>Feed Company 5</td>
<td>14</td>
<td>~900,000 tonnes</td>
</tr>
<tr>
<td>Feed Company 6</td>
<td>150</td>
<td>170,000 tonnes</td>
</tr>
<tr>
<td>Feed Company 7</td>
<td>34 (plus 62 indirect)</td>
<td>160,000 tonnes</td>
</tr>
</tbody>
</table>

6.5 Results

6.5.1 Interview content analysis:

A word frequency analysis carried out on the interview transcripts showed that there was a focus on business related issues such as costs and time (see Table 6.6). This was followed by an emphasis on international trade and the countries involved as the U.S., the EU and Ireland were cited relatively frequently. Business and government were the two most frequently mentioned actors. The negative term ‘problem’ appeared 21 times in total across all seven interviews.
Table 6.6: Word frequency count of feed industry interviews (words with a count over 11)

<table>
<thead>
<tr>
<th>Word Type</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM(s)</td>
<td>179</td>
</tr>
<tr>
<td>Issue(s)</td>
<td>142</td>
</tr>
<tr>
<td>feed</td>
<td>89</td>
</tr>
<tr>
<td>product(s)</td>
<td>80</td>
</tr>
<tr>
<td>Ireland/Irish</td>
<td>62</td>
</tr>
<tr>
<td>Question(s)</td>
<td>62</td>
</tr>
<tr>
<td>cost(s)</td>
<td>60</td>
</tr>
<tr>
<td>time</td>
<td>57</td>
</tr>
<tr>
<td>business</td>
<td>45</td>
</tr>
<tr>
<td>industry</td>
<td>44</td>
</tr>
<tr>
<td>Maize/corn</td>
<td>43</td>
</tr>
<tr>
<td>Europe/European</td>
<td>41</td>
</tr>
<tr>
<td>U.S./America</td>
<td>40</td>
</tr>
<tr>
<td>enough</td>
<td>34</td>
</tr>
<tr>
<td>fair</td>
<td>31</td>
</tr>
<tr>
<td>side</td>
<td>31</td>
</tr>
<tr>
<td>company</td>
<td>29</td>
</tr>
<tr>
<td>doing</td>
<td>28</td>
</tr>
<tr>
<td>last</td>
<td>28</td>
</tr>
<tr>
<td>people</td>
<td>28</td>
</tr>
<tr>
<td>probably</td>
<td>27</td>
</tr>
<tr>
<td>actually</td>
<td>26</td>
</tr>
<tr>
<td>looking</td>
<td>25</td>
</tr>
<tr>
<td>down</td>
<td>25</td>
</tr>
<tr>
<td>relation</td>
<td>25</td>
</tr>
<tr>
<td>good</td>
<td>24</td>
</tr>
<tr>
<td>trying</td>
<td>23</td>
</tr>
<tr>
<td>source</td>
<td>23</td>
</tr>
<tr>
<td>particular</td>
<td>22</td>
</tr>
<tr>
<td>point</td>
<td>22</td>
</tr>
<tr>
<td>obviously</td>
<td>22</td>
</tr>
<tr>
<td>media</td>
<td>22</td>
</tr>
<tr>
<td>market</td>
<td>21</td>
</tr>
<tr>
<td>whole</td>
<td>21</td>
</tr>
<tr>
<td>want</td>
<td>21</td>
</tr>
<tr>
<td>problem</td>
<td>21</td>
</tr>
<tr>
<td>demand</td>
<td>21</td>
</tr>
<tr>
<td>grain</td>
<td>20</td>
</tr>
<tr>
<td>information</td>
<td>20</td>
</tr>
<tr>
<td>soy/soya</td>
<td>20</td>
</tr>
<tr>
<td>government</td>
<td>19</td>
</tr>
<tr>
<td>change</td>
<td>18</td>
</tr>
<tr>
<td>fact</td>
<td>17</td>
</tr>
<tr>
<td>deal</td>
<td>17</td>
</tr>
<tr>
<td>price</td>
<td>17</td>
</tr>
<tr>
<td>food</td>
<td>17</td>
</tr>
<tr>
<td>material</td>
<td>16</td>
</tr>
<tr>
<td>perspective</td>
<td>16</td>
</tr>
<tr>
<td>world</td>
<td>16</td>
</tr>
<tr>
<td>ingredients</td>
<td>15</td>
</tr>
<tr>
<td>events</td>
<td>15</td>
</tr>
<tr>
<td>past</td>
<td>15</td>
</tr>
<tr>
<td>satisfied</td>
<td>15</td>
</tr>
<tr>
<td>understand</td>
<td>15</td>
</tr>
<tr>
<td>answer</td>
<td>15</td>
</tr>
<tr>
<td>absolutely</td>
<td>15</td>
</tr>
<tr>
<td>risk</td>
<td>15</td>
</tr>
<tr>
<td>zero</td>
<td>14</td>
</tr>
<tr>
<td>country</td>
<td>14</td>
</tr>
<tr>
<td>level</td>
<td>14</td>
</tr>
<tr>
<td>unapproved</td>
<td>14</td>
</tr>
<tr>
<td>raw</td>
<td>14</td>
</tr>
<tr>
<td>tons</td>
<td>14</td>
</tr>
<tr>
<td>distillers</td>
<td>13</td>
</tr>
<tr>
<td>free</td>
<td>13</td>
</tr>
<tr>
<td>testing</td>
<td>13</td>
</tr>
<tr>
<td>animal</td>
<td>13</td>
</tr>
<tr>
<td>gluten</td>
<td>12</td>
</tr>
<tr>
<td>meat</td>
<td>12</td>
</tr>
<tr>
<td>supply</td>
<td>12</td>
</tr>
<tr>
<td>materials</td>
<td>12</td>
</tr>
<tr>
<td>opinion</td>
<td>12</td>
</tr>
<tr>
<td>work</td>
<td>12</td>
</tr>
<tr>
<td>system</td>
<td>12</td>
</tr>
<tr>
<td>lines</td>
<td>12</td>
</tr>
</tbody>
</table>
The word frequency count results can also be depicted graphically in the form of a “wordle tool” (a graphic showing words that occur more frequently in a source text more prominently than those words that occur less frequently) (see Figure 6.16).

*Figure 6.16: Wordle presentation of Feed Industry Interviews*
6.5.2 Source of feed components:

The feed companies interviewed sourced their protein products (e.g. soya) primarily from South America while maize based products had been mainly sourced from North America and Argentina. The vast majority (over 95%) of the animal feed produced in Ireland contains GM components. Those feed companies offering non-GM identity-preserved product lines, often to fulfill specific contract requirements, have indicated they are sourcing non-GM soya from outside the EU.

[non-gm soya] Coming out of the Mato-Graso area in Brazil. Now also, we use a lot of maize in our diet. But the maize we would source would be all French maize. We wouldn't take the risk, say, of maybe taking in U.S. maize or Brazilian maize into our poultry mill.

Interviewee G

On the maize side, for the non-GM maize, we have stuck almost rigidly over the last five or seven years to French maize, has been the easiest and ideal source to draw from.

Interviewee B

6.5.3 Timing of when GM became an issue for the Irish feed industry:

The matter of GM technology within the feed chain first became a concern for the feed companies interviewed in 1997 (Webb, 2011). However, it has become a major issue for the industry more recently when supplies were halted in 2007 and at various points thereafter as a result of the low level presence of unapproved GM material in soya and maize shipments into Europe.

Well, I suppose it would have been as far back as 2005, 2006. The main stop of supplies to us would have been whatever maize gluten feeds and cereals would have stopped, and that would have been around 2007. But really, the problem started prior to that.

Interviewee D
It has been an issue in the background for a number of years now. But as far as our company is specifically concerned, it's probably more in the last three years really when I suppose the markets became particularly volatile.

Interviewee C

Even to '06 or '07, let's say basically, we had issues with the availability of materials via distiller’s gluten. And, it is really from then, that the whole thing has got very, very tight.

Interviewee G

As a result most of the respondents indicated that their company had to change business practices to manage GM related issues. The impacts of GM plant technology on the Irish feed chain can be categorized into several groupings, all of which have had some degree of associated cost. These include sourcing of new products, product testing, supply interruption risk and loss of competitiveness.

6.5.4 Impact 1: Sourcing of new products

All but one feed company had to find new sources of raw material to deal with the issue of GM in the feed value chain.

we had to turn our backs on several countries that supplied raw material, for example the U.S.

Interviewee F

This shift in sourcing location was costly on two fronts for many feed companies. Not only was the new replacement product more expensive, but companies had to invest effort and expend resources on arranging the logistics.

...you do have to change your buying patterns because if some of the products are effectively being banned from importation we have to replace those with other products and that's where we've seen the huge sort of upset in logistics and also an upset in just the pure cost of replacing cheaper imported products.
with European grown products. The simple fact of the matter was they were more expensive.

*Interviewee E*

Running around attempting to secure replacement product as there is not only a direct premium required but also there are increases in cost for replacement component

*Interviewee F*

It was to do with sourcing one material versus another, which is more expensive..... There was no account taken, to my knowledge, of the time that people spent sourcing the grain, procuring the grain, and making all the arrangements around that.

*Interviewee A*

Furthermore, in certain situations, the sourcing of new material required feed companies to reformulate certain product lines they had in place.

*The biggest one, obviously, is cost of the replacement raw materials, but you then, as I say, have a huge amount of management hours in sourcing new products and then educating your customers in these new products. Our customers then have to spend a lot of time, their nutritionists have to spend a lot of time reformulating their diets and taking these products out and replacing them with other products. As I said, no one I know within industry has sat down and worked out the man hours and logistical cost of this because no one wants to because it would just.....make you cry.*

*Interviewee E*

*There is a cost to reformulate product to ensure that maize remains as the first ingredient (10 times table), normally as 10.1%. As maize is not high in protein*
there needs to be components added but the mix must maintain maize as the highest ingredient. This can be costly and difficult.

Interviewee F

6.5.5 Impact 2: Product Testing

Subsequent to the introduction of GM traits into maize and soya bean production in North and South America, the Irish feed industry had to implement product testing of raw material imports to satisfy either or both the EU’s zero tolerance for unapproved events and requirements under contracts for certain upstream customers who wished to be supplied with GM-free feed. In both cases the costs for such identity preservation have been borne by the feed industry.

The testing and the flushing, and the dedicated intakes and transports, we have to bear the costs of that overhead as such...... For the bit of IP we use, we have to have a dedicated intake, dedicated transport, flushing procedures. So there is a lot of actions that we carry out internally, and then as well as that, obviously, we carry out a non-GM testing regime, which can be pretty expensive.

Interviewee G

This requirement and related responsibility for testing and proof of identity preservation has been passed back to those suppliers of the feed manufactures (e.g. shippers, grain elevators, etc). Nevertheless, the associated costs have been passed forward in the value chain to buyers of Irish animal feed.

To basically prove that the material is GM free, and free of various other non-desirables. To GM, we would basically be passing the buck to our suppliers to ensure that we wouldn't buy anything without the contracts being very specifically clear that the material is suitable for entry into the European Union.

Interviewee C
And the cost issue would have been related to the fact that our cost of ingredients increased as a result of it all, and then we had to pass that on to our end user.

Interviewee D

Respondents indicated that in their opinion there was a difference between testing for unapproved events in the context of EU regulatory requirements and testing to prove a feed component is free from GM material to meet a supply contract requirement. The asynchronous approval situation caused by EU regulations was a major source of concern as it was deemed beyond the direct control of the feed manufacturer, as opposed to the contact requirements for non-GM that were considered a “business decision”.

It's a pretty black and white issue as far as we're concerned. You can either buy it safely or you can't. If you can buy it safely and it's competitive, you buy it. If it's not, you don't. It's not a, there is no sort of fundamental change to the way you trade as a result of, you deal with whatever legislation is in front of you basically.

Interviewee C

The non GM is customer demand, which we're fine with. You know, you've got a customer who wants a product in that category, and there's a price, and they pay, and you do it. That's a business decision. We have complete control over that one. The issues I was referring to are to do with the case of authorizations of GM variety on the one hand and the zero tolerance there is for the unapproved traits on the other hand. Because in those two instances, we have no control at all, in particular, on the zero tolerance point. That's a huge issue, because of the increased precision of analysis, and zero can really mean zero.

Interviewee A

6.5.6 Impact 3: Supply risk

The feed companies interviewed raised supply risk as a key impact of the introduction of GM plant material into the feed chain. This was supported by the fact that since 2006 several
shipments of soya and maize into the EU had tested positive of unapproved GM events and the shipments in question were denied use in feed manufacturing.

Difficulties we've had is, I suppose, proving that most of the cargos are not contaminated with any GM source that have not been registered.

Interviewee B

Because when you are dealing with them in mass commodities and with ships coming in from all over the world with 20,000, 30,000, 40,000, 50,000 tons of product on its bulk commodity. It is not possible to sterilize that in terms of unapproved events. All you can do is police it reasonably effectively, and then have an eye to the risks involved.

Interviewee C

I suppose, the shippers and the importers were reluctant to bring product in, so we then physically, in Ireland, didn't have a supply of it, if you know what I mean. It was just that our supplier wasn't prepared to take the risk, into Ireland.

Interviewee D

6.5.7 Impact 4: Loss of competitiveness

The accumulation of impacts on the Irish feed manufacturing industry resulting from the introduction of GM soya and maize has led respondents to claim an overall impact of a loss of competitiveness. This is exacerbated by the fact that the Irish feed manufacturing industry that operates on very tight margins and is subject to both supply and demand pressures by virtue of the fact they are near the center of the agri-food value chain (Bröring, 2009). This situation, coupled with the importance of animal feed as the primary input into Irish agri-food products has put the entire Irish agri-food sector at a marked disadvantage.
Ireland, because of its high dependency on ruminant feeds, worked up a consumption of these products [maize and soya] to almost a level of one million tons a year. It allowed Ireland to be competitive with the rest of Europe from the point of view that there were a cheap ingredient. They competed with the cheap ingredients which the food manufacturers in Europe had available to them. So we were able to compete and supply food into Europe at no extra cost, whereas when our GM episode arrived, and when we lost these products, we had to then turn back into Europe to find products which were non-GM or which were approved GMs. And that goes into the cost of our feed to the ruminant industry and left us slightly uncompetitive. And that's where the South American beef market began to come back into Europe, then, in a big way.

Interviewee B

And the cost issue would have been related to the fact that our cost of ingredients increased as a result of it all, and then we had to pass that on to our end user.

Interviewee D

You are piling cost onto European [feed] industry.....

Interviewee A

...the added cost associated with non-GM will make meat production in the EU uncompetitive. The added costs include paper trails to ensure product is non-GM, testing of product to verify, added premiums, etc.

Interviewee F

There is an enormous double standard within EU legislation where we are basically holding our farmers to far higher standards than we are allowing competitor products into the EU on and that is a fundamentally flawed
model.......you are basically condemning your own farmers to a much higher
cost model

Interviewee C

One respondent questioned the benefit of spending extra resources to mitigate adventitious
presence of GM content in feed supplies as a result of asynchronous approvals between the
EU and soya and maize producing countries.

We literally flushed that money down the toilet. It served no useful purpose. We
gained nothing from spending that money other than we supplied our
customers. But there was no benefit.

Interviewee A

The lack of a level playing field was cited as a key issue, since from a competition
perspective, EU feed producers (and more specifically Irish feed producers) were subject to an
ongoing burden that producers in other jurisdictions did not face.

...like it or not there is not a massive market out there. And no matter what
people with different agendas will say there isn't a mass market out there for
the volume of food that we produce here at a premium. And unless we have a
level playing field on our costs, then the long term survival of the industry is
questionable.

Interviewee C

What we want is a level playing field with everyone else across the world and
that's why we wanted the asynchronous approval system changed and brought
up to speed.

Interviewee E
To my mind, this is an example of gross waste. What I mean by that is that if you follow the logic of what we're doing through, what it means in practice is that a non-European farmer - and I use the word farmer advisedly - can feed these unapproved ingredients to livestock and subsequently supply livestock products to the European market with no restriction. A European farmer is prohibited from using these ingredients, to my knowledge.

Interviewee A

6.5.8 Impact 5: Influences on GM issue:

Supermarkets

Those interviewed identified supermarket retailers as an important key driver in the GM feed issue in Ireland.

It's a supermarket differentiation that has created a holy mess for the industry.... maybe 1999, not even 2000. Superquinn were the first to really introduce non-GM chickens....Ireland is very much dominated by the Tesco supermarket and maybe our eggs seem to be positioned into that basket. Which, in effect, is calling the tune from a non-GM point of view...And that was an issue that spilled over from Tesco. Tesco began to differentiate their products by saying that they wanted to put all the eggs on the shelf that were fed on non-GM food. But they never advertised the fact that the eggs they were selling were from non-GM fed chickens.......

Interviewee B

And at the end of the day, you know the supermarkets are the people that drive the retail cost of food. And you know, essentially their modus operandi is to just buy the cheapest possible product from wherever it comes from.

Interviewee C
I certainly think it [non-GM] a niche market. That, again, has been led by supermarket driven demand, but, again, from my point of view, that just really is a PR exercise and the premiums for non-GM material, especially soya, are going up year on year because obviously the supply is reducing as farmers see much better yield for going the other way.

Interviewee E

In our case we have main contracts with UK and Irish retailers who require that feed used their in poultry production would be non-GM……..It [non-GM] is driven by the retailers but you can’t even test the end meat or milk product for GM. It’s crazy.

Interviewee F

We are approved under Tesco, M&S and approved by Superquinn as well, under all these retailers models, we have to carry out some non-GM tests.

Interviewee G

6.5.9 Government

All of the interviewees were very critical of the response by the Irish Government (Fianna Fail/Green Coalition - 2007-2011) to the GM issue and the associated impacts on the feed industry. Frustration was also expressed by respondents at the EU for their inaction on the issue.

Completely dissatisfied [with Government response] ....... In so far as political sentiment is important, if that is what is preventing progress on this issue, it needs to be tackled.

Interviewee A
The last one [Irish Government] went to bed with the Green Party. They gave them total latitude, when it came to GM issues, and they stood back from us. To some degree, the country was held up, as a result of this.

Interviewee B

I do not think there has been anything really proactive coming out of the Department of Agriculture for probably a decade on this issue. It is just a morass of inactivity basically; in my opinion (chuckle).....it is just that nobody in Europe wants to take up the baton. It is not just the Irish Department of Agriculture, but there is prevarication going on Europe wide on the subject. It is a total "head in the sand" attitude.

Interviewee C

I was definitely not satisfied with the process that it took to get there. And indeed, their approval of events was very unsatisfactory, the time delay.

Interviewee D

...the coalition government has been held at ransom by one of the minor parties. I think when that came apart and the minor parties didn't have the sway in the last vote, that summed up the whole process.

Interviewee E

Not at all satisfied, pure ideology in the last government cost the feed industry. There were options to allow them to get what they wanted but they weren’t considered.

Interviewee F

I think they were very poor, and in one situation we had Minister Sergeant come round and visit us to talk with the whole GM issue. And quite simply when the guy landed here he did not have a clue what he was talking about. He
had a technical assistant who was very clued in in fairness but again they were coming from a one-sided argument. Basically they did not care that the extra cost that farmers have to spend because of the increase in feed price. They were not interested in anything else bar their own Party stance, the Green Party stance on GM crops, etc.

Interviewee G

6.5.10 Media

In terms of interviewees opinion on how the Irish GM feed issue was portrayed in the media, most indicated the media were negative to neutral on the issue. One respondent was critical of the feed industry’s approach to the media. The media was not considered a trusted source of information regarding GM feed by any of the interviewees.

I think a terribly bad job has been done in the media. And I include my own industry in this…..And my reaction to that is that at a fairly significant business or political level, somebody needs to grasp that communication.

Interviewee A

If you're talking localized, within Ireland, "The Irish Times" have been quite good as well, reporting on it. Obviously, more from a consumer point of view, but they still have highlighted issues surrounding it.

Interviewee D

I think there's been the odd article which has been absolutely very balanced and just told the facts and didn't try and scare people. But I can't remember which paper that was in or by which journalist, to be honest.

Interviewee E
Hard to know. Like in the reality, I suppose farmer’s bible in reality which is our customer base is the Farmer's Journal. But in reality, again the Farmers Journal tends to be, a one sided debate from the point of view, all right it is the farmer’s bible as such. But at the end of day, one week it is for the grain man, or the beef man. And next week it is not for them.

Interviewee G

6.5.11 Public Perception:

Several of the interviewees bemoaned the negative public perception that exists concerning GM plant biotechnology and its use in the agri-food chain.

And I think there has to be a recognition of the fact that we've drifted into an area which is, let's call it, anti-science, anti-technology and, by the way, anti-reality. We're allowing a perception to fester, which is that Europe can sail off in this [non-GM] direction.

Interviewee A

Really, it was, the ignorance on behalf of most of the residents of Europe. They've been very much, I suppose, anti-GMs, for no reason at all. Other than they don't understand the whole mechanism. It's a science that is probably, far beyond, maybe, a lot of comprehension..........And at this stage, maybe, we are suffering as a result. And people have just the wrong impression of what genetic modification is....... It's an emotive subject, which is out in the grain area, more than anything else, and in the soya bean area. Of course, there are other products that have been GM for years, as you know. No one has made any fuss about them including, I suppose, the medical professionals who have used them as well.

Interviewee B
In addition to the issue of public perception one interviewee also raised the issue of how the feed market has perceived the EU’s management of the issue of GM material in the agri-food chain.

*But the perception of this around the world is hopeless. People laugh at this. They cry about it. They react with astonishment to it. In lots of cases, people find it hard to believe that what we're discussing actually can operate in a sophisticated, modern market such as the European Union.*

**Interviewee A**

6.5.12 Future of non-GM and GM feed:

Most interviewees held the view that GM-free feed product is a niche market driven by certain retailers that is diminishing in size.

*What I would say, it [GM-free feed demand] has decreased. I couldn’t say by what proportion in that period. It's not something we measure.*

**Interviewee A**

*It is decreasing slightly as some of the retailers are moving away from non-GM, I believe ASDA does not require its poultry feed to be non-GM anymore.*

**Interviewee F**

*Oh, it's definitely decreased. …...Like, we ourselves would be more or less on roughly the same level as we would have been, say, five years ago. But I know some of other feed mills who we would be, you know, talk to and do a bit of contract manufacturing for, they would have quit the IP [identity-preservation] non-GM side of their business.*

**Interviewee G**

*It's such a small, specialized market. There isn't room for every person to having it. At the moment, we do a lot of pigs. So unless it comes directly from the monogastric side, pigs or poultry, at present, it would only be one or two*
percent of our total business. So, in the short term, definitely, I can say we wouldn't be going down that route. We just wouldn't have the facilities in house to separate lines in that.

Interviewee D

I certainly think it's a niche market. That, again, has been led by supermarket driven demand.

Interviewee E

Because the levels of non-GM products available are diminishing by the year. So it's going to be more difficult to try and segregate and separate and everything else......They will go for the cheapest product. And it doesn't matter. They're not going to question that there's GM or non-GM.

Interviewee B

However, several interviewees made the point that if contracts existed for non-GM feed, promulgated by those willing to pay for the extra costs involved, they would certainly continue to provide the product as specified.

There is a demand for non GM feeds into the sectors that are prepared to pay for that.

Interviewee C

In our case we have main contracts with UK and Irish retailers who require that feed used their in poultry production would be non-GM.

Interviewee F

Interviewees also highlighted that GM technology and GM feed will continue to play an important role in Irish agriculture.

And in order to give our farmers any sort of living at all, I think you really need free access to genetically modified goods, but you do need to have a system that
is more user friendly anyway.

**Interviewee C**

they will be required to ensure competiveness as other countries selling products such as meat into the EU can use GM, the added cost associated with non-GM will make meat production in the EU uncompetitive. The added costs include paper trails to ensure product is non-GM, testing of product to verify, added premiums, etc.

**Interviewee F**

Because obviously in reality GM crops in the future from the point of view that they are getting better yield. They are making them more resistant to disease and everything else. I think yeah, they are going only to increase quickly in America and South America over the next what, 10 years?...... so basically to feed the increasing population, I think we definitely need GM to be made more available.

**Interviewee G**

They will go for the cheapest product. And it doesn't matter. They're not going to question that there's GM or non-GM.

**Interviewee B**

[Interviewer’s Question] From your perspective, do you consider that GM dry feed will be necessary to meet the future needs of the animal sector?

Yes.

**Interviewee D**
6.5.13 GM Issue Progress:

Most interviewees believed the situation regarding GM material in the EU feed chain is improving. The source of this optimism lies in the recently announced new thresholds for GM events not approved by the EU which have been increased.

...since, I suppose, the early days of the GM issue, we've got the EU to agree on 0.9% contamination, which Tesco has accepted. And at least that has given us a little bit of latitude in way that we've been able to get through the diet with a few ingredients which don't throw up any GMs and may be from GM sources but don't throw up any GMs within the total recipe. From that point of view, we've had some lee-way.

Interviewee B

But if you had done the same survey 24 months ago it would have been very different, if you know what I mean. The panic stages are off within the feed field but it's still something that's going to have to be looked at on a more ongoing basis. But I suppose the immediate issue with supply within our trade is resolved temporarily. Or in the short term, anyway...... thresholds are there, which has enabled us to start using these byproducts again, the distiller's grains and the maize gluten feed. So that has alleviated, in the last 12 to 18 months -- 12 months, so it is really.

Interviewee D

Well, obviously we know I have a bit of light at the end of the tunnel with the small tolerance, but it is a very, very small tolerance and I'm not sure that that really will, with such a small tolerance, whether that's really going to improve things or not.

Interviewee E
Well it has eased somewhat from the point of view that there have been further approvals over the past, what three to four years? In terms of feed being approved and such, and that has eased some of the pressure. But no, there is a long way to go before we will be happy.

**Interviewee G**

Nevertheless, some interviewees believed the situation regarding GM has deteriorated

*And the reason I said that I see the situation as having got much worse is because of the increasing pace of GM change.*

**Interviewee A**

6.6 **Discussion:**

Results from this study show the Irish feed industry, which plays a critical role in Irish food production, has experienced the serious issues and impacts as a result of how the introduction of GM technology into the agri-food value chain occurred in Ireland. By employing a strategic analysis framework (modeled on the structure of macro-environmental scanning frameworks, e.g. political, economic, social and technological [PEST] analysis (Glaister and Falshaw, 1999), social, legal, economic, political and technological [SLEPT] (Ortiz and Tajes, 2010)) the results can provide both a deeper understanding of the impacts of GM technology on the Irish feed industry and insights into the feed industry’s attitudes to the situation.

6.6.1 **Economic Issues:**

The economic issues experienced by members of the Irish feed industry as a result of how GM technology was managed were both numerous and various in type. They can be categorized in the following headings as i) Operational costs, ii) Competitive advantage costs, and iii) Non-GM business lines:

i) Operational Costs:

Within the operational costs category interviewees focused on three main cost types, namely:

a) **Replacement product costs:** Interviewees highlighted the fact that new feed component products to replace product that would have been either GM in nature
or at risk of testing GM positive were more expensive. This expense was a combination of the fact that it was more expensive to ship under identity-preserved conditions and the fact there was less available product a yearly basis.

b) Logistical costs: Aside from the actual cost of new replacement product, the feed industry experienced considerable logistical costs in replacing feed component products. These costs included time and effort in sourcing new product, finding new shippers, developing and reviewing new contracts, demurrage costs, developing new product formula, etc.

c) Product testing costs: As a result of the lack of legal thresholds and a zero tolerance for unapproved GM traits in imported feed components, the Irish feed industry were required to carry out testing for unapproved events for products that were not considered identity-preserved. While the cost of non-GM products sourced under contracts that required identity preservation could be passed on to the customer, the testing for unapproved events in non-identity-preserved feed components was a cost that had to be either absorbed or passed along the agri-food value chain.

ii) Competitive Costs

Interviewees found it frustrating that they were part of an agri-food chain within the EU that, when compared to other jurisdictions, was put at a competitive disadvantage as a result of the impacts and issues relating to GM technology. This was compounded by the fact that cheaper finished product (e.g. beef, chicken, etc.) from these non-EU agri-food value chains that used GM feed were allowed access to the EU market, while imports of GM feed components were restricted as a result of either slow approvals or lack of decision making at a political level. This allowed non-EU agri-food products to be more competitive and to increase their sales, thus reducing or limiting market share of EU agri-food products which in turn put pressure (e.g. reduced orders) on all parts of indigenous EU agri-food value chains, including Irish feed manufacturers. Interviewees expressed the need for reforms regarding how the issue of GM feed is approached so a level playing field between EU and non-EU countries can be created as soon as possible.
iii) Non-GM business lines:

While according to most interviewees certain key supermarkets were driving the demand for non-GM feed, interviewees highlighted the fact that the non-GM business line was in fact either a niche market and/or a contract requirement to their customers. Several interviewees believed that the demand for non-GM feed was decreasing. Moreover, a number of those interviewed believed that increased access to GM feed components was required to meet the animal feed needs of the future.

6.6.2 Legal Issues:

The legal situation pertaining to GM feed in the EU was identified by interviewees as a key factor impacting their business. In their opinion, there was a lack of a reasonable threshold for GM content in imports of compound feed components, perpetuating a legal zero-tolerance for unapproved events in feed raw material that put their supply chain at risk of enforcement action. This situation forced the feed industry and their suppliers to take risk mitigation actions to assure compliance (e.g. product testing, segregation of product, etc.). However, interviewees noted that while these legal mitigation actions are both time consuming and expensive, they have not always succeeded. As a result, in 2006 and 2007 many maize and soya suppliers into the EU market simply did not ship as the risk of testing positive for an unapproved event was deemed too high. There was general agreement that the approval system for GM traits for use in animal feed was problematic. The interviewees also welcomed the recent changes in EU legislation that increased the threshold for unapproved GM events in feed under certain conditions.

6.6.3 Political Issues:

All interviewees expressed considerable frustration regarding the political system both within Ireland and at the EU level. This attitude was held by several interviewees that there was inaction and time delays in regards to EU approvals of GM traits. Moreover, most expressed the view that the Irish Government (Fianna Fail/Green Party coalition in power 2007-2011) at the time was ineffective on the issue of GM feed. Several interviewees suggested the Green
Party was the problem and that the Greens cared more about their anti-GM political viewpoint than increases in feed prices for the Irish farmer. This was reinforced when shortly after the Green party left the coalition Government the remaining political party changed its voting position in the EU concerning approvals of GM traits and supported EU Commission in its moves to amend EU regulation to increase thresholds of unapproved events in GM feed (Department of Agriculture Food and Fisheries, 2011).

6.6.4 Social Issues:

A number of interviewees were very conscious of the negative perception held by the public on the topic of GM technology. Several interviewees suggested lack of knowledge was the driver behind the negative public perception. The interviewees adoption of the ‘deficit model’ (Sturgis and Allum, 2004) as an explanation is noteworthy. In terms of media coverage those interviewed believed the media took an approach to GM reporting that was somewhere between negative and neutral in tone. One interviewee blamed the feed industry for the “bad job” in the media. This attitude towards the media is noteworthy considering the research findings in Chapter 4 that showed the feed issue as the most prominent GM issue in the three main daily broad sheets in Ireland between June 2007 and June 2010 and that articles related to feed were more likely to be positive in tone. Some interviewees also indicated that the downward change in socio-economic conditions in Ireland and the need in the future to ensure food security for a growing population would mean the of use GM technology in the agri-food chain in the future would be highly likely.

6.6.5 Technological Issues:

Interviewees cited technological issues as key concerns, which included rapid advances in the introduction of GM crop varieties and enhanced sensitivity in GM testing (the latter is considered a key driver to delimitation and demarcation in the EU’s governance of biotechnology (Lezaun, 2006)). Both occurring together were deemed to have had a large impact because while the EU GM trait approvals were slow/delayed there was, at the same time, a rapid commercialization of new and stacked GM traits into maize and soya varieties in countries that supplied the Irish feed industry. This led to the exporting country and the EU
having asynchronic approvals of GM events that could be tested for using ever more sensitive protocols in co-mingled imports into the EU. These issues became such a challenge that the IGFA (as did the Japanese feed industry) wrote to the head of Syngenta, a GM crop developer in April, 2011 concerning the commercial release of a new corn variety Agrisure RW™. The correspondence from the IGFA highlighted the fact that “commingling and adventitious presence of unapproved varieties is therefore a major concern” and asked Syngenta to provide information regarding its stewardship plan considering “the potential crisis Syngenta will precipitate when this variety is released” (See Annex 1).

This study provides evidence that the implementation of GM traits into the Irish feed system has seen issues arise across the economic, legal, political, social and technological arenas that have had impacts on numerous and diverse stakeholders. The relationships between these arenas are complex and far from linear as many interdependencies exist. Each area impacts some or all of the other areas in various ways. While complex, the pattern of impacts and issues that arise with GM technology entering the agri-food chain is not dissimilar at a macro level to the introduction of any new technology into a value chain.

However, in the case of the Irish feed industry there are several key elements across the impact areas have led to a more challenging situation:

1. The Irish feed industry is the more reliant on imports than any other EU country, namely maize and soya feed components (Economic).
2. Feed component producing countries approved a higher number of new maize and soya varieties between 2005 and 2007 than in any similar time period before (see Table 6.4) (Technological, Legal).
3. The EU GM trait approval system was subject to political delays (Legal, Political).
4. A 27.4 fold increase in GM notification to the EU’s RASFF occurred in 2006 peaking further to 166 GM notifications in 2009 (see Figure 6.15) (Legal, Technological).
6. Maize and soya feed component prices raised rapidly between 2006 and 2008, reflecting the increase in global agricultural community prices (see table 6.2 and 6.3) (Economic, Social).
6.7 Conclusions

The study of the Irish feed industry’s experience of the introduction of GM technology into the agri-food value chain shows that the introduction of a new technology can have impacts that are multi-dimensional and can have knock on effects and feedback loops that can impact all along a value chain. These effects are shaped by the commercial relationships in the value chain and are under constant negotiation and re-negotiation depending on the changes in the legal, commercial, political or technological arenas that influence the value chain and even frame the value chain. This supports prior research that showed that the final determination of how “value” from modern agri-biotechnology will be distributed along the value chain will depend on the relationships and the alignment of strategies of the various players along the agri-food chain (Kalaitzandonakes, 1999).

Furthermore, this study shows the key role biopolitics (Morris and Adley, 2000a, Nuti et al., 2007) can have at the science-policy interface and the reframing power it has on a value chain. Such evidence includes the striking change in the Irish Government’s policy to support thresholds for unapproved GM events that occurred within weeks of the Green Party leaving its coalition.

Key Recommendation: Development of Value Chain Impact Assessments:

This study supports the need for companies and/or industry groups to develop technology specific Value Chain Impact Assessments as part of their foresight exercises to consider the reframing of their value chain that can occur as a result of the introduction of new technologies. These should include strategic analysis based on consideration of a broad range of risk types including not only economic costs and benefits but also technological, political, social, and legal ones. Linkages between these risk areas should be assessed and mapped to enable identification of impact type and complexity to allow the correct prioritization of any mitigation plans required.
Chapter 7

GM glyphosate tolerant maize cultivation in Ireland: An *Ex-ante* environmental and agronomic analysis to improve risk management

“It might seem unfair to reward a person for having so much pleasure over the years, asking the maize plant to solve specific problems and then watching its response.”

Barbara McClintock’s statement on receiving the Nobel Prize for Medicine (1983)

To demonstrate a policy approach proposed in Chapter 2 that examines both risk and benefits (rather than just risks), a case study was undertaken using a product-based approach that assesses risks and benefits appropriately by taking into account current products and practices thus putting the new product in context from a risk management perspective. Doing so also demonstrates why such an approach is preferable to a process-based approach that simply examines the risks of an innovative plant biotechnology in isolation and out of the appropriate context. As maize is an important source of animal feed in Ireland and is thus a key element of the Irish agri-food chain, coupled with the fact that maize is a crop for which GM herbicide (glyphosate) tolerant varieties could soon be available in Ireland, it was decided that the case study focus on Irish maize production.
7.1 Irish Maize Production: Background

In the Republic of Ireland, maize (Zea mays L.) is primarily grown as livestock fodder using early maturing maize hybrids. Cultivation of Irish maize during 2009 was 20,900 hectares (ha) (Figure 7.1) and was, as is normal, primarily concentrated in the east, south, and south-east of Ireland (Central Statistics Office, 2009 www.cso.ie ). From 2000 to 2007 the area under maize cultivation in Ireland increased by 49.5%, the highest rate of any arable crop. Maize is an attractive forage crop for Irish dairy and beef farmers as it is high yielding, suitable for use as winter feed material, allows for early harvest and provides for excellent animal performance (Juniper et al., 2007, Crowley, 1998). After grass from pasture, forage maize is currently the cheapest per utilized dry matter tonne forage crop grown in Ireland (O’Mahony, 2009). There are two systems of maize cultivation, namely covered cultivation and open cultivation. Covered cultivation of maize in Ireland employs a thin layer of oxo-biodegradable plastic film which is laid on the soil surface at seeding as a mulch. The resulting increased accumulated temperatures allow for higher yields and earlier harvest under Irish conditions. This system can, as outlined by O’Brien and Mullins, “increase dry matter yield by approximately 3000 kg ha\(^{-1}\) and ensure consistency in yield and quality from year to year” (O’Brien and Mullins, 2009, p330).

Figure 7.1: Silage maize cultivation in Ireland 2000-2009

The renewed increase in Irish maize production is primarily due to the introduction of a range of much improved early maturing varieties adapted to the lower temperatures of Northern Europe which have given higher yields coupled with successful employment of covered maize cultivation (Keady et al., 2005, Walsh et al., 2008). Nevertheless, maize producers face a number of key issues that will impact future maize cultivation in Ireland. These include:

a) Fluctuations in animal feed prices:
Since late 2006 fluctuations in the price of key animal feed components have been evident with soya bean meal and flaked maize remaining 41.7% and 30.9% above their September 2006 prices respectively when compared to their February 2010 price (Figure 7.2). Such animal feed cost instability has increased producers interest in Irish grown maize for animal feed use. As such, silage maize is currently regarded as an important part of the feed supply chain for Irish dairy and beef producers. Key studies have reported that freely feeding maize either to cattle or mixed with grass silage-based diets increased dry matter intake (DMI) and resulted in better performance (e.g. growth, weight gain, etc) of both beef cattle (O'Kiely and Moloney, 1995, O'Kiely and Moloney, 2000, Keady and Kilpatrick, 2004) and early lactation dairy cows (Burke et al., 2007). According to Keady et al. there can be considerable savings realised (i.e. via animal feed concentrate) considering that the “potential concentrate sparing effect of including maize silage as 0.40 of the forage component of grass silage based diets was between 2.0 and 3.4 kg per cow daily” (Keady et al., 2008, p10).
b) Planned changes in EU herbicide regulations

The banning of atrazine in Ireland (Council Directive 91/414 O.J. [L230]) which took effect in June 2007 removed a key weed management product in Irish maize cultivation (Burke, 2007, O’Brien and Mullins, 2009). This led to pendimethalin (the active ingredient in Stomp® 400 SC and PDM 330) becoming the primary plant protection product used in Irish maize production. According to Dewar, further changes are expected in the near future as of the 981 existing and 136 new active ingredients that are under consideration by application of article 8 of Directive 91/414/EEC, only 14.7% are approved, while 54.5% are unapproved, and 30.8% are awaiting a decision (Dewar, 2010). In addition, the EU has recently moved to implement a new ‘Thematic Strategy for Pesticides’ which is predicted to remove from use or restrict a number of key plant protection products currently used by maize growers (Dewar, 2009). The EU’s new pesticide strategy contains four legal elements: a proposed Regulation to replace the pesticide authorisation Directive 91/414/EEC (Balderacchi and Trevisan, 2010) which will come into force on 14 June 2011, a planned new Sustainable Use Directive, new Statistics Regulations, and revisions to the machinery directive allowing certification of new spray
equipment. The new regulations signal the fact that the EU is moving from a ‘risk assessment’ based regulatory framework to simply a ‘hazard’ based framework. It is likely that the new legal provisions will leave Irish farmers with a yet further diminishing set of plant protection options for the cultivation of maize.

c) Possible changes in Ireland’s climate:
Irish researchers, O’Brien and Mullins, have suggested that

“by 2040, temperatures in Ireland are predicted to increase by 1.25-1.5°C, with rainfall expected to increase by up to 15% in the winter months and to decrease by up to 20% over the summer. This change in climate will increase the potential for greater forage maize cultivation in Ireland” (O’Brien and Mullins, 2009, p324).

which is important when the fact that maturation time for maize in such conditions may be shortened by up to two weeks. While enhanced temperatures and CO₂ levels could lead to increased silage maize yields of 16% to 22% at a 20% increase in temperature (Jones and Abdulla, 2010) there is the risk that increased winter precipitation may have a negative impact on yields (Holden and Brereton, 2003). Added to the change in climate, further increases of silage maize cultivation are likely to occur as more climatically suitable maize varieties become available on the Irish market.

d) Desire for improved sustainability in agricultural practices:
Over the next decade Irish farmers will be urged to decrease the environmental footprint of their activities. As a result, maize farmers will be seeking ways to improve efficiency while increasing sustainability. While growing maize in Ireland is overall more energy intense than growing grass pasture, maize has a number of key sustainability benefits. For example, it has been shown in dairy cattle that supplementing maize for other feed resulted in 22% lower N₂O emissions per kg of milk production when compared to pasture (Luo et al., 2008). Lou et al. concluded this resulted from the considerably higher efficiency of nitrogen use from low-protein maize silage as opposed to grass. While such benefits may increase the demand for maize silage Irish maize growers will also have to reduce their environmental footprint as net energy yields of maize for use in silage are normally higher when compared to grassland
The options for improving sustainably in Irish maize production are limited due to the nature of the Irish climate and the very specific demands of the Irish cattle sector who are the primary end users of silage maize in Ireland. However, as pointed out by Kelm et al., considering:

“both nitrate-leaching losses and a necessary minimum quantity of grass herbage in a well-balanced ration, research has suggested that a high proportion of maize silage in combination with N-unfertilized grass/clover swards used in a mixed cutting/grazing system could represent a good trade-off between the leaching of nitrates and energy efficiency” (Kelm et al., 2004, p69).

The use of genetically modified (GM) herbicide-resistant (HT) maize has been suggested as a possible approach to meeting future changes faced by Irish maize growers as herbicide tolerant maize claims to offer a number of advantages over current maize production which include the reduction in the number of spray applications, a less hazardous herbicide regimes, possible increased farm income, and the potential to implement reduced-till practices and increased biodiversity (Duke and Powles, 2008, Kleter et al., 2008, O’Brien and Mullins, 2009, Wolfenbarger and Phifer, 2000, Devos et al., 2008a, Gustafson, 2008, Leonard, 2008, Brookes and Barfoot, 2009, Gianessi, 2005, Cerdeira and Duke, 2006, Ammann, 2005, Qaim and Subramanian, 2010). However, to date, no Irish experimental field trials of HT GM maize have occurred to examine the benefits and risks of GM HT maize use by Irish maize producers. In the absence of Irish experimental field trials it is thus necessary to employ ex-ante methods to examine the potential environmental and agronomic impacts of GM HT maize cultivation in terms of various herbicide regimes compared against existing maize production practices used in Ireland. This will allow a basis for a comprehensive risk and benefit assessment and provide an initial set of data on which to frame future Irish field trial research if required. This study is the first joint environmental and agronomic assessment of GM maize cultivation in Ireland.

7.2 GM Herbicide Resistant Maize
There are several forms of HT maize available that have been developed which include GM glyphosate tolerant maize (Roundup Ready™), GM glufosinate-ammonium tolerant maize
(Libery Link™) and non-GM imidazolinone tolerant maize (Clearfield™). In 2008, 5.7 m ha of GM HT maize was grown in the world, accounting for 7.2% of the total area planted with HT GM crops (James, 2009 personal communication). As suggested by O’Brien and Mullins:

“GM HT maize resistant to herbicides (such as glyphosate) would be highly suited to the Irish agri-environment because maize is unable to compete with weeds during the first month after sowing and mid-to-late season chemical control is hampered by the maize crop canopy” (O’Brien and Mullins, 2009, p330).

GM HT maize field trials are currently on-going across Europe with trials in Denmark, the Czech Republic, Spain, France, Hungary, Portugal, Romania and Sweden (EU SNIF database: http://gmoinfo.jrc.ec.europa.eu/).

Only GM glyphosate tolerant maize will be considered in this study due to the fact non-GM Clearfield™ maize is currently not available in Europe and GM glufosinate-ammonium tolerant maize is unlikely to be used in Ireland in light of the fact that glufosinate-ammonium may be deemed unable to meet the hazard ‘cut off’ point in the EU’s new pesticide regulations as occurred under a preliminary Swedish Government review (Government of Sweden, 2007). For a review of glyphosate, N-(phosphonomethyl) glycine readers are referred to Chapter 1.

7.3 Materials and Methods

7.3.1 POCER indicator

Over the last number of decades a great number of indicator instruments have been developed to measure pesticide risk to humans and the eco-system. Many of these indicator tools allow policy makers to measure risks of pesticides, examine the effects of risk reduce measures and compare risk reduction scenarios in different situations. However, as pointed out by Reus et al., these indicator tools can result in differences in their assessment of risk caused due to the differences in the considerations used in calculating the risk to the environment (Reus et al., 2002). However, as there is currently an absence of a harmonized indicator at an EU level this leaves a question of which indicator should be used? In the literature a number of indicator reviews are available (Bockstaller et al., 2009, van der Werf and Petit, 2002, Devillers et al., 2005, Bol et al., 2003, Dale and Polasky, 2007). What can be concluded is that here are two
main types of indicator: Pesticide Use Indicators (PUIs) and Pesticide Risk Indicators (PRIs). In PUIs the total amounts of pesticide use or total number of sprayings is relied upon while in PRIs the combined hazard and exposure characteristics for one or several environmental at risk groups (e.g. farm worker, air, birds, earthworms) are considered individually (Bol et al., 2003). In examining the most widely available PRIs used by public authorities (Table 7.1) it was decided to use a PRI that was modern, had a high number of parameters that functioned together, had a solid track record and had good readability, feasibility and reproducibility (Bockstaller and Girardin, 2003, Bol et al., 2003). To this end the POCER (Pesticide Occupational and Environmental Risk) indicator was chosen. Nevertheless, all indicators suffer from specific weaknesses and none are perfect (e.g. POCER only considers the risk of the pesticide actives and does not take account of the biological risks of surfactants chemicals that could be contained in the commercial formulation of the marketed product).

**Table 7.1: Pesticide risk indicators used by public authorities**

<table>
<thead>
<tr>
<th>Risk indicator</th>
<th>Level of complexity</th>
<th>Country</th>
<th>Survey period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Aquatic Risk Index – NL (Lutsk, 2000)</td>
<td>*</td>
<td>The Netherlands</td>
<td>1984-</td>
</tr>
<tr>
<td>Index of Load (Gravesen, 2000)</td>
<td>**</td>
<td>Denmark</td>
<td>1986–</td>
</tr>
<tr>
<td>POCER-1 (Vercruysse and Steurbaut, 2002)</td>
<td>***</td>
<td>Belgium</td>
<td>2002</td>
</tr>
<tr>
<td>SYNOPSIS-1 (Gutsche and Rosberg, 1999)</td>
<td>***</td>
<td>Germany</td>
<td>1987, 1995</td>
</tr>
</tbody>
</table>

*Note: Complexity range is defined by the function of the number of parameters required for the calculation, ≤ 5, 6-20, ≥ 21 is represented by *, **, *** respectively.*

**Source:** (Bol et al., 2003)

As described by Vercruysse and Steurbaut, the POCER was developed in 2002 at Ghent University (Vercruysse and Steurbaut, 2002). Claeyss et al. explain that it is a comparative risk analysis tool “for applicators and decision-makers that calculates the impact of pesticide
treatments on the applicator, the worker, the bystander, groundwater, surface water, bees, earthworms, birds, useful arthropods and persistence in soil” (Claeys et al., 2005, p779) . By its use, plant protection products impacts human health and environment can be thus calculated. These calculations can then compared and contrasted, resulting in an assessment of different crop protection regimes (Vercruysse and Steurbaut, 2002). As outlined in detail by Devos et al. the areas for impact analysis use criteria set out in European Directive 91/414/EEC - Annex VI which stipulates the requirements for commercial use of plant protection products in the EU. These risk areas fall within the ten categories, three of which related to human occupational, non-dietary exposure (categories 1 to 3) in addition to the seven concerning the environment (categories 4 to 10). The full list of the risk categories assessed by the POCER Indicator is outlined below (Table 7.2).

Table 7.2: Risk Categories assessed by POCER Indicator

<table>
<thead>
<tr>
<th>Pesticide Risks Areas Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
</tbody>
</table>

Source: (Devos et al., 2008a, Vercruysse and Steurbaut, 2002)

For each of the risk categories measured a risk index (RI) is derived which is the quotient of the exposure assessment and the effect assessment for a specific pesticide in that particular category. For the exposure assessment internally accepted exposure values are employed while toxicological reference values taken from European Directive 91/414/EEC (Annex VI) are used to determine the effect assessment of a particular pesticide in each category. As
explained by developed by Vercruysse and Steurbaut and employed by Devos et al., to assess the total risk in each category each RI is transformed into an “exceedence factor (EF)” which defines a high and low end within each category. Those EF values ≤0 are defined as zero are considered a low (negligible) risk, whilst EF values of ≥1 are scored as one and reflect a high (unacceptable) risk. EF values between 0 and 1 are considered an intermediate risk (Devos et al., 2008a, Vercruysse and Steurbaut, 2002).

To assess the risk of a particular pesticide regime each individual active substance present in the pesticide regime is calculated separately and then added together after which the total risk is converted to an EF which in doing so reflects the additive effect of a particular pesticide regime. Due to the very limited data available on antagonistic or synergetic impacts of actives in pesticide applications these effects are not incorporated into the POCER analysis. The total risk value of a particular pesticide regime is calculated by summing the active substances’ EF values for each of the ten risk categories to give a total risk value for human health and the environment conveyed as a single number from 0 to 10 which can then be used to compare between different pesticide regimes. In this study, a comparison of the POCER values for the current recommended herbicide regimes for maize cultivation in Ireland with the different herbicide regimes that would be employed if GM glyphosate tolerant maize was used in Ireland was carried out.

7.3.2 Recommend herbicide regimes for conventional maize in Ireland

Conventionally cultivated maize in Ireland requires the use of herbicide to ensure the crop is protected from weed competition (see Figure 7.3). In Ireland, the two methods for conventional Irish maize cultivation are either growing the crop covered under plastic or in open cultivation. Both methods require herbicide regimes that involve product application either at the pre-emergence stage, the post-emergence stage (2–4 leaf stage) or at both stages. In Table 7.3 the full list (pre-emergence stage and post-emergence) of state recommended herbicide regimes (and related herbicides Table 7.4) for maize cultivation are outlined and their respective active ingredients are named. The composition, product dose and application rate listed provides data to allow for the calculation of the RI for exposure assessment. For
each of the active ingredients toxicological reference values are listed in Table 7.5 which provides data for the calculation of the RI for effect assessment.

*Figure 7.3: Maize growth under plastic showing the effect of herbicide use vs. no herbicide*

Source: Maizetech Ltd., Ireland
### Table 7.3: Recommended herbicide regimes and herbicides for Irish conventional maize cultivation

<table>
<thead>
<tr>
<th>Plastic Crops/Pre-emerg.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-A</strong></td>
<td>PDM 330 4.5 l/ha</td>
</tr>
<tr>
<td><strong>Pre-B</strong></td>
<td>PDM 330 4.5 l/ha + Calaris 1.0 l/ha</td>
</tr>
</tbody>
</table>
| **Pre-C**                | PDM 330 4.5 l/ha + Cadou Star 0.75 kg/ha (under rows of plastic at sowing time)  
followed by 1.5 l/ha Calaris (between rows of plastic 4 weeks after sowing) |
| **Open Crops**           |  |
| **OpenA**                | Calaris 1.25 - 1.5 l/ha |
| **OpenB**                | PDM 330 4.5 l/ha + Cadou Star 0.75 kg/ha |
| **OpenC**                | Callisto 1.5 l/ha + 2.5 l/ha PDM 330 |

### Table 7.4: Recommended herbicides for Irish conventional maize cultivation

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Active Ingredient</th>
<th>Composition</th>
<th>Product dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow1</td>
<td>Bromptril P 1.5 l/ha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow2</td>
<td>Titus 50 g/ha + Agral 0.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow3</td>
<td>Starane2 1.0 l/ha</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: Tim O’Donovan, Teagasc*
<table>
<thead>
<tr>
<th>Product</th>
<th>Active Ingredients</th>
<th>g/L</th>
<th>P, L/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadou Star</td>
<td>Flufenacet</td>
<td>480</td>
<td>0.85kg/ha</td>
</tr>
<tr>
<td></td>
<td>isoxaflutole</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Stomp 400SC</td>
<td>pendimethalin</td>
<td>400</td>
<td>3.75</td>
</tr>
<tr>
<td>PDM330</td>
<td>pendimethalin</td>
<td>400</td>
<td>0.85kg/ha</td>
</tr>
<tr>
<td>PDM330 + Cadou Star (0.75kg/ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flufenacet</td>
<td></td>
<td>0.85kg/ha</td>
</tr>
<tr>
<td></td>
<td>isoxaflutole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PDM330 (4L) + Calaris (1.5L/ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pendimethalin</td>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Terbuthylazin +</td>
<td>330</td>
<td>1.0 - 1.5</td>
</tr>
<tr>
<td></td>
<td>mesotrione</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Calaris</td>
<td>Terbuthylazin +</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>mesotrione</td>
<td></td>
<td>1.0 - 1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Alpha Bromotril P</td>
<td>bromoxynil</td>
<td>240</td>
<td>1.5 - 2.5</td>
</tr>
<tr>
<td>Callisto</td>
<td>Mesotrione</td>
<td>200</td>
<td>0.75 - 1.5</td>
</tr>
<tr>
<td>Starane *2</td>
<td>fluroxypyr</td>
<td>288</td>
<td>1.0</td>
</tr>
<tr>
<td>Titus + Agral</td>
<td>Rimsulfuron + surfacant</td>
<td>250</td>
<td>50 g/ha + 0.1</td>
</tr>
<tr>
<td>Titus + bromoxynil</td>
<td>Rimsulfuron +</td>
<td></td>
<td>40-50 g/ha +</td>
</tr>
<tr>
<td></td>
<td>bromoxynil</td>
<td></td>
<td>0.5-1.0 l/ha</td>
</tr>
</tbody>
</table>

Source: Tim O’Donovan, Teagasc

7.3.3 Recommend Regimes for GM glyphosate tolerant maize in Ireland

GM glyphosate tolerant maize would allow new set of herbicide regimes to be used in maize cultivation in Ireland. As previously outlined this work uses only glyphosate tolerant GM corn as a comparison to the current maize herbicide regimes employed in Ireland. The use of GM glyphosate tolerant corn would allow for the application of glyphosate which is a broad-spectrum herbicide thus enabling post-weed management of the crop and better opportunity for weed management timing. Research has shown the greatest results with GM glyphosate tolerant corn are obtained by applying glyphosate after crop emergence, but before the weeds reach a height of 10 cm in height but no longer than 23 days post seeding, and before growing
has gone beyond the V4 stage (Cox et al., 2006, Gower et al., 2003, Myers et al., 2005).
However, not all weeds are equally susceptible to glyphosate (Norsworthy et al., 2001) and depending on the local weed populations, application rates of glyphosate may need to be modified accordingly. In addition, GM glyphosate tolerant corn has not been approved for commercial use in the EU as a result projected glyphosate regimes had to be derived from what is currently used where GM glyphosate tolerant corn is commercially available (Leroux GD, 2005) and regimes used in experimental trials in north western Europe (Grenouillet, 2007, Monsanto, 2009, Verschwele, 2010). As a result, a broad number of different glyphosate regimes (Table 7.5) for use with GM glyphosate tolerant corn were included in our POCER comparison analysis. As with the herbicides used in conventional maize production in Ireland the compositional and application rate data of the active ingredients in the glyphosate regimes were used to calculate RI for exposure and effect assessments for use in the POCER indicator. The toxicological reference values used for glyphosate to determine the RI for effect assessment can also be found in Table 7.6 (shaded).

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Active Ingredient</th>
<th>Composition g/L</th>
<th>Product dose P, L/ha</th>
</tr>
</thead>
</table>

Table 7.5: Glyphosate based herbicide regimes for use with GM glyphosate tolerant maize
<table>
<thead>
<tr>
<th>GM HT-Maize</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gly 1</td>
<td>Roundup</td>
<td>glyphosate</td>
<td>360</td>
<td>2 L(1 spray)</td>
</tr>
<tr>
<td>Gly 2</td>
<td>Roundup</td>
<td>glyphosate</td>
<td>360</td>
<td>2.5 L (1 spray)</td>
</tr>
<tr>
<td>Gly 3</td>
<td>Roundup</td>
<td>glyphosate</td>
<td>360</td>
<td>3L (1 spray)</td>
</tr>
<tr>
<td>Gly 4</td>
<td>Roundup</td>
<td>glyphosate</td>
<td>360</td>
<td>2.5L + 1.25L (2 sprays)</td>
</tr>
<tr>
<td>Gly 5</td>
<td></td>
<td>glyphosate</td>
<td>360</td>
<td>2.0L + 2.0L (2 sprays)</td>
</tr>
<tr>
<td>Gly 6</td>
<td>Roundup</td>
<td>glyphosate</td>
<td>360</td>
<td>2.5L + 2.5L (2 sprays)</td>
</tr>
<tr>
<td>Gly 7</td>
<td>Roundup</td>
<td>glyphosate</td>
<td>360</td>
<td>3.0L + 3.0L (2 sprays)</td>
</tr>
<tr>
<td>Gly 3+A</td>
<td>Roundup  + Cadou Star(0.75kg/ha)</td>
<td>glyphosate</td>
<td>360</td>
<td>3.0L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flufenacet</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flufenacet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gly 3+B</td>
<td>Roundup  + Calaris (1 spray of each)</td>
<td>glyphosate</td>
<td>360</td>
<td>3.0L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Terbuthylazin + mesotrione</td>
<td></td>
<td>1.5L</td>
</tr>
<tr>
<td>Gly 3+C</td>
<td>Roundup  + Callisto (1 spray of each)</td>
<td>glyphosate + Mesotrione</td>
<td></td>
<td>3.0 + 200g/L</td>
</tr>
</tbody>
</table>
Table 7.6: Toxicological reference values used for the active substances compared

<table>
<thead>
<tr>
<th>Active substance</th>
<th>Source</th>
<th>DT50 (d)</th>
<th>Koc (mg/g)</th>
<th>AOEL (mg/kgBW/d)</th>
<th>derm abDE (%)</th>
<th>MTC (mg/l)</th>
<th>LD50, bird (mg as/kgBW)</th>
<th>LD50, bee (µg as/bee)</th>
<th>LC50, worm (mg as/kg soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>flufenacet</td>
<td>EU</td>
<td>34</td>
<td>353</td>
<td>0.017</td>
<td>10</td>
<td>0.0000408</td>
<td>1608</td>
<td>25</td>
<td>226</td>
</tr>
<tr>
<td>isoxaflutol</td>
<td>EU</td>
<td>1.3</td>
<td>112</td>
<td>0.02</td>
<td>60</td>
<td>0.0016</td>
<td>2150</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>mesotrione</td>
<td>EU</td>
<td>5</td>
<td>109</td>
<td>0.015</td>
<td>3</td>
<td>0.07</td>
<td>2000</td>
<td>11</td>
<td>438</td>
</tr>
<tr>
<td>pendimethalin</td>
<td>EU</td>
<td>90</td>
<td>15744</td>
<td>0.234</td>
<td>10</td>
<td>0.0003</td>
<td>1421</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>terbutylazine</td>
<td>Public</td>
<td>3.21</td>
<td>220</td>
<td>0.0022</td>
<td>10</td>
<td>0.000016</td>
<td>1000</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>bromoxynil</td>
<td>EU</td>
<td>4.5</td>
<td>173.5</td>
<td>0.01</td>
<td>10</td>
<td>0.00012</td>
<td>217</td>
<td>5</td>
<td>45</td>
</tr>
<tr>
<td>fluroxypyr</td>
<td>EU</td>
<td>34</td>
<td>51</td>
<td>0.8</td>
<td>10</td>
<td>1.23</td>
<td>2000</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>rimsulfuron</td>
<td>EU</td>
<td>7.2</td>
<td>49.0</td>
<td>0.07</td>
<td>10</td>
<td>0.54</td>
<td>2250</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>EU</td>
<td>12</td>
<td>884</td>
<td>0.2</td>
<td>3</td>
<td>7.29</td>
<td>2000</td>
<td>100</td>
<td>480</td>
</tr>
</tbody>
</table>

Key:

“DT50 = half-life (days)
Koc = adsorption coefficient (mg/g)
AOEL = acceptable operator exposure level (mg/kg body weight/day)
AbDE = dermal absorption factor (%)
MTC = maximal tolerable concentration (mg/l)
LD50-birds = lethal dose (mg/kg body weight)
LC50-earthworms = lethal concentration (mg/kg soil)
LD50-bees = lethal dose (lg/bee)” (Vercruysse and Steurbaut, 2002, Devos et al., 2008a)
7.4 Pesticide Occupational and Environmental Risk (POCER) Indicator Results

7.4.1 Human health:
Results from the POCER analysis (Table 7.7) show that, in terms of risk to human health, all but one of the herbicides currently recommended for use in conventional maize cultivation in Ireland have a higher risk to the pesticide operator than if glyphosate was used alone. Only Starane*2, the post-emergent herbicide containing the active fluroxypyr is considered less of a risk to pesticide operators. This is due to fluroxypyr’s relative high acceptable operator exposure level (AOEL) as fluroxypyr causes auxin-type responses in those weeds that are vulnerable to it (Anon, 1998). However, in Irish maize production fluroxypyr is rarely, if ever, used alone as normally a pre-emergent herbicide would also be applied. As such, any combination of the recommended pre-emergent herbicides used with post-emergent Starane*2 (i.e. fluroxypyr) on conventional maize would elevate the total combined risk to the pesticide operator over that of two glyphosate applications (one pre-emergent and one post-emergent) were used on GM glyphosate tolerant maize. Analysis also shows regimes and products containing terbuthylazin (e.g., Calaris) were shown to be of considerable high risk to both pesticide operators and farm workers. The risk to bystanders from the pesticide regimes examined was extremely small and temporary, resulting in 0 EF values. As a result, the overall human health risk was lower for glyphosate based regimes.
<table>
<thead>
<tr>
<th>Active</th>
<th>Application Rate (kg a.s./ha)</th>
<th>operator</th>
<th>worker</th>
<th>bystander</th>
<th>persistency</th>
<th>Ground water</th>
<th>surface water</th>
<th>birds</th>
<th>earthworms</th>
<th>bees</th>
<th>sum human</th>
<th>sum environment</th>
<th>Total (human + environment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>flufenacet</td>
<td>0.48</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.21</td>
<td>0.62</td>
<td>0.00</td>
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<td>0.00</td>
<td>1.00</td>
<td>0.83</td>
<td>1.83</td>
</tr>
<tr>
<td>isoxaflutol</td>
<td>0.10</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Cadou Star</td>
<td>sum</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.21</td>
<td>0.62</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>1.00</td>
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<td>1.83</td>
</tr>
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<td>0.91</td>
<td>0.00</td>
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<td>0.00</td>
<td>0.42</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.91</td>
<td>0.42</td>
<td>1.33</td>
</tr>
<tr>
<td>terbutylazin</td>
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<td>1.00</td>
<td>0.14</td>
<td>0.00</td>
<td>0.00</td>
<td>0.05</td>
<td>0.74</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.14</td>
<td>0.79</td>
<td>1.93</td>
</tr>
<tr>
<td>mesotrione</td>
<td>0.07</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Calaris 1 l/ha</td>
<td>sum</td>
<td>1.00</td>
<td>0.14</td>
<td>0.00</td>
<td>0.00</td>
<td>0.08</td>
<td>0.74</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>1.14</td>
<td>0.83</td>
<td>1.97</td>
</tr>
<tr>
<td>terbutylazin</td>
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<td>1.00</td>
<td>0.24</td>
<td>0.00</td>
<td>0.00</td>
<td>0.10</td>
<td>0.83</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.24</td>
<td>0.92</td>
<td>2.16</td>
</tr>
<tr>
<td>mesotrione</td>
<td>0.11</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Calaris 1.5 l/ha</td>
<td>sum</td>
<td>1.00</td>
<td>0.24</td>
<td>0.00</td>
<td>0.00</td>
<td>0.13</td>
<td>0.83</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>1.24</td>
<td>0.96</td>
<td>2.20</td>
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<tr>
<td>rimsulfuron</td>
<td>0.04</td>
<td>0.47</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.47</td>
<td>0.00</td>
<td>0.47</td>
</tr>
<tr>
<td>BROMOXYNIL</td>
<td>0.50</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.13</td>
<td>0.38</td>
<td>0.00</td>
<td>0.00</td>
<td>0.40</td>
<td>1.00</td>
<td>0.91</td>
<td>1.91</td>
</tr>
<tr>
<td>Titus + bromoxynil</td>
<td>sum</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.16</td>
<td>0.38</td>
<td>0.00</td>
<td>0.00</td>
<td>0.40</td>
<td>1.00</td>
<td>0.94</td>
<td>1.94</td>
</tr>
<tr>
<td>rimsulfuron</td>
<td>0.05</td>
<td>0.52</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.52</td>
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<tr>
<td>BROMOXYNIL</td>
<td>1.01</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.22</td>
<td>0.55</td>
<td>0.00</td>
<td>0.00</td>
<td>0.40</td>
<td>1.00</td>
<td>1.16</td>
<td>2.16</td>
</tr>
<tr>
<td>Titus + bromoxynil</td>
<td>sum</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.23</td>
<td>0.55</td>
<td>0.00</td>
<td>0.00</td>
<td>0.40</td>
<td>1.00</td>
<td>1.18</td>
<td>2.18</td>
</tr>
<tr>
<td>rimsulfuron</td>
<td>0.05</td>
<td>0.52</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.52</td>
<td>0.00</td>
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<tr>
<td>BROMOXYNIL</td>
<td>0.36</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.10</td>
<td>0.30</td>
<td>0.00</td>
<td>0.00</td>
<td>0.40</td>
<td>1.00</td>
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<td>1.79</td>
</tr>
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<td>BROMOXYNIL</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.16</td>
<td>0.42</td>
<td>0.00</td>
<td>0.00</td>
<td>0.40</td>
<td>1.00</td>
<td>0.98</td>
<td>1.98</td>
</tr>
<tr>
<td>FLUROXYPYR</td>
<td>0.29</td>
<td>0.28</td>
<td>0.00</td>
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<td>0.00</td>
<td>0.20</td>
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<td>0.00</td>
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<td>0.00</td>
<td>0.28</td>
<td>0.20</td>
<td>0.48</td>
</tr>
<tr>
<td>GLYPHOSATE</td>
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<td>0.60</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.20</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.60</td>
<td>0.20</td>
<td>0.80</td>
</tr>
<tr>
<td>GLYPHOSATE</td>
<td>1.10</td>
<td>0.64</td>
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<td>0.00</td>
<td>0.23</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.64</td>
<td>0.23</td>
<td>0.87</td>
</tr>
</tbody>
</table>
7.4.2 Persistence in the soil
All herbicide regimes (both in conventional and GM maize cultivation) studied had ‘persistency’ EF values of 0.00 indicating the very low persistence in the soil of the actives examined. This, as outlined by Devos et al., is because half-lives (DT50) (Table 7.6) of “active substances shorter than or equal to 90 days soil persistence are generally considered to be low” (Devos et al., 2008a, p1067). As shown in Table VI there is a considerable range of DT50 values (ranging from 1.3 [isoxaflutol] to 90 [pendimethalin]) within this ‘low’ category. It should also be noted that soil half-lives are can be impacted by local temperature, moisture and soil (Arias-Estévez et al., 2008).

7.4.3 Risk of ground and surface water pollution:
Every chemical applied to farmland has the potential to reach water bodies by numerous pathways. As explained by Garratt and Kennedy, the risk of water contamination is influenced by the combination of:

“leachable compounds, vulnerable soils, shallow groundwater and high product usage; surface water contamination from drains […] when heavy rain falls soon after application, […] and surface water contamination from drift when the distance between the spray boom and water body is small and product usage is high” (Garratt and Kennedy, 2006, p1138).

For the herbicide regimes examined, POCER derived ER values for ground water and surface water were calculated (Table 7.7). All but one of the currently recommended herbicide products for Irish maize cultivation had a higher combined risk value (EF) to ground water and surface water when compared to glyphosate (EF=0.20). Only Starane*2, which contains the active fluroxypyr, has a combined value (EF=0.20) for risk to ground and surface water equal to that of the glyphosate applied at the lowest level. However, as Starane*2 is only recommend for use on post-emergent maize a pre-emergent product would also have to be used in addition. None of the recommended pre-emergent actives have a lower combined risk to ground and surface water than glyphosate used at a low rate as a post and pre-emergent...
control method. Other herbicide products examined had combined ground and surface water EF values ranging from a high of EF=0.96 for Calaris (terbuthylazin + mesotrione) to EF=0.42 for Stomp 400 (pendimethalin). Our results confirm the findings of other studies (Mamy et al., 2005, Wauchope et al., 2002, Devos et al., 2008a, Giesy et al., 2000, Shipitalo et al., 2008, Screpanti et al., 2005, Kleter et al., 2008) and show glyphosate used alone via GM glyphosate tolerant maize cultivation could lower the risk to ground and surface water when compared to current recommended herbicide regimes for Irish maize cultivation.

The low EF value obtained for glyphosate is due in part to the fact the assessments and modelling of glyphosate transport show it is subject to high sorption in the soil matrix and high levels of degradation in soil due to the action of microbes (Klier et al., 2008). As a result, the risk of leaching believed to be low (Klier et al., 2008, Vereecken, 2005). Borggaard and Gimsing point out that in non-structured sandy soils give way to that limited leaching while in structured soil types “subsurface leaching to drainage systems was observed in a structured soil with preferential flow in macropores, but only when high rainfall followed the glyphosate application” (Borggaard and Gimsing, 2008, p441). Research examining leaching of glyphosate in boreal (low P) sandy soil found that 0.51% of the original glyphosate applied leached while 0.07% of aminomethyl phosphonic acid (AMPA) glyphosate’s metabolite leached (Kjær et al., 2005) and glyphosate residues and AMPA were not found in subsurface drain flow from boreal sandy soil studied in Finland (Laitinen et al., 2009). Recently, by using ultra-sensitive analysis methods glyphosate has been detected in groundwater in the Spain (Catalonia region) (Sanchís et al., 2011).

Another factor for glyphosate’s lower risk to water systems is its low acute toxicity to fish, Daphnia and algae which was reflected in the calculated EF value of 0.0 for acute risk to aquatic organisms. As highlighted by Cerdeira and Duke, glyphosate is one of only nine synthetic herbicides approved for use in aquatic sites in the U.S.A. as it has been shown to be relatively safe for usage in such environments. (Cerdeira and Duke, 2006). This is underpinned by Devos et al. who state, that according Solomon an Thompson (Solomon and
Thompson, 2003), the “risk to aquatic organisms from glyphosate is negligible or small at application rates <4 kg GLY ha⁻¹” (Devos et al., 2008a, p1067). This is due to the evidence that when in surface water, glyphosate is known to disperse quickly when compared to the majority of other herbicides (Solomon and Thompson, 2003). An analysis carried out by Struger et al. over two years, found that in surface waters in southern Ontario, Canada, where glyphosate tolerant crops are grown commercially and glyphosate applied,

“no samples out of a total of 502 samples showed concentrations exceeding the Canadian Water Quality Guideline for glyphosate of 65 lg a.e./L which is considered protective of aquatic life. Typical surface water concentrations of glyphosate as measured in amphibian habitats in this study (99% CL\21 lg a.e./L) are well below a variety of toxicity thresholds for aquatic organisms and thus unlikely to pose a substantial risk to either sensitive amphibian larvae or other aquatic biota in these systems” (Struger et al., 2008, p383).

Field research has also shown that Roundup™, the commercial formulation which used glyphosate as an active has had no impact on fish in studied sites in China (Tsui and Chu, 2008). Previous research in Ireland has used Roundup™ on a main Irish river (River Boyne) as it was approved for use in and around watercourses (Caffrey, 1996).

According to Mamy et al., the overall risk of ground and surface water contamination by glyphosate seems to be mitigated due to the three main factors (1) soil minerals with variable-charges (e.g. iron-oxides), (2) degradation by soil microbes and (3) glyphosate’s low acute risk to aquatic fauna. However, as discussed previously, while many factors could impact glyphosate’s mobility in soils, local soil structure and rainfall are the most important variables (Mamy and Barriuso, 2007, Mamy et al., 2005). Nevertheless, research has also shown that derivatives of glyphosate can be found to be more mobile (Mamy et al., 2008). In addition, some commercial glyphosate formulations have been found to have greater toxicity to organisms in aquatic environments than glyphosate itself (Folmar et al., 1979) as these
formulations can contain a number of different surfactants with varying degrees of aquatic toxicity (Dill et al., 2010).

7.4.4 Acute risk to birds, bees and earthworms

Results of the POCER analysis show that all but one currently used herbicide actives recommended for Irish maize cultivation pose a very low risk of acute toxicity to invertebrates and birds. The regimes utilising bromoxynil are however considered medium risk to bees (EF=0.4) as bromoxynil has a relatively low lethal dose for bees (see LD50-bees in Table 5). The general low toxicity of the other currently used herbicides reflect a move since the nineties to use active ingredients that have superior (eco)toxicological profiles (Devos et al., 2008a). On a toxicology basis glyphosate compares favourably with currently recommended herbicide actives as it has a very high lethal dose level for birds and bees. According to Duke and Powles, glyphosate “is one of the least toxic pesticides to animals” (Duke and Powles, 2008, p320) while Dill et al. state that glyphosate shows “no evidence of carcinogenicity, mutagenicity, neurotoxicity, reproductive toxicity, or teratogenicity” (Dill et al., 2010, p15). However, Dill et al. go on to point out that some of the formulation materials used glyphosate based preparations can be more toxic than the glyphosate itself. It should be noted that the POCER analysis carried out here only examines the active components of the herbicides in question. As a result other compounds in the formulation are not analyzed from a risk perspective. For example, in certain commercial preparations of Roundup™, polyoxyethylene amine (POEA) is also used as a surfactant which in itself can be more toxic than glyphosate (Relyea, 2005).

7.4.5 Overall results for environmental and human risk:

In Table 7.8, a full list of herbicide regimes currently recommended for Irish maize cultivation is compared to that of a list of possible herbicide regimes for use in GM glyphosate tolerant maize cultivation. Based on the individual environmental and non-dietary human health risk indicators assessed and the calculation of POCER exceedence factor (EF) our results indicate that the use of glyphosate only regimes in Irish maize cultivation (enabled by the cultivation of GM glyphosate tolerant maize) would lower the risk to the environment and human health.
when compared to currently recommended herbicide actives for maize production in Ireland (Figure 7.4). The results confirm that, within an Irish maize production context, the use of GM HT crops as Kleter suggests about GM HT crops in general, “*may provide alternative weed management options with potential significant and positive effects on the environment if applied under the appropriate conditions*” (Kleter *et al.*, 2008, p487).

*Table 7.8: POCER EF Values of herbicide regimes used in Irish conventional maize production and possible GM glyphosate tolerant maize*

<table>
<thead>
<tr>
<th>Regime</th>
<th>Product Name</th>
<th>Product dose P, L/ha</th>
<th>POCER EF of Active(s)</th>
<th>Total Product POCER EF Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Covered Cultivated</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PreA</td>
<td>PDM 330</td>
<td>4.5 L/ha</td>
<td>1.33</td>
<td>1.33</td>
</tr>
<tr>
<td>PreB</td>
<td>PDM 330 + Calaris</td>
<td>4.5 L/ha + 1.0 L/ha</td>
<td>1.33 + 1.97</td>
<td>3.3</td>
</tr>
<tr>
<td>PreC</td>
<td>PDM 330 + Cadou Star</td>
<td>4.5 L/ha + 0.75 kg/ha</td>
<td>1.33 + 1.83</td>
<td>5.36</td>
</tr>
<tr>
<td>Followed by 1.5 l/ha Calaris (between rows of plastic 4 weeks after sowing)</td>
<td>1.5 l/ha</td>
<td>2.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Open Cultivated</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OpenD</td>
<td>Calaris</td>
<td>1.25-1.5 L/ha</td>
<td>1.33</td>
<td>2.20</td>
</tr>
<tr>
<td>OpenE</td>
<td>PDM 330 + Cadou Star</td>
<td>4.5 L/ha + 0.75 kg/ha</td>
<td>1.33 + 1.97</td>
<td>2.16</td>
</tr>
<tr>
<td>OpenF</td>
<td>Callisto + PDM 330</td>
<td>1.5 L/ha + 2.5 L/ha</td>
<td>1.33 + 1.83</td>
<td>1.73</td>
</tr>
<tr>
<td><strong>Follow – up treatments (normally required)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow1</td>
<td>Bromptril P</td>
<td>1.5 L/ha</td>
<td>2.16</td>
<td>2.16</td>
</tr>
<tr>
<td>Regime</td>
<td>Product Name</td>
<td>Product dose</td>
<td>POCER</td>
<td>Total Product POCER EF Value</td>
</tr>
<tr>
<td>--------</td>
<td>--------------</td>
<td>--------------</td>
<td>-------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Follow2</td>
<td>Titus + Agral</td>
<td>50 g/ha+ 0.1%</td>
<td>0.52</td>
<td>0.52</td>
</tr>
<tr>
<td>Follow3</td>
<td>Starane2</td>
<td>1.0 L/ha</td>
<td>0.48</td>
<td>0.48</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GM Glyphosate Tolerant Maize Herbicide Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gly1</td>
</tr>
<tr>
<td>Gly2</td>
</tr>
<tr>
<td>Gly3</td>
</tr>
<tr>
<td>Gly4</td>
</tr>
<tr>
<td>Gly5</td>
</tr>
<tr>
<td>Gly6</td>
</tr>
<tr>
<td>Gly7</td>
</tr>
<tr>
<td>Gly3+A</td>
</tr>
<tr>
<td>Gly3+B</td>
</tr>
<tr>
<td>Gly3+C</td>
</tr>
</tbody>
</table>

(Table 7.8 continued)
Figure 7.4: Comparison of POCER Exceedence Factors for GM glyphosate tolerant and Conventional Maize Herbicide Regimes
7.5 **Agronomic analysis:**
For agricultural technologies to be adopted they need to offer producers an incentive. Such incentives can include direct financial benefits (e.g. input cost savings), ease of use, improved efficacy, etc. However, as suggested by Weaver, the profitability of HT crop technologies, depend on a host of local factors (e.g. local weather conditions, planting history, local market conditions, etc.) (Weaver, 2004). As a result, this segment of this research examines the potential agronomic impact of using GM glyphosate tolerant maize for Irish producers of forage maize. Using an analysis method described in Flannery *et al.*, 2005 (Flannery *et al.*, 2004) an ex-ante quantitative agronomic costs and benefits analysis of GM HT maize cultivation compared to current Irish maize production was undertaken. As there are a range of possible glyphosate regimes possible using the GM glyphosate tolerant maize our analysis considers both a high cost and low cost glyphosate option.

7.4.1 **Model assumptions:**
In comparing both the GM glyphosate tolerant maize scenario and the current conventional maize scenario all figures used are based on prior work by O’Mahony that gives crop production data for Ireland (Table 7.9). This work includes variable costs and certain key elements of fixed costs such as “*materials (seed, fertilizers, herbicides, fungicides, insecticides, growth regulators), machinery hire (plowing, tilling, sowing, spraying, fertilizer spreading, harvesting), and miscellaneous costs (interest [7%] and transport)*” (O’Mahony, 2009, p1, O’Mahony, 2008, p1).
Table 7.9: Costs and returns of Irish forage crops in 2009

<table>
<thead>
<tr>
<th></th>
<th>Fodder Beet</th>
<th>Swedes</th>
<th>Kale</th>
<th>Rape</th>
<th>Stubble Turnip</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials</strong></td>
<td>811</td>
<td>455</td>
<td>352</td>
<td>230</td>
<td>193</td>
<td>633</td>
</tr>
<tr>
<td>Seed</td>
<td>128</td>
<td>80</td>
<td>102</td>
<td>30</td>
<td>78</td>
<td>200</td>
</tr>
<tr>
<td>Fertilisers</td>
<td>410</td>
<td>215</td>
<td>250</td>
<td>200</td>
<td>115</td>
<td>370</td>
</tr>
<tr>
<td>Sprays:</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbicides</td>
<td>180</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>63</td>
</tr>
<tr>
<td>Fungicides</td>
<td>35</td>
<td>35</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Insecticides</td>
<td>58</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Hire Machinery</strong></td>
<td>633</td>
<td>229</td>
<td>158</td>
<td>158</td>
<td>142</td>
<td>539</td>
</tr>
<tr>
<td>Seedbed Prep + sow</td>
<td>210</td>
<td>175</td>
<td>140</td>
<td>140</td>
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<td>185</td>
</tr>
<tr>
<td>Sprayer</td>
<td>72</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td>Fertiliser Spreading</td>
<td>36</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>Harvesting + covering</td>
<td>315</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td><strong>Total Variable Costs</strong></td>
<td>1444</td>
<td>684</td>
<td>510</td>
<td>388</td>
<td>336</td>
<td>172</td>
</tr>
<tr>
<td><strong>Green Yield (Tonnes/ha)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaves (+roots)</td>
<td>124</td>
<td>74</td>
<td>37</td>
<td>42</td>
<td>25</td>
<td>55</td>
</tr>
<tr>
<td><strong>Dry Matter (Tonnes/ha)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UTILISED</td>
<td>13.0</td>
<td>5.2</td>
<td>4.0</td>
<td>3.5</td>
<td>2.5</td>
<td>12.5</td>
</tr>
<tr>
<td><strong>COST (Euro/Tonne DM)</strong></td>
<td>111</td>
<td>132</td>
<td>128</td>
<td>111</td>
<td>134</td>
<td>94</td>
</tr>
</tbody>
</table>

*Source: (O’Mahony 2009)*

An additional seed cost for GM cultivars could be a technology fee for HT maize set at €15/ha for Europe (Demont et al., 2008) but this technology fee was removed from GM glyphosate tolerant maize seed in 2005 in all other markets where it is commercially planted. A further additional cost in the cultivation of GM HT crops could be the requirement to pay a co-existence fee of approximately €25/ha on all GM crops grown (Flannery et al., 2004). It is envisaged that such a fee would be used create a fund to compensate for contamination damages to non-GM crops (Beckmann et al., 2006, Devos et al., 2009). However, in Ireland, no regulations or structures yet exist to determine how and when such compensation would be paid (Koch, 2007). Overall, the potential GM specific cultivation costs amount to approximately 40€/ha (GM seed premium cost [€15/ha extra] and a co-existence fee [€25/ha extra].
Generic forms of the herbicide active glyphosate on the Irish market result in a broad range of pricing options for Irish farmers; from brand named products (~8€/L in 2009) to generic formulations (~4€/L in 2009). This is reflective of the fact that as patents on glyphosate (the herbicide molecule itself) terminate, generic versions of glyphosate products will appear more frequently on the market thus leading to a likely reduction in the price of glyphosate due to competition. According to Dill, this reduction in price is considered a potential driver in the adoption of glyphosate-resistant crops (Dill, 2005). A zero GM yield gain scenario was assumed as there is no yield increase expected from GM HT maize (Brookes, 2005). Reduced till farming practice savings were not included as they are unlikely to apply to Irish maize production.

7.6 Agronomic Analysis Results

Analysis shows that in the case of GM glyphosate tolerant maize being cultivated in Ireland in a low glyphosate cost scenario, the reduction in spray costs (via a lowering of herbicide costs), combined with the additional GM costs would result in a cost saving of €4.62/ha (0.39%), representing a 0.35% increase in gross margin (Table 7.10; Figures 7.5 and 7.6). However, in a high glyphosate cost scenario there was an additional cost of €29.5/ha (2.54%) representing a 2.21% decrease in gross margin (Table 7.10; Figures 7.5 and 7.6). The combined cost of a GM co-existence fee and a GM seed premium (€40/ha) was key as results suggest GM glyphosate tolerant maize production could be as competitive as conventional methods but benefits in a high glyphosate cost scenario would be eroded if a co-existence fee and GM seed price premium together exceeds €29.5 per hectare (Figures 7.5 and 7.6, shaded segments of bars).
Table 7.10: Comparison of total Conventional and GM glyphosate tolerant maize production cost and profit margins

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>GM</th>
<th>GM vs. conventional</th>
<th>Diff</th>
<th>Saving/ (cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2008</td>
<td>2009</td>
<td>AVG</td>
<td>2008</td>
<td>2009</td>
</tr>
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<td>52.5</td>
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|                          |                   |                          |                   |       |              |
| **Maize low cost spray scenario (2.5L + 1.25L ha\(^{-1}\) application + generic glyphosate priced at avg 4€/L in 2009 and 5€/L in 2008)** |        |        |       |        |              |
| Yield (t/ha)             | 52.5   | 52.5   | 52.5  | 52.5   | 52.5   | 52.5  | 0                  | 0    | 0             |
| Price (euro/t)           | 45     | 50     | 47.5  | 45     | 50     | 47.5  | 0                  | 0    | 0             |
| Output                   | 2362.5 | 2625   | 2493.75 | 2362.5 | 2625   | 2493.75 | 0                  | 0    | 0             |

355
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<th>Seed</th>
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<tr>
<td>Other costs</td>
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</tr>
<tr>
<td><strong>Total costs</strong></td>
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<td><strong>1172</strong></td>
<td><strong>1160</strong></td>
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<tr>
<td>Gross margin</td>
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<td>2008</td>
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<td>2009</td>
<td>AVG</td>
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<tr>
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<th>GM</th>
<th>GM vs. conventional</th>
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(Table 7.10 continued)
Figure 7.5: Total cost of planting conventional vs GM glyphosate tolerant maize

![Total cost of planting conventional vs GM glyphosate tolerant maize](image)

- Indicates €40 joint cost of GM seed premium and co-existence fee.
Results show cultivation of GM GLY tolerant maize under Irish conditions could decrease key environmental risks compared with current conventional maize production if producers used GLY only regimes. From both a non-dietary human health and environmental impact perspective GLY only regimes, enabled by the cultivation of GM GLY tolerant maize, could provide for an overall lower pesticide risk profile in Irish maize production. The overall human health risk was found to be reduced for herbicide regimes that used only GLY as an active when compared to the other conventional regimes analyzed. While all indicators are relative and suffer from specific weaknesses thus none are perfect (e.g. POCER only considers the risk of the pesticide actives and does not take account of the biological risks of surfactants
chemicals that could be contained in the commercial formulation of the marketed product) our results show GLY only regimes could lower the risk to ground and surface water when compared to current recommended herbicide regimes for Irish maize cultivation. Using GLY only regimes in the cultivation of GM maize would have no added acute risk to birds, bees and earthworms. Questions of impact on overall biodiversity from production of GM GLY tolerant maize can only be determined via fields trials as growing conditions, in-field seed banks, site flora and fauna are all highly local-specific variables that would be impacted by herbicide regimes changes and resulting weed shifts. For example, field trials in the province of Spain have shown that the number of arthropods, especially spiders and springtails, is greater in fields planted with GM GLY tolerant maize (NK603) where GLY is applied as a post-emergent spray compared with plots of a comparable conventional variety grown with conventional tilling and herbicide use (Morris and Adley, 2001).

While results show that from an Irish maize cultivation perspective clear environmental benefits could be accrued from employing GM GLY tolerant maize cultivars (Figures 7.4 & 7.5) questions regarding the agronomic benefits remain. Analysis shows that, notwithstanding the fact the cost of GLY is a factor in determining the agronomic impact of cultivating GM GLY tolerant maize, the two key variables limiting financial benefits will be (1) the premium charged on GM seed and (2) the costs of any proposed co-existence fee. The findings suggest GM GLY tolerant maize production could be slightly more competitive than conventional methods in a low GLY cost scenario but benefits in a high GLY cost scenario would be eroded if a co-existence fee and GM seed price premium together exceeds €29.5 per hectare.

7.8 Conclusions
Results from this study support the proposal that GM HT crops resistant to herbicides (such as GLY) could be highly suited to the Irish agri-environment (O’Brien and Mullins, 2009). Evidence indicates that GM GLY tolerant maize is a worthwhile candidate for field trial study in Ireland which would allow greater quantification of the projected environmental benefits and agronomic impacts under Irish growing conditions. In addition, field trials would allow
for the determination of the optimal herbicide regimes and application rates for Irish conditions and examination of possible benefits of increased weed control flexibility in Irish maize production that could be attained by the addition of a new weed control strategy via GM GLY tolerant technology. Field trials, carried out over a multi-year period, would also allow for determination the best rotation options to be used with GM GLY tolerant maize and would produce local biosafety data. Such information gleaned from experimental field trials is important as the use of a broad efficacy spectrum herbicide, such as GLY, can have variable efficacies depending on the weed species and weed growth stages encountered locally. As with any herbicide, the value (both from an environmental and an agronomic perspective) of GLY can be preserved only by proper management. Therefore, research and the resulting guidance pertaining to the use of GM HT technology within Irish conditions are essential to preserving the long-term benefits of this technology.
Conclusions

“The risks that hurt people and the risks that upset people are almost completely unconnected”

Peter M. Sandman, Risk Communications Consultant, as quoted in New York Times article by Henry Fountain, January 15, 2006

Human efforts to control the level, efficiency and quality of food production date back to the dawn of civilization. The use of plants in food and fibre production today forms the foundation of our society. Modern plant science applied at the molecular genetic level to plant breeding is the most recent effort in this long tradition. This effort is the culmination of work in the last four decades in the development and the application of plant science and modern biotechnology (e.g. recombinant DNA technology) in this area. Scientists can now control the expression of traits in plants such as enhanced quality, improved pest resistance, better agronomic advantages, and can produce new substances such as plastics and new bioactives for pharmaceutical applications.

These biotechnological innovations, while carrying great benefits, also raise numerous concerns. Questions have been raised regarding almost all aspects of these innovations, including (but certainly not limited to); Is the resulting food safe to consume? How will these biotechnologies affect our health and the environment? What are the economic ramifications of having corporations own the knowledge necessary to achieve these benefits? Can these developments harm the ‘natural evolution’ of species on our planet? Are we “playing God”? These concerns and others have led to heated public/political debates in many countries and even violent/illegal acts in some. They have also made the shaping of public policy and
resulting regulation in this area an on-going political issue, posing multifaceted challenges for many governments and politicians.

Since much of the debate surrounding the introduction of modern plant biotechnology, and specially recombinant DNA technology, into agriculture and food production has been framed in terms of risks and benefits, it has become necessary to develop complex mechanisms for risk-management (i.e. what to do about the risk). Four categories of risk have been identified and explored well in the literature in this area: risk to human health; risk to the environment; socio-economic risk; and ethical/moral risk. However, a crucial fifth category must be taken into account, which is ‘biopolitical’ risk. This is the risk of the politicization of modern biotechnology and its political impacts within the political stream (which can influence public policy at local, national, and international levels). While not as publicly acknowledged as the other four risk categories, biopolitical risk must also be managed and mitigated. Questions arising from the risk-management of modern plant biotechnology within the biopolitical sphere are at the core of this thesis and underlie the approach and research undertaken.

In Ireland, these questions have unique importance and must be considered in the specific context of an island whose economy heavily relies on agriculture, with a proclaimed ambition to promote a knowledge-based economy. Being situated in the European Union, where biotechnologies related to genetic modification of crops and food have met with extremely strong resistance and even rejection, Ireland, as an EU member state must also take into account the EU regulatory and policy dynamics. However, the need to improve Irish agriculture in a sustainable manner while ensuring that Irish agri-food production is competitive globally means that Ireland should have - in its own right - a solid, coherent and forward looking policy approach to dealing with modern plant biotechnology.

This thesis therefore examines the following questions: what shapes plant biotechnology risk management policy in Ireland and how has the policy developed? What can be learned and understood in order to develop an improved national policy approach to modern plant
biotechnology? To answer this question, this study explores a set of complex issues, in an attempt to gain insight into various aspects of the question.

The first aspect is the science behind these innovations. To fully comprehend the benefits and the risks offered by plant biotechnology, one must ask in what ways this technology actually differs from more traditional methods of breeding. Defining these elements in a policy oriented manner allows us to understand in what ways this technology frames risks and how such framing could be considered in light of the new benefits it offers. Chapter 1 therefore offers an introduction by examining the evolution of plant breeding and the term ‘biotechnology’ in order to place them in a historical context. This allows an understanding of the framing of these issues which is of importance since framing often establishes the science-policy relationship and influences the way this relationship evolves.

Chapter 1 proceeds to demonstrate that ‘genetic modification’ is not a new notion. Rather, humans have long been involved and invested in this endeavor, which has become increasingly more complex and technical over time, culminating in the modern plant breeding technologies of our time. Consequently, a new set of policy oriented definitions that describe plant biotechnology are developed and proposed. Such definitions can be used in the policy arena as the basis for key tools, such as risk assessment, risk management, risk communication and science communication.

A second aspect is the policy making process as it relates to modern plant biotechnology both in Ireland and at the EU level. In order to understand how related issues and risks are managed, one must understand how public policy is developed and how and why it evolves overtime. Chapter 2 addresses these questions. The analysis of the development and evolution of public policy over an extended period of time requires a theoretical framework. A theory of policy evolution/change can offer conceptual tools and practical methods (such as diagnostic and prescriptive inquiry) that are applied to a specific issue or context (in this case, the evolution of Irish and EU policy relating to modern plant biotechnology by using recombinant
DNA as an example), allowing a structured analysis. This permits insights into why public policy and its outputs evolve, stay fixed, vary between sectors, and differ in terms of their impacts on various publics. Following the introduction of the theoretical framework, chapter 2 proceeds to offer a detailed description of the evolution of public policy in Ireland (between 1974 and 2011) and the EU (between 1973 and 2011). Results show that in the case of Ireland the policy model of punctuated equilibrium is at play, expressed by long periods of stability, punctuated by sudden shifts that are characterized by radical change mainly driven by political considerations. In case of the EU, results show that its policy and related regulatory mechanisms are dysfunctional and probably unsustainable, but cannot be easily described as fitting a punctuated equilibrium model.

The third aspect that needs to be addressed in order to explore the optimal way to risk-manage plant biotechnology in Ireland, is the attitude of the Irish public. In a modern democracy, public attitudes greatly influence the shaping of public policy and therefore play a crucial part in determining the best approaches to risk management. It is therefore vital to explore the attitudes of the Irish public towards plant biotechnology as they evolved over time. Chapter 3 offers such an analysis. It presents the theoretical framework for the analysis of public attitudes, a review of studies and surveys that explored Irish public attitudes towards biotechnology between 1989 and 2010 (with a focus on transgenic plants/food), followed by an extensive longitudinal analysis of Irish results from the Eurobaromter studies. This longitudinal analysis is based on data derived from five surveys carried out between 1991 and 2010 inclusively, covering over 5,000 respondents and on the analysis of data regarding phone calls received by the Food Safety Authority of Ireland between 2000 and 2010.

The analysis reveals a number of interesting patterns, shedding light on the fact that levels of awareness of modern biotechnology in Ireland have grown over time while levels of scientific literacy in the context of GM technologies have been low and improved only slightly since 1996. In general terms, the Irish remain relatively optimistic about modern biotechnology, while animal cloning and genetically modified food seem to attract little support from the Irish
public at the present time. Finally, it is shown that the Irish publics’ responses in the Eurobarometer surveys are consistently characterized by high levels of ‘don’t know’ responses in the area of modern biotechnology (and specifically plant biotechnology). This provides evidence that - contrary to the deficit model - it is possible to have strong support without knowledge (as was the case prior to 1999 in Ireland) and also to have low support with knowledge (as evident in the 2005 and 2010 results). It is hoped that this analysis will provide a better basis for science communication strategies in the future.

Moreover, to fully comprehend the shaping and the evolution of public attitudes, one must explore the key factors that influence these attitudes. While time and research constraints made it impossible to examine all these key factors, this research focused on two of the most important ones: print media and expert opinion. These elements are addressed in chapters 4 and 5. Chapter 4 offers both an intensity analysis of the number of modern plant and agri-biotechnology related articles that appeared in the Irish Times from 1996 to mid-2010 and a content analysis, covering reports on agri-biotechnology in Ireland’s top three daily newsprint publications between 2007 and 2010. Results from the Irish Times intensity analysis show that the number of articles covering this issue has significantly reduced from a peak in 1999 (corresponding with a period of significant shift in public attitudes and EU policy towards GM food and plants) and has reached its lowest levels over the period analysed (1996 to 2010). The content analysis of the three main daily newspapers shows that the majority of articles were found to be neutral or balanced (47.4%), while 27% had a positive tone and 25.6% a negative tone. The citation of risk in the articles examined (32.9%) occurred less frequently than benefit (39%). While issues regarding animal feed were the most frequently cited topic in the articles examined, there is evidence that the politicisation of the GM issue was a key driver. EU bodies, anti-GM NGOs and Government bodies occupied the top three actors cited. It was also found that different newspapers employed different framings. The articles published by the Irish Times had a more ethical frame, as opposed to the market and policy framings employed by the Irish Examiner and the Irish Independent.
Chapter 5 proceeds to explore the role that expert opinion plays in shaping public attitudes and in influencing public policy. First, a literature review is presented regarding expert opinion and its role in the policy process. Second, quantitative surveys are used to measure the attitudes of Irish university-based life scientists toward modern plant biotechnology (including recombinant DNA technologies) in 1999 and 2008. Results from both surveys - and a comparison between the two - allow a comprehensive in-depth view of expert attitudes and their evolution over time. Results show that Irish university life scientists’ attitudes to GM technology are context dependent, but generally very supportive of continued research in this area. A key area of change, reflecting a shift in respondents’ attitudes, is the decreased level of respondents’ health concerns regarding GM food. Their attitudes towards the quality of media coverage of GM related issues is consistently negative and they tend to trust their own peer group. However, Irish life scientists’ attitudes, like those of the public, can be strongly influenced by core psychometric factors. This shows that expert opinion is dynamic in nature and is not uniquely different from public opinion in terms of the forces that can influence it.

A case study, presented in Chapter 6, was carried out on the animal feed industry in Ireland, which is a key section in the innovation value-chain due to its unique location linking plant products and food products (i.e. meat and dairy) along the food chain. The feed industry plays a pivotal role in the Irish economy, which relies heavily on cattle production. Data gleaned from seven qualitative phone interviews carried out with members of the Irish feed industry during 2011 are analysed in chapter 6. This analysis sheds light on key problems of the current policy approach. These problems are categorized into the areas of economic, technological, legal and political. Interviewees highlight difficulties such as remaining competitive in the global market; the inflexibility of regulations and their disconnection with actual risk, communicating effectively with their clients about their needs and preferences; and the negative attitude of certain Government members. These results clearly indicate the important role ‘biopolitics’ play at the science-policy interface and the reframing power it has on the value chain.
The outcome of the multi-perspective and multi-layered analysis offered in chapters 1 through 6 is a synthetic view of the Irish context and a comprehensive understanding of the complex factors one needs to take into account in order to assess the best way to risk-manage plant biotechnology in Ireland. Taking all these factors into account, what emerges is a clear vision of an improved approach to risk-management in the Irish context. Currently, the Irish policy approach is based on a distinction between GM and non-GM methods of production as reflected in the EU’s regulatory approach. However, this approach leads to inconsistency in the evaluation of the risks and benefits of modern plant biotechnology.

To resolve many of the difficulties that stem from this approach, it is proposed to adopt a policy approach that focuses on the product, rather than on the process by which this product is produced. The assessment of plant traits and the evaluation of the risks and benefits resulting from their introduction into the agri-food system, should be carried out in the context of equivalent products and practices. Such a contextual and relative risk assessment should look at the full range of risks and benefits in comparison to currently available products and practices; current health and environmental risk/benefits; current cost-benefit analysis in current production; social acceptance; political issues and ethical/moral concerns. In particular, this policy approach would have ‘biopolitical’ benefits. It would allow decision-makers to have greater reach and flexibility in framing and communicating risk mitigation options pertaining to novel products derived from an ever growing range of plant biotechnologies. These benefits will result from framing risk management in terms of comparative risk and benefits of the plant trait in question, rather than the process by which the trait was produced.

To demonstrate this proposed policy approach in action, a second case study is offered in chapter 7. The chosen case study is that of maize production in Ireland. Maize is an important source of animal feed in Ireland and is thus a key element of the Irish agri-food chain. Maize is a crop for which GM varieties could soon be available in Ireland. These GM maize varieties are likely to be herbicide (glyphosate) tolerant in nature. The analysis offered in chapter 7
demonstrates how a product-based approach that assesses risks and benefits appropriately by taking into account current products and practices, can put the new product in context from a risk management perspective. It also demonstrates why this is much preferable to a process-based approach that simply examines the risks of an innovative plant biotechnology in isolation and out of the appropriate context. Based on this proposed approach, chapter 7 employs an *ex-ante* environmental and agronomic analysis of the risks and benefits of GM herbicide (glyphosate) tolerant maize, comparing it with current non-GM maize production in Ireland. The results of this analysis show that GM herbicide maize could decrease key environmental risks compared with the use of glyphosate-only regimes and that it could even be slightly more competitive.

In conclusion, in light of the fundamental importance of integrating modern plant biotechnology appropriately and effectively into the Irish economy, this study offers a multi-disciplinary analysis of the various key elements involved in the risk-management of modern plant biotechnology. In response to the question “what is the best way to risk-manage plant biotechnology in Ireland” it offers some key recommendations for a policy approach that is evidence-based, comprehensive, contextualized, and takes into consideration biopolitical risk. These recommendations include:

- Employing new definitions of plant biotechnology in the policy arena that better put modern plant biotechnology into context from a risk management perspective.

- Acknowledging and incorporating the important role of ‘biopolitical’ risk in risk management approaches to plant biotechnology.

- During periods of relative political stability Ireland should design and implement a review of policy towards the risk management of modern biotechnology that will be open, transparent and forward looking.
• Serious consideration should be given to moving to a product-based risk management approach, which would be more sustainable in the long term in the face of advancing science and technology.

• Developing and implementing innovative methods of science communication that rely on long term engagement strategies (e.g. employing targeted social marketing techniques). One stream should focus on modern plant biotechnology.

• The Irish print media and Irish scientists should develop joint training initiatives at both the academic and the professional level to allow professional exchange and to build bridges across the different disciplinary cultures.

• Irish science students need to have greater and better focused training/education to understand the policy process and how to work at the science-policy interface (e.g. development of a university level science-policy course, second level science-policy curriculum units for the classroom, and fellowships for work experience programs that place scientists in Irish policy areas).

• Value Chain Impact Assessments should be developed and employed as foresight exercises to consider impacts of new innovative technologies on the entire value chain (from laboratory bench to retail shelf) before their introduction at the early stage of technology development.

Finally, future research directions recommended in light of the outcomes of this study include:

• A content analysis of the political record in Ireland regarding plant biotechnology over time (using the data from the Houses of Parliament).

• Qualitative research examining past decision-makers’ attitudes and insights into how the issue of modern plant biotechnology has been managed in Ireland and lessons learned.
• Research to examine the attitudes and insights of other key groups in the agri-food value chain regarding modern plant biotechnology and its related innovations (e.g. farmers, retailers, etc.)

• Analysis of whether and how the findings of this research could be applied to other areas (e.g. nanotechnology) to allow lessons learned regarding risk management policy in the plant biotechnology area to be applied elsewhere.
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Appendix A:
Irish Life Scientist Survey

Dear Madam/Sir,

As part of ongoing research conducted by the Genetics & Biotechnology Lab (hyperlink: www.ucc.ie/spillane) at University College Cork we are carrying out a survey of Irish university scientists on the issue of plant biotechnology. This research is conducted as a component of a TEAGASC funded research project.

Please take some time to fill out the following survey (approx. completion time is 9 minutes). After completion of the survey you will have the opportunity to select a charity to which a donation (£5.00) will be made.

The information gathered will be completely confidential and will be used by UCC for research purposes only. It may be used for published research but no individual data will be identifiable in any publications or other materials arising from the research.

If you have any questions or concerns regarding the research please feel free to contact me at shane.morris@student.ucc.ie

Thank you for your time and help with this project.

Kindest regards,
Shane Morris, Science Policy Researcher, Genetics & Biotechnology Lab

&

Charlie Spillane, Principal Investigator, Genetics & Biotechnology Lab

**1. Please enter your age in the box below:**

**2. Please indicate your sex by clicking on one of the circles below:**
- Male
- Female

**3. Please indicate the highest qualification you currently hold:**
- Doctorate
- Masters
- Bachelor's

**4. Are you currently employed by an Irish University as academic faculty:**
- Yes
- No

5. Please describe your area of expertise:
6. Do you have concerns regarding genetically modified (GM/GE) food? (i.e. food produced using recombinant DNA technology)

☐ No
☐ Yes

7. Please indicate the nature of your concerns regarding GM food

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<tbody>
<tr>
<td>Environmental concerns</td>
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<tr>
<td>Health concerns</td>
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<tr>
<td>Socio-economic concerns</td>
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<tr>
<td>Ethical concerns</td>
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<tr>
<td>Other concerns</td>
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<tr>
<td>Other (please specify)</td>
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</tbody>
</table>

8. How acceptable is genetic manipulation (via recombinant DNA) in the following organisms:

<table>
<thead>
<tr>
<th>Organism</th>
<th>Very Acceptable</th>
<th>Somewhat Acceptable</th>
<th>Neither</th>
<th>Somewhat Unacceptable</th>
<th>Very Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbes</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Plants</td>
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<td></td>
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<tr>
<td>Animals</td>
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<td></td>
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<tr>
<td>Human Cells</td>
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</table>

9. Genetic engineering involves new methods that make it possible for scientists to create altered plants and animals by taking a gene or genetic information from a plant, animal or microbe and using that gene to provide new properties to the cells of another plant or animal.

The following are some possible products and uses that this technology can offer. Please indicate your approval rating for each of the following:

<table>
<thead>
<tr>
<th>Product/Use</th>
<th>Strongly Approve</th>
<th>Somewhat Approve</th>
<th>Not Sure</th>
<th>Somewhat Disapprove</th>
<th>Strongly Disapprove</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits and vegetables with extra resistance to disease</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Putting vaccines into foods so medications can be administered more easily</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Potatoes that are resistant to blight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Better tasting fruits and vegetables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bacteria to help clean up oil spills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fruits and vegetables made less expensive</td>
<td></td>
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<tr>
<td>New types of grass that won’t have to be cut as often</td>
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<tr>
<td>Fruits and vegetables with longer shelf life.</td>
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<tr>
<td>New drugs to cure human disease</td>
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<tr>
<td>Hormones like insulin to help diabetes</td>
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</tbody>
</table>
**10. Would you be willing to buy the genetically engineered (GE/GM) foods below if they were at the same price as similar GE products:**

<table>
<thead>
<tr>
<th>Food</th>
<th>YES</th>
<th>NO</th>
<th>NOT SURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potatoes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baby Food</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheese</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bread</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sugar</td>
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<td></td>
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<tr>
<td>Tomatoes</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Beer</td>
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</tbody>
</table>

**11. Do you agree with experimental field trials of blight resistant genetically modified potatoes in Ireland?**

- No
- Don’t know
- Yes

**12. Do you agree that there should be an immediate complete ban of all GM foods and their production in Ireland?**

- Yes
- Don’t Know
- No

**13. Please indicate the level to which you agree with the following statement:**

"Genetically engineered crops can help Irish farmers use less chemical herbicides"

- Strongly Agree
- Somewhat Agree
- Not Sure
- Somewhat Disagree
- Strongly Disagree
14. Do you agree with the destruction of GM field trials by activists?
- Strongly agree
- Somewhat agree
- Don't know
- Somewhat disagree
- Strongly Disagree

15. In your opinion, how likely is it that within the next 20 years developments in GM technology will have a substantial role in reducing world hunger?
- Likely
- Unlikely
- Not Sure

16. How likely is it, that within the next 20 years, there will be a complete public rejection of GM foods.
- Don't know
- Likely
- Unlikely

17. How likely is it that within the next 20 years there will be reduced herbicide and insecticide usage due to GM crops?
- Likely
- Unlikely
- Do not know

18. Are you aware of the Irish Government’s current GM food/crop policy?
- Yes
- No
**19. Please indicate your agreement with the following elements of the Irish Government policy on GM food/crops**

<table>
<thead>
<tr>
<th></th>
<th>Agree completely</th>
<th>Agree somewhat</th>
<th>Neither Agree or Disagree</th>
<th>Disagree somewhat</th>
<th>Disagree completely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ban on experimental GM crop trials</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Ban on commercial GM crop production</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Allow import of GM animal feed</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

The quality of science and technology reporting that you have seen/heard in Ireland

**20. Please select a response that would describe the quality of science and technology media reporting (via Newspapers and TV) that you have seen/heard in Ireland**

- ☐ Excellent
- ☐ Good
- ☐ Average
- ☐ Poor
- ☐ Very Poor

Within the last two years have you been contacted by the national media in relation to your research?

**21. Within the last two years have you been contacted by the national media in relation to your research?**

- ☐ Yes
- ☐ No

**22. Have you ever contacted the national media to complain about coverage of a science issue?**

- ☐ Yes, more than once
- ☐ Yes, once
- ☐ No
23. Please indicate how strongly you agree or disagree with the following statement: "Scientists do not trust journalists to reflect their view correctly and fear the journalist will twist the scientists words".

- Strongly Agree
- Somewhat Agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

24. SECOND LAST QUESTION: Who do you believe can be trusted the most to tell the factual truth about new genetically modified food crops grown in fields.

Please list from 1-10, where 1 is in your opinion, the most trusted source of information.

- Concern/pressure groups
- Farming groups
- Universities
- Irish Government agencies
- TV and newspapers
- Consumer organisations
- Biotechnology Industry
- Religious organisations
- Medical Profession
- European Union
- None of the above

25. Scientific advice plays an important role in policy formulation. If you were to give advice to an Irish politician regarding genetically modified crops what would it be?

26. Please select a charity below who you would like to receive a donation

- Irish Cancer Society
- Bóthar
- Barnardos
- Maynooth Clinic Centre
- Concern
Appendix B: Qualitative responses in the 2008 Irish Life Scientist Survey

Qualitative responses to the open end question of “If you were to give advice to an Irish politician regarding genetically modified crops, what would it be?”

1. Be realistic and scientific and take informed advice. Adopt the precautionary principle (which does not mean doing nothing). Don’t simply follow the herd (he who shouts loudest is not always right).
2. GM in actual fact allows us accelerate breeding and achieve what is probably achievable over a much longer term by conventional breeding. Irish politicians need to be properly informed as to the facts regarding GM.
3. I haven't thought about this.
4. Be open minded to both the benefits and the potential dangers. Farmers have been using animal husbandry for years to produce animals with a specific genetic disposition. why is science any better or worse.
5. Do your homework. Consult with the experts not with the people who stand to gain financially from promoting a non GM agenda. Proposing to make Ireland GM free is farcical and anti-competitive. Fund the process for the proper dissemination of scientific information. Organise a structure where members of the public can be properly informed on these issues. Try and oust the greens!
6. To research this area extensively in Ireland to alleviate public concerns and move forward with this necessary technology.
7. Determine the safety and benefit of the methods used in generating genetically modified crops.
8. Encourage research on GM crops in order to reap the benefits of science for mankind.
9. Don't listen to extremists but proceed cautiously.
10. Proceed slowly with field trials making sure no possibility of cross-pollination outside of study area. This is difficult to control and that’s the big issue! Don’t listen to those who have a vested interest in promoting this business or those who’s research is funded by agribusiness!
11. Try to keep it out of the country.

12. Tread carefully.

13. Don’t believe the interest groups. The scientists have a vested interest (personally and in their subject areas), the biotechnology companies have vested interests for profit; the farmers have some interests if it is profitable; the consumers ought to have only the interests of the consumers and the politicians ought to be free of all groups by not asking any support of any kind from these groups. Universities and research institutions also have vested interests for the finance they can earn and for their reputations as research bodies etc. The public can best be served by those deciding having no vested interests of support from any organisations.

14. The potential benefits out-weigh the (unknown) risks and therefore further research should be supported.

15. Ensure you get reliable and scientifically validated information

16. Genetically modified crops can offer advantages over non GM crops. They can offer farmers greater productivity and diversity thus offering wider markets and greater profit. The effects of non-natural, altered or high levels of proteins present in GM foods needs to be tested fully to ensure allergic reactions and other health effects are not promoted by these foods. The evidence to date indicates that these foods are safe. Each new GM crop generated needs to undergo rigorous testing (part of which are field trials) as well as the food that arises from that crop. Health concerns surrounding drugs produced by GM crops/organisms is not an issue. A balanced and fair assessment of GM crops/foods is needed. The scientific facts must not be clouded by emotion which can lead to perceived disadvantages/advantages of GM crops/foods.

17. Do not take a polarised position. Listen to both sides and make informed judgement without prejudice. Wishful thinking!!!

18. Provide scientists and the Biotech sector with sufficient levels of funding to establish a rock solid scientific basis for GM crops, to conduct the environmental and food safety/toxicity studies that are required (over a number of years!) that will provide the level of confidence to all sectors (including the consumers, producers and environmentalists/conservationists) in GM crops.

19. Genetic engineering is used successfully to produce medicines; no one seems to have a problem with recombinant insulin, for example. Plus, crossing plants to produce offspring with desirable characteristics has been done for many, many years. GM crops are essentially the same, but with a bit more human input into producing a desirable quality.

20. Don't go down that route. We have no idea of the long term consequences.
21. Use the best advice available nationally and internationally. Set up advisory groups composed of stakeholders.

22. Seek advice from a good number (how many is good?) of scientific experts- both with a conceived vested interest (in GM production) and more importantly those without. Experts should be national and international. Listen to concerns of pressure groups against GM crops, but address these concerns with reasoned arguments. Don't be swayed by blatant scare tactics- but also don't assume the scientist is always correct- be balanced, but logical.

23. To get off the fence (i.e importing GM crops yet banning production here) and support technology

24. In principle no problems but whether it is always needed has to be looked after in detail. E. g. development of new medical treatments there should be no problem but whether the herbicide resistance of a GE plants to one herbicide of a company is so favourable is a question.

25. Consider other approaches to reduce herbicide/pesticide use, and ensure sustainable food security. Ensure that approaches taken are driven by need for food security and not by agri-business profits.

26. Allow basic research into the proof of concept (say, high yield, disease resistance, etc.) research in the University/ public-owned research labs; Place stringent conditions on qualification for field trials; minimize the influence on policy of major players (beneficiaries/ or losers) in the GM crops area; follow-up (and collaborate with) researchers in similar areas elsewhere. And very important, (as the ultimate guardian of the public good) lead (but never follow) GM companies in the science, technology and judgement. In short, keep on researching the foundations of GM crops, but adopt a "wait-and-see" approach regarding full-blown commercialization.

27. Listen to those who are qualified.

28. Proceed with controls

29. Get fully informed. Have an unbiased expert to back you up.

30. 1) China and USA have extensive use of GM crops but have not suffered the nightmare scenarios presented by the anti GM lobby groups. Irish farmers need GM crops to be competitive, and for food security reasons. 2) The technologies have moved on.

31. Make sure you understand the science. Evaluate the potential risk in a realistic way. Don’t pay attention the NIMBY pressure group loonies - pressure groups are formed to oppose any new initiative.

32. Get educated about the science of genetic engineering and the nature of the genetic changes being engineered into crops.
33. *I would be concerned over the workability of an (informal) ban on GM cultivation in Ireland, esp. the incentive that may exist for an individual producer to deviate. Is GM-free status really obtainable?*

34. *Carry out agreed rigorous scientific trials, disseminate results clearly and in a simple language, consult all stakeholders and when all are informed, follow scientific advise that makes economic and logical sense from producer, processor and consumer viewpoints.*

35. *That their decisions should be evidence-based and not pressure group driven. The evidence base should be from neutral parties without an agenda which would exclude the industry and green community.*

36. *GM Crops are not the evil entity they have been portrayed as. GM Crops can be good and will be useful in the future.*

37. *GM crops are necessary, and are part of the future of agriculture.*

38. *Consider the individual GM products on a case-by-case basis - evaluate the products rather than the technology. Use a risk assessment strategy when evaluating each potential product - 1).what, if any, is the risk of an unforeseen negative side-effect from the GM crop: 2). is the risk greater than from a conventional non-GM crop with a similar trait; 3). are there any benefits to mitigate any such risks. In Ireland, arable farming is being abandoned by the government - it DOES make pragmatic business (not scientific) sense to make the country GM free.*

39. *Negotiate the labyrinth to public opinion to allow growth of GM crops.*

40. *No scientist knows the facts as to what exactly governs and how the genome is controlled yet. Extra chromosomal elements, augmentative activities and interactive communications and interdependencies are not well understood. All species are interdependent ...... changing one impacts on many more directly and indirectly.*

41. *As with most of the questions in this survey, this is a general question but the answers have to be specific to particular cases - not all crops are the same and not all genetic engineering is the same. Before giving any kind of advice I would actually want to know a) what kind of crops they were talking about, b) what level of policy were they drafting, and c) I would have to research the actual relevant papers.*

42. *To treat it like any other technology. It has huge potential to benefit society but needs to well monitored and regulated. Policy should be developed in those areas to ensure that procedures for utilisation of the technology are adequate.*

43. *Listen to the best evidence both for and against and make up your own mind*
44. Rigorous independent Irish testing is required. Companies, governments and Peter Mandelson are not to be trusted. There is too much money and political pressure behind the use of GM products. Each product is unique and requires proper testing. Europe should not cave into outside political pressure regarding the sale and use of GM products.

45. Don't trust the media and pressure groups; Don't assume that GM crops are the answer to all the worlds problems. GM crops should be used with caution.

46. Use the 'precautionary' principle, not the 'ostrich' principle.

47. People who are not sufficiently informed should not give advice.

48. Seek out research that is broad based and long term in their approach to understanding and determining the effects of GM foods. Scientists do make mistakes and can be myopic in their research.

49. Before getting into GM explore the traditional avenues of breeding.

50. I cannot give informed advice. I would suggest he listens to informed independent advice from sources on both sides of the issue.

51. It would be to cast aside their preconceived notions soaked up from the media and elsewhere and sit down with a good scientific communicator and listen to the facts, no hearsay, no hype - just simply the facts.

52. GM crops are certainly worth exploring but its premature to sanction their widespread use. Increased crop yields and disease resistance will always be temporary. Perhaps better farming practices would be more successful that genetic engineering in the long run.

53. Instead of playing politics, inform people with real, trustworthy data and international reports, what if any, risks exist really exist with GM crops. If not enough data is available to base a solid judgement then GM crops should be banned until such time as sufficient data is available to make a valid case and decision. Do not be forced into decisions based on either ill- informed activist, nor commercially oriented biotech companies and industries. Biological diversity is important in combatting disease and resistance, and in adapting to environmental changes. We must avoid becoming dependent for seeds on a single supplier or suppliers, being forced into using specific pesticides etc, and creating potentially catastrophic situations where a climatic/ environmental change, new disease or whatever causes the GM crop available to be destroyed or whatever i.e. we should avoid the situation whereby we are dependent on companies producing seed stocks for varieties which are too specific and too inflexible (i.e. too little genetic diversity).

54. Seek the advice of academic scientists actively working in the GM area.
55. Get independent scientists to peer review.
56. Perform some field trials in an Irish context.
57. Get informed independent expert advice.
58. Consult with relevant academics, nationally and internationally.
59. Communication of the key issues is critical. People are suspicious by secret trials etc, openness is the best policy, educate us all on the GM technology.
60. Do much more ecological / environmental research into the potential impacts in the future should GM crops either escape unwantedly into the environment or should they be adopted wholesale.
61. Take Care
62. Never make any decisions unless you have consulted with expert scientists.
63. To incentive to the people with the example, "eating GM crops".
64. Allow field trials to see if the GM technology actually confers any benefit. The outcome in the UK was that for several crops there was no distinction between GM and non-GM varieties.
65. Ensure GM is for the good of the consumer or the environment, not the company that produces/distributes/sells it.
66. Don't throw the baby out with the bath water!!!
Appendix C:
Feed Industry Questionnaire

1. What are the primary countries from which you source main raw material?

2. When was the first time genetic modification (GM) became an issue for your company?

3. Have you made changes in your business practices to manage GM issues?: Yes, No, Don’t Know
   If Yes:
   i. How have your buying patterns changed? (Prompt if required: what and when?)
   ii. Have you had to seek new customers? Y/N, if Y why?
   iii. Have you had to seek new suppliers? Y/N, if Y why?
   iv. Have GM related changes made purchasing/trading more financially risky? Y/N, if Y why?
   v. Did you change feed formulations as a result of GM issues?
   vi. Did you change storage requirements as a result of GM issues?
   vii. Have GM related changes been driven by contract requirements?
   viii. Overall, what has been the most costly change regarding GM issues?
   ix. Overall, what has been the most time consuming ongoing change regarding GM issues?

4. Since starting to be an issue for your organization has the GM issue become:
   Worse, better or remained the same?

5. Can you describe the most difficult GM issue you have experienced to date?
i. How did you obtain information to understand and deal with the issue?
   (Prompt if required: regarding commercial aspect or feed safety aspect)

6. Who, in your opinion provides the most impartial information with regard to genetically modified feed (rank 1 thru 12 where 1 is most trusted and 12 is least trusted):

   Environmental Concern/Pressure groups:
   Farmers groups:
   Universities:
   Government agencies
   European Union
   T.V. and newspapers
   Internet
   Biotechnology Industry:
   Religious organisations
   Medical profession
   Political Parties

7. How satisfied are you with the current Irish Government’s response to the GM issues you have faced to date?:
   Not at all satisfied
   Slightly satisfied
   Somewhat satisfied
   Very satisfied
   Extremely satisfied

8. Would you support a change in the 0.9% threshold for unapproved GM events? If Y, what change?

9. Do you consider that GM-derived animal feed will be necessary to meet the future needs of the animal sector in the Ireland? If so why?
10. In your opinion, what is the relative demand in Ireland for non-GM animal feed compared to all other categories of animal feed? Very High, High, Medium, Low, Very Low

11. To what extent has demand for non-GM animal feed increased/decreased in Ireland over the past 5 years?

12. Do you consider that GM-derived components currently used in animal feed in Ireland present any risk to:
   - animal health Y/N/DK
   - human/consumer health Y/N/DK
   - environmental risk Y/N/DK
   - farmers livelihoods Y/N/DK
   - animal export trade Y/N/DK

13. How many employees does your company/organization have in Ireland?

14. What is the annual volume (MT) of animal feed you sell?

15. Are you a member of Irish Grain and Feed Association (IGFA)?