Drivers of Consolidation in the Seed Industry and its Consequences for Innovation

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Prepared by:
Piet Schenkelaars, Schenkelaars Biotechnology Consultancy
Huib de Vriend, LIS Consult
Nicholas Kalaitzandonakes, University of Missouri

In cooperation with:
Alexandre Magnier, University of Missouri
Douglas Miller, University of Missouri

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EXECUTIVE SUMMARY

Key question

The key question posed by the Commission on Genetic Modification (COGEM) for this study was whether the plant breeding sector worldwide is monopolised by large multinationals due to the application of genetic modification, and if so, what might be the possible consequences for innovation in this sector? To answer this question, a triangular study approach was chosen, in which: 1) the relevant literature was reviewed; 2) interviews were held with eleven top executives from the seed industry for a perspective from 'within', and; 3) an economic assessment was conducted to examine the relationship of industry concentration, market power and innovation in three US seed markets where genetically modified (GM) seeds have been broadly used, namely, cotton, soybean and maize. The findings from these three different types of analyses were then compared and synthesised, providing answers to the study's key question.

Three waves of structural change

Over the last one hundred years the global seed industry experienced significant structural changes. Three major waves of structural changes in the seed industry were indentified through exploration of historical data and review of the literature:

1. The first wave started in the early 1930s when new commercial seed firms were established and continued to adapt public research on hybridisation and other innovations, leading to growth in maize and other seed sectors.
2. The second wave started in the 1970s fostered by the introduction of various intellectual property (IP) rights, such as plant breeders rights (PBRs) and patents, which promised to increase returns from investments in plant breeding research and development (R&D). The introduction of stronger IP rights set off a wave of mergers and acquisitions (M&As) by R&D-minded pharmaceutical, petrochemical and agrochemical companies from the US and Europe. Independent market leaders and smaller regional and local seed companies generally maintained their market position and by the early 1990s many of the multinationals that led M&As activities in the 1970s and 1980s had divested their seed germplasm assets. In the end, a limited amount of consolidation was observed in a few seed sectors in the US and elsewhere.
3. The third wave started in the 1980s when, inspired by the potential of biotechnology, a handful of agrochemical multinationals from the US and Europe invested substantially in genomics, genetic modification (GM) and other new technologies. For the commercial introduction of a new GM or biotech seed, biotechnology know-how, access to seed germplasm and IP had to be coordinated. This led to a strong wave of strategic M&A activities by these few multinationals which vertically integrated germplasm and GM/biotech assets.

Between 1985 and 2009 annual sales in the global seeds market increased from 18 billion US dollar to about 44 billion US dollar. Over the same period, the ownership structure in the seed industry changed drastically. In 1985 the top nine seed companies had a share of 12,7% of the global seeds market. In 1996 the top nine seed companies had a share of 16,7% and only one was owned by a multinational. In 2009 the share of the top three seed companies, all of them owned by multinationals, had explosively grown to of 34% of the global seeds market.

The dynamic interplay of scientific breakthroughs, government policies and business strategies

The literature review and the interviews with top executives from the seed industry further revealed an ongoing dynamic interplay between scientific breakthroughs, government policies and business strategies.

- **Scientific breakthroughs:** Publicly funded research in plant sciences and molecular genetics has led to scientific breakthroughs in plant breeding, such as hybridisation, GM technologies as well as genotyping and phenotyping technologies. Each scientific breakthrough drove a wave of private investments in the seed and biotech industry.
- **Government policies:** Governments around the world have generally pursued growth in agricultural productivity through various policies. On the one hand, science and technology (S&T) policies and Intellectual Property laws have sought to create incentives for innovation. This positively influenced the seed and biotech firms to invest, merge and expand. On the other hand, biosafety/GMO regulations were implemented to manage food and environmental safety. The relatively high regulatory compliance costs for GMO approvals, however, have probably discouraged small and medium sized seed and biotech firms and public sector institutions to bring GM crops to the market. Finally competition and antitrust laws were implemented to manage market risks. Both in the US and in Europe biotech firms were required to divest certain germplasm assets before certain mergers and acquisitions could be approved.
- **Business strategies:** Scientific breakthroughs, especially in plant biotechnology, and government policies, in particular on IP rights, created profit opportunities for innovations in plant breeding. The literature review revealed the use of a variety of business strategies in response to these opportunities: Investments in in-house R&D in plant science and breeding, R&D collaboration with private and public partners, M&As and pursuit of IP rights including through (cross)licensing of IP. The increasing investment in R&D for biotech seed innovations as well as large GMO regulatory compliance and legal expenditures incentivised seed companies to grow in size and expand in new markets in order to achieve critical mass.

The role of R&D investments, IP and regulatory costs

There was a divergence of views among the interviewees about the role of IP and legal costs as drivers of structural change; some interviewees considered IP and legal costs negligible compared to the overall costs of business operations while others considered (increased) IP and legal costs substantial. In a similar vein, there was a divergence of opinions on the role of patent laws on structural change and the level of innovation in the seed industry. Some interviewees suggested that patent laws were indispensable for private investment in R&D while others argued that patent laws have a negative impact on the overall innovative activity in the seed industry.

The estimated costs for bringing a GM crop to the market provided by the interviewees also varied widely, from 15-30 million US dollars to 100-180 million US dollars. Similarly, the estimated regulatory compliance costs for GMO approvals provided by the interviewees varied from 10-30 million US dollars to 80-110 million US dollars. With a view to stewardship programmes, several interviewees pointed out that in cases of licensing the recipient of GM material, e.g. another seed company, had to have the appropriate tools to follow the stewardship requirements to prevent liability claims accruing to the developer. In addition, maintaining and having access to regulatory data packages and stewardship programmes will be vital for the development of a market for generic GM/biotech seeds.

Economic analysis of three seed markets with GM varieties.

The substantial adoption of GM technology in the US for maize, soybean and cotton made these markets prime objects for an economic analysis. The relationships between concentration, market power, price markups, R&D expenditures and product innovation in seed markets were empirically examined. The levels of concentration in the US seed markets for cotton, soybean and maize were measured by using the Herfindahl-Hirschman Index (HHI).

- **Cotton**: Since 1965 the HHI in the US cotton seed industry has been relatively high exceeding 1,800, which is the threshold between moderate and high levels of concentration in industries. The HHI jumped drastically in the early 1990s but it has declined slightly since the mid-2000s. Measures indicated that the US cotton seed market has remained concentrated but with significant variation in the positions of the firms in the seed industry. The presence of new entrants and share gains through organic growth of existing firms against the market leader indicate a vigorous competitive rivalry in the US cotton seed market.
- **Maize and Soybean:** The HHI values for the US maize and soybean seed industry have stayed close to 1,800 from 1992 to 2009. The economic analysis further suggested that firms in these seed markets exercised limited market power and charged markups for their hybrids, proprietary varieties and GM/biotech traits. For all key firms in the industry, the revenue streams from these markups were in line with increasing R&D expenditures over the period of analysis. Firms in these seed industries have reinvested their profits from innovation into more R&D. The number of product offerings increased significantly and the average length of the product lifecycle in the industry declined – both indicators of increasing product innovation.

The economic analysis therefore suggests that the high levels of concentration in the US seed markets for cotton, maize and soybean and the introduction of GM varieties therein have not had negative impacts on the level of innovation in these crops over the last seventeen years.

Conclusions

Over the last hundred years the global seed industry has undergone three major waves of structural changes. The ongoing dynamic interplay between diverse scientific breakthroughs, government policies and business strategies shaped these structural changes. Advancements in plant science and plant breeding, the introduction of IP rights in plant breeding and biotechnology, the increasing R&D costs expended by seed companies and their need to remain competitive by expanding and accessing new markets were all major drivers of structural change, leading to a large consolidation in the global seed business. The third and most significant wave of structural changes began in the 1980s, when a handful of agrochemical multinationals from the US and Europe with substantial investments in GM/biotechnology maintained and expanded their presence in the global seed industry through strategic M&As activities in order to vertically integrate seed germplasm assets and GM/biotech assets. Their entry changed drastically the ownership structure in the seed industry.

This study revealed a number of drivers for structural changes in the plant breeding sector during the last century. Application of genetic modification has been one of the main drivers in the last two decennia. Consolidation has also taken place in seed markets without GM varieties, where many breeders applied other innovative plant breeding technologies and plant biotechnologies. Therefore, the relative importance of GM as a driver varies per seed market.

According to the economic analysis, the high levels of concentration in the US seed markets for cotton, maize and soybean have not had negative impacts on innovation over the last seventeen years; a period that coincided with the substantial adoption of GM technology by these US seed markets.

Nonetheless, from the literature review and the interviews with the top executives from the seed industry, the following concerns have emerged:

- Under-investment in public sector R&D for plant breeding of minor crops and to public goods like environmental protection and food safety.
- Patents provide essential incentives for R&D investment but can also stifle innovation in the seed industry.
- It is expected that R&D costs will remain at a high level. Since high R&D costs are one of the main drivers, this will likely contribute to further concentration and consolidation in the seed industry.
- GMO regulatory compliance costs that discourage public research institutes and small companies to engage in the development and commercialisation of GM crops and stewardship programmes for compliance with post-marketing monitoring of GM crops and government policies and/or market standards for the adventitious presence of GM traces in non-GM products, particularly in the case of licensing.
- Lack of maintenance of and access to regulatory data packages and stewardship programmes after expiration of a patent on a GM/biotech trait. Access to this information will be vital for the development of a market for generic GM/biotech seeds.

SAMENVATTING

Kernvraag

De kernvraag van de Commissie Genetische Modificatie (COGEM) voor deze studie was of de zaaigoedindustrie wereldwijd wordt gemonopoliseerd door grote multinationals vanwege de toepassing van genetische modificatie, en zo ja, wat de mogelijke consequenties kunnen zijn voor innovatie in deze sector. Om deze vraag te beantwoorden werd gekozen voor een driehoeksaanpak, waarin: 1) de relevante literatuur werd bestudeerd; 2) interviews met elf top functionarissen uit de zaaigoedindustrie werden gehouden voor een perspectief van 'binnenuit', en; 3) een economische evaluatie werd uitgevoerd voor de bestudering van de relatie tussen industrieconcentratie, marktmacht en innovatie in drie Amerikaanse zaaigoedmarkten waar veel genetisch gemodificeerd (gg) zaaigoed wordt gebruikt, namelijk katoen, soja en maïs. De bevindingen van deze drie verschillende typen van analyse werden vervolgens vergeleken en samengebracht om de kernvraag van deze studie te beantwoorden.

Drie golven van structuurverandering

De laatste honderd jaar heeft de mondiale zaaigoedindustrie significante structurele veranderingen ondergaan. Aan de hand van historische gegevens en de literatuurstudie werden drie belangrijke golven van structurele verandering in de zaaigoedindustrie vastgesteld:

1. De eerste golf startte in de dertiger jaren van de vorige eeuw, toen nieuwe commerciële zaadbedrijven werden opgericht en doorgingen met het aanpassen van publiek onderzoek naar hybridisatie en andere innovaties, hetgeen leidde tot groei van de maïszaadsector en andere zaadsectoren.
2. De tweede golf startte in de zeventiger jaren van de vorige eeuw en werd gestimuleerd door de introductie van diverse intellectuele eigendomsrechten, zoals kwekers- en octrooirechten, die beloofden het rendement van investeringen in plantenveredelingsonderzoek en –ontwikkeling (O&O) te verhogen. De invoering van sterkere rechten voor intellectueel eigendom (IE) zorgde voor een golf van fusies en overnames door onderzoeksgerichte farmaceutische, petrochemische en agrochemische multinationals in de VS en Europa. Onafhankelijke marktleiders en kleinere regionale en lokale zaadbedrijven behielden in het algemeen hun marktpositie en aan het begin van de negentiger jaren van de vorige eeuw desinvesteerden veel van de multinationals die in de zeventiger en tachtiger jaren fusies en overnames hadden geleid hun bezittingen in zaadkiemplasma. Uiteindelijk werd slechts in enkele zaaigoedsectoren in de VS en elders een beperkte consolidatie waargenomen.
3. De derde golf startte in de tachtiger jaren van de vorige eeuw, toen, geïnspireerd door de mogelijkheden van de biotechnologie, een handvol agrochemische multinationals in de VS en Europa aanzienlijk investeerden in genoomonderzoek, genetische modificatie en andere technologieën. Voor de commerciële introductie van een nieuw gg/biotech gewas moesten kennis van biotechnologie, toegang tot zaadkiemplasma en intellectueel eigendom worden gecoördineerd. Dit leidde tot een sterke golf van strategische fusies en overnames door deze paar multinationals die bezittingen in zaadkiemplasma en gg/biotech eigenschappen verticaal integreerden.

Tussen 1985 en 2009 steeg de jaarlijkse verkoop in de mondiale zaaigoedmarkten van 18 miljard VS dollar tot ongeveer 44 miljard VS dollar. Gedurende deze periode veranderde de eigendomsstructuur in de zaaigoedindustrie drastisch. In 1985 hadden de top negen zaadbedrijven een aandeel van 12,7% van de mondiale zaaigoedmarkt. In 1996 hadden de top negen zaadbedrijven een aandeel van 16,7% van de mondiale zaaigoedmarkt en slechts één was in het bezit van een multinational. In 2009 was het aandeel van de top drie zaadbedrijven, allen in het bezit van een multinational, explosief gegroeid naar 34% van de mondiale zaaigoedmarkt.

De dynamische wisselwerking tussen wetenschappelijke doorbraken, overheidsbeleid en ondernemingstrategieën

Het literatuuronderzoek en de interviews met top functionarissen in de zaaigoedindustrie lieten verder een voortdurende dynamische wisselwerking tussen wetenschappelijke doorbraken, overheidsbeleid en ondernemingstrategieën zien.

- **Wetenschappelijke doorbraken**: Publiek gefinancierd onderzoek in de plantenwetenschappen en moleculaire genetica heeft geleid tot wetenschappelijke doorbraken in de plantenveredeling, zoals hybridisatie, genetische modificatie technologieën evenals technologieën voor genotypering en fenotypering. Elke wetenschappelijke doorbraak dreef een golf van private investeringen in de zaaigoed en biotechnologie industrie aan.
- **Overheidsbeleid**: In het algemeen hebben overal ter wereld overheden productiviteitsgroei in de landbouw nagestreefd door middel van beleid. Enerzijds hebben wetenschaps- en technologie (W&T) beleid en wetten voor Intellectueel Eigendom beoogd stimulansen voor innovatie te creëren. Dit heeft zaadbedrijven en biotech bedrijven positief beïnvloed om te investeren, fuseren en uit te breiden. Anderzijds werd regelgeving voor bioveiligheid/gg-organismen (ggo's) ingevoerd voor het beheren van voedsel- en milieuveiligheid. De relatief hoge regelgevingskosten voor ggo-toelatingen hebben echter waarschijnlijk kleine en middelgrote zaad- en en biotech bedrijven en publieke sector instellingen ontmoedigd om gg-gewassen naar de markt te brengen. Tenslotte werden concurrentie- en antikartelwetgeving ingevoerd om marktrisico's te beheren. Zowel in de VS en Europa werd van biotech bedrijven vereist om bepaalde bezittingen in zaadkiemplasma te desinvesteren, voordat bepaalde fusies en overnames konden worden goedgekeurd.
- **Ondernemingstrategieën**: Wetenschappelijke doorbraken, speciaal in de plantenbiotechnologie, en overheidsbeleid, in het bijzonder voor intellectuele eigendomsrechten, schiepen winstkansen voor innovaties in de plantenveredeling. Het literatuuronderzoek liet het gebruik van een verschillende ondernemingstrategieën zien als response op deze kansen: Investeringen in eigen onderzoek en ontwikkeling (O&O) in de plantenwetenschap en plantenveredeling, O&O samenwerking met publieke en private partners en het verkrijgen van IE rechten, inclusief door middel van (kruis)licenseren van IE. De stijgende investeringen in O&O voor biotech zaadinnovaties evenals de hoge uitgaven om te voldoen aan ggo-regelgevingsvereisten en juridische kosten hebben zaadbedrijven gestimuleerd om in omvang te groeien en naar nieuwe markten uit te breiden voor het bewerkstelligen van voldoende kritische massa.

De rol van O&O investeringen, IE en regelgevingskosten

De geïnterviewden verschilden van mening over de rol van IE en de juridische kosten als aandrijvers van structurele verandering; sommige geïnterviewden beschouwden IE en juridische kosten als verwaarloosbaar in vergelijking met de totale kosten van de bedrijfsactiviteiten, terwijl anderen de (toegenomen) IE en juridische kosten als aanzienlijk beschouwden. Er was een vergelijkbaar verschil van mening over de rol van octrooiwetten op structurele verandering en het niveau van innovatie in de zaaigoedindustrie. Sommige geïnterviewden meenden dat octrooiwetten onmisbaar zijn voor private investeringen in O&O, terwijl anderen van mening waren dat octrooiwetten een negatieve invloed hebben op de totale innovatieve activiteit in de zaaigoedindustrie.

De schattingen van de kosten voor het naar de markt brengen van een gg-gewas, die door de geïnterviewden werden aangeleverd, liepen ook ver uiteen, van 15-30 miljoen VS dollar tot 100-180 miljoen VS dollar. De schattingen van de geïnterviewden van de kosten voor het verkrijgen van een markttoelating van een ggo liepen vergelijkbaar uiteen, van 10-30 miljoen VS dollar tot 80-110 miljoen VS dollar. Met een blik op stewardship programma's gaven verschillende geïnterviewden aan dat in het geval van licenties de ontvanger van gg-materiaal, een ander zaadbedrijf, over geschikte instrumenten moet beschikken om de stewardship programma's op te volgen ter voorkoming van aansprakelijkheidsclaims voor de ontwikkelaar. Hiernaast zal het in stand houden van en toegang hebben tot toelatingsdossiers en stewardship programma's van vitaal belang zijn voor de ontwikkeling van een markt voor generiek gg/biotech zaaigoed.

Economische analyse van drie zaaigoedmarkten met gg-variëteiten

De aanzienlijke adoptie van gg-technologie in de VS voor maïs, soja en katoen maakte deze markten tot primaire doelen voor een economische analyse. Deze relaties tussen concentratie, marktmacht, prijstoeslagen, O&O uitgaven en productinnovatie werden empirisch bestudeerd. De niveaus van concentratie in de Amerikaanse zaaigoedmarkten voor katoen, soja en maïs werden gemeten met behulp van de Herfindahl-Hirschman Index (HHI).

- **Katoen**: Sinds 1965 heeft de HHI in de Amerikaanse katoenindustrie de drempelwaarde van 1800 tussen matige en hoge niveaus van concentratie in relatief hoge mate overschreden. De HHI sprong drastisch omhoog in het begin van de negentiger jaren van de vorige eeuw maar is sinds een paar jaar terug iets afgenomen. Metingen gaven aan dat de Amerikaanse zaaigoedindustrie voor katoen geconcentreerd is gebleven maar met een significante variatie in de posities van de bedrijven in de zaaigoedindustrie. De aanwezigheid van nieuw toetreders en de aandeelgroei door middel van organische groei van bestaande bedrijven tegen de marktleider in geven aan dat de concurrentie op de Amerikaanse markt voor katoenzaaigoed stevig is.
- **Maïs** en **Soja**: In de Amerikaanse zaaigoedmarkten voor soja en maïs van 1992 tot 2009 zijn de HHI waarden dichtbij 1800 gebleven. De economische analyse liet verder zien dat bedrijven in deze zaaigoedmarkten beperkte marktmacht hebben uitgeoefend en voor hun hybriden, variëten en gg/biotech eigenschappen prijstoeslagen hebben berekend. Voor alle sleutelbedrijven in de industrie waren de opbrengsten van deze prijstoeslagen in lijn met de toenemende O&O uitgaven gedurende de periode van analyse. Bedrijven in deze zaaigoedindustrieën hebben hun winsten geherinvesteerd in meer O&O. Het aanbod van het aantal producten nam significant toe en de

gemiddelde lengte van de productlevenscyclus in de industrie nam af – beide indicatoren van toenemende productinnovatie.

De economische analyse geeft dus aan dat de hoge niveaus van concentratie in de Amerikaanse zaaigoedmarkten voor katoen, maïs en soja en de introductie van gg-variëteiten hierin de laatste zeventien jaar geen negatieve invloed hebben gehad op het niveau van innovatie in deze gewassen.

Conclusies

De laatste honderd jaar onderging de mondiale zaaigoedindustrie drie belangrijke golven van structurele verandering. De voortdurende dynamische wisselwerking tussen verschillende wetenschappelijke doorbraken, overheidsbeleid en ondernemingsstrategieën vormden deze structurele veranderingen. Voortgang in de plantenwetenschap en plantenveredeling, de invoering van IE rechten in de plantenveredeling en biotechnologie, de stijgende O&O kosten bij zaadbedrijven en hun behoefte om concurrerend te blijven door uitbreiding en toegang tot nieuwe markten waren allen belangrijke aandrijvers van structurele veranderingen die leidden tot een grote consolidatie in de mondiale zaaigoedindustrie. De derde en meest significante golf begon in de tachtiger jaren van de vorige eeuw, toen een handvol agrochemische multinationals uit de VS en Europe met aanzienlijke investeringen in genetische modificatie/biotechnologie hun aanwezigheid in de mondiale zaaigoedindustrie handhaafden en uitbreidden door middel van strategische fusies en overnames voor de verticale integratie van bezittingen in zaadkiemplasma en GM/biotech eigenschappen. Hun toetreding veranderde de eigendomsstructuur in de zaaigoedindustrie drastisch.

De studie bracht een aantal aandrijvers voor structurele veranderingen in de plantenveredelingssector gedurende de laatste eeuw aan het licht. Toepassing van genetische modificatie is de laatste twintig jaar één van de belangrijke aandrijvers geweest. Consolidatie vond ook plaats in zaaigoedmarkten zonder gg-variëteiten, waar veredelaars andere innovatieve plantenveredelingstechnologieën en plantenbiotechnologieën toepasten. Het relatieve belang van genetische modificatie als aandrijver varieert dus per zaaigoedmarkt.

Volgens de economische analyse hadden de hoge concentraties in de Amerikaanse zaaigoedmarkten voor katoen, maïs en soja geen negatieve invloeden op innovatie gedurende de laatste zeventien jaar; een periode die samenviel met de aanzienlijke adoptie van genetische modificatie technologie door deze Amerikaanse markten.
Niettemin kwamen uit het literatuuronderzoek en de interviews met de top functionarissen uit de zaaigoedindustrie de volgende zorgen naar voren:

- Ondermaatse investeringen in het publieke sector O&O voor plantenveredeling van kleine gewassen en voor publieke goederen als milieubescherming en voedselveiligheid.
- Octrooien voorzien in wezenlijke stimulansen voor O&O investeringen maar kunnen innovatie in de zaaigoedindustrie ook belemmeren.
- Het is te verwachten dat O&O kosten op een hoog niveau zullen blijven. Aangezien hoge O&O kosten één van de belangrijke aandrijvers is, zal dat vermoedelijk bijdragen tot verdere concentratie en consolidatie in de zaaigoedindustrie.
- GGO regelgevingskosten die publieke onderzoeksinstellingen en kleine en middelgrote bedrijven ontmoedigen om zich bezig te houden met de ontwikkeling en commercialisering van gg-gewassen en stewardship programma’s om te voldoen aan

post-marketing monitoring van gg-gewassen en overheidsbeleid en/of marktstandaarden voor de onvermijdbare aanwezigheid van gg-sporen in niet-gg producten, in het bijzonder in het geval van licensering.

- Gebrek aan onderhoud van en toegang tot toelatingsdossiers en stewardship programma’s na afloop van een octrooi op een gg/biotech eigenschap. Toegang tot deze informatie zal van vitaal belang zijn voor de ontwikkeling van een markt voor generiek gg/biotech zaaigoed.

1. INTRODUCTION TO THE STUDY

In October 2009, the Commission on Genetic Modification (COGEM, the scientific advisory commission to the Netherlands government on issues related to genetic modification), published a call to submit study proposals for the project "Multinationals in biotechnology". The call text indicated that "a consequence of scaling up in the plant breeding sector might be that only a few globally operating companies exist in the nearby future. The advent of biotechnology in plant breeding seems to be one of the factors that play a role in scaling up. Application of biotechnology can help speeding up plant breeding and developing novel crops. However, biotechnology is also expensive and breeding firms have to invest large funds in R&D. Large companies are better able to do so. Genetic modification also seems to be tightly associated with scaling up. Genetically modified crops have mainly been developed by five large multinationals. They own the majority of patents on genetic modification and are able to cover the high costs of safety dossiers to be submitted for approval. On the one hand the multinationals cross-license among themselves and exchange information, while on the other hand they compete each other, sometimes in court. The picture of monopolisation is widely supported and an important argument in the public debate. The issue is whether this picture of monopolisation of the plant breeding sector is really correct. Is it that black-and-white or has the picture more nuances? Are a limited number of Western multinationals going to control the breeding market or even the food market? Or will enough smaller companies be left over? What is the role of patents? What is the role of Asian governmental companies? Can governments implement actions to mitigate undesirable monopolisation?" The objective of study was described as "an inventory of data, with a quantified substantiation, on possible monopolisation of the plant breeding market worldwide and potential consequences thereof and an analysis of possibilities that governments have to mitigate potential negative consequences of a possible monopolisation."

After submission of a study proposal and deliberations with the COGEM and the Steering Committee, **it was decided to focus the study on the question whether the plant breeding sector worldwide is becoming monopolised by a relatively small number of large multinationals due to the application of genetic modification, and if so, what might be possible consequences for innovation in this sector.** Potentially positive consequences might include augmenting the pace of innovation that may lead to increased choice, higher quality and/or lower prices for farmers and consumers. Potentially negative consequences might include slowing the pace of innovation that may adversely affect choice, quality and prices for farmers and consumers.

This report presents the findings from this study that was based on a triangular approach, consisting of: 1) a literature review; 2) a series of interviews with representatives of seed and biotechnology companies, and; 3) economic analyses of the consequences of structural changes in the US seed markets for maize, soybean and cotton that have widely adopted GM varieties since the early 1990s.

Section 2 of this report provides a review of the application of plant science to plant breeding as one of the main drivers of the structural evolution of the seed industry over the last hundred years.
Section 3 identifies and examines two other main drivers of structural changes in the seed industry: Government policies and business strategies in the seed industry. This section closes

by a review of government actions to enforce competition and antitrust laws in the seed industry in the US, EU and India over the last decade.
Section 4 presents an assessment by seed industry executives of the structural changes, their drivers and their consequences for innovation, based on semi-structured interviews.
Section 5 presents economic analyses of the consequences of structural changes in the US seed markets for GM maize and soybean and examines the relationships between concentration and market power, price markups, R&D expenditures and product innovation.
Section 6 summarises the main findings and draws conclusions.

The study has benefitted from feedback and insights from the COGEM Steering Committee that comprised the following members:

1. Hans Dons, BioSeeds B.V. (chair)
2. Orlando de Ponti, former Director R&D Nunhems B.V. and former President of the International Seed Federation.
3. Lous van Vloten-Doting, Commissie van Wijzen FES
4. Ruben Dekker, Ministry of Infrastructure and Environment
5. Bart Erkamp, COGEM (staff)

It should be noted that the quality and reliability of the information compiled for this study and its conclusions are the sole responsibility of the authors and that this study report does not represent views of the COGEM in any way.

Piet Schenkelaars, Schenkelaars Biotechnology Consultancy, Netherlands
Huib de Vriend, LIS Consult, Netherlands
Nicholas Kalaitzandonakes, University of Missouri, Columbia, US

2. SCIENCE AS DRIVER OF STRUCTURAL CHANGE IN THE SEED INDUSTRY

This section offers a brief historical review of the application of plant science to plant breeding as one of the main drivers of the structural evolution of the seed industry since the 1930s.

2.1 Application of plant science to plant breeding

Genetic improvement of plants began in the Neolithic age with the domestication of cereals and pulses. Since then, farmers achieved steady increases in plant yields. In the 20th century an impressive acceleration in the capacity to produce more food per unit of land has been achieved by exploiting advances in plant science for plant breeding.

The experiments of Gregor Mendel with garden peas in the later part of the 19thcentury gave rise to extensive scientific research into the inheritance of traits in other plants and crops. In the US a significant proportion of this later research focussed on maize, as it was the dominant crop in US agriculture and its yields had remained stagnant for some time. This public research resulted in major technological breakthroughs in plant breeding, in particular hybridisation. Essentially, hybridisation is a plant breeding process in which, so-called, inbred lines are crossed to create plants with greater yield potential than exhibited by either parent; the so-called 'heterosis effect'. However, the enhanced vigour of a hybrid is not transmitted to its offspring.

Furthermore, in the period from 1945 to 1970, the exploitation of other advances in plant science for plant breeding, such as in vitro technologies (multiplication, haploidisation) and mutagenesis, led to the development of 'high-yielding varieties' of rice, wheat, and other crops. When combined with the use of fertilisers, pesticides and other inputs, these 'high-yielding varieties' experienced yearly yield increases of more than one percent through the 1990s. In the context of developing countries, this extraordinary growth in agricultural output is often referred to as the "Green Revolution".

Moreover, largely publicly funded research in molecular biology that started in the late 1930s and early 1940s led to the discovery of the double helix structure of DNA by Watson and Crick in 1953, which contributed to the development of new tools for plant breeding like genetic modification (recombinant DNA technology; transgenesis) in the 1980s and 'marker-assisted selection' (MAS) and other 'molecular marker' technologies in the 1990s. In the late 1990s, further advances in molecular genetics and improvement of sequencing and computing power contributed to the emergence of genomics as a new discipline within the life sciences. As a result of these advances in plant sciences and molecular genetics, a series of novel plant breeding techniques has been developed in the first decade after the millennium change, like RNAi, oligo-nucleotide mediated mutation induction, Zinc-finger nuclease induced mutation, agro-inoculation, reverse breeding, and epigenetic modification.

The exploitation of these scientific advances has resulted in substantial increases in the yields of all major crops in the US, the EU and other parts of the world over the past seventy years. About half of the yield gains can be attributed to genetic improvements achieved by plant breeders. The other half can be attributed to mechanisation and irrigation, resulting from advances in engineering, and usage of fertilisers and other chemical compounds to control pests, diseases and weeds, based on advances in (bio)chemistry, plant physiology, plant pathology, entomology, weed science, soil ecology, agronomy, etc. (EASAC 2004).

2.2 Structural evolution of the seed industry

Before the emergence of commercial seed companies most farmers engaged in plant breeding by exploiting chance mutations and natural selection processes and were dependent on seed saved from their own crops grown in the previous season. It was common for farmers to share surplus seed with family and neighbours. The advent and expansion of governmental seed certification and quality assurance schemes in the early 20th century brought about large increases in the number of farmers who purchased seed from commercial traders (Fernandez-Cornejo 2004). In those days most commercial seed suppliers were small, family-owned private companies, which lacked the financial resources to pursue their own research and development (R&D) activities. Their primary role was to multiply and sell seeds of varieties selected by individual farmers or developed by the public sector.

During the last eight decades, the global seed business has privatized breeding and other plant sciences research and structural changes occurred, lately often resulting from activities of multinational firms. The speed of such structural changes has been different across crops and countries. Generally, there have been three major waves of restructuring:

Commercial seed firms adopting the public research results in hybrid maize breeding
By the late 1920s several new commercial seed firms took over the publicly supported research efforts in hybrid maize breeding in the early 1930s and helped to reverse the trend of stagnant maize yields in the US. By 1960 the share of maize acreage cultivated with hybrid seed in the US had reached 95 %, replacing almost all open-pollinated (non-hybrid) maize varieties. Similar developments were also experienced in Europe where the success of hybrid maize was followed by hybrid varieties of other crop species. Since the emergence of the commercial seed industry in the US in the early 20th century, assets have changed hands frequently and most of today’s leading seed companies are the products of mergers and acquisitions (M&As). Until the late 1960s, assets in the seed industry were primarily traded among seed companies.

M&A activities by R&D-minded petrochemical and pharmaceutical multinationals
The introduction of Intellectual Property (IP) rights, such as Plant Breeders’ Rights (PBRs), which promised to assure returns on investment in plant breeding research, set off a wave of M&A activities by R&D-minded petrochemical and pharmaceutical multinationals. PBRs were foreseen for the first time by the Plant Breeders’ Decree of The Netherlands in 1941. In 1961 PBRs were adopted by a convention of the international Union for the Protection of New Varieties of Plants (UPOV), followed by Plant Variety Protection Act (PVPA) in the US in 1970. In the decade thereafter more than 50 US seed companies were acquired by such multinationals. For example, Ciba Geigy, a chemical company (now part of Syngenta), acquired 4 seed companies, and Sandoz, a pharmaceutical company, acquired 2 seed companies. However, the petrochemical and pharmaceutical multinationals mainly acquired and merged small and medium sized regional seed companies, which lost market share over time (Fernando-Cornejo et al. 2002; Kalaitzandonakes et al. 2003). Both independent market leaders, e.g. Pioneer and DeKalb, and smaller regional and local seed companies maintained their market position despite the significant capital resources of the new multinationals entering the seed industry.

By the early 1990s, many of the multinational firms that led the M&As activity in the previous decades had divested their seed assets, because the need for geographic adaptation of all new seed varieties placed bounds on R&D scale economies. The potential economies of scale in distribution and marketing of seeds were even more limited. With crop yields being the primary differentiating factor among seed brands, smaller regional companies could effectively compete against much larger national and multinational firms with extensive marketing and distribution networks. The regional seed companies produced and distributed a small number of varieties within limited geographic regions where they demonstrated competitive yield performance. The regional firms were often relatively more profitable as they were able to avoid the excessive inventory costs that frequently hampered the national firms. As a consequence, by the early 1990s, many of the multinational firms that led the M&A activity in the previous two decades had divested their seed assets; see 3.2.2.

M&As by agrochemical multinationals for vertical integration of GM and seeds assets

However, a handful of multinationals with significant investments in genetic modification (GM) maintained and expanded their presence in the US seed industry. Since the advent of GM research in the mid-1970s, superior seed genetics (seed germplasm) were recognised as an essential complementary asset for delivering new biotechnologies to seed markets. For the commercial introduction of a new biotech seed to be successful, the intellectual property (IP), the biotechnology know-how and the seed germplasm had to be coordinated. In the 1990s this need for coordination led to a wave of strategic M&As by a few multinationals to vertically integrate seed germplasm and GM assets (Kalaitzandonakes and Bjornson, 1997, Fernandez-Cornejo 2004; Moss 2009; Cowan et al. 2010). The strategies to vertically integrate seed germplasm and GM assets were as old as the agricultural biotechnology industry itself. For example, GM pioneers, like David Padwa, the founder of the early biotechnology start-up Agrigenetics, began to acquire regional seed companies in 1975 in order to finance biotechnology research and development (R&D) and deliver its products to the market. Other early GM start-ups, like Calgene, Biotechnica International and Mycogen, had similar strategies and acquired a number of seed companies in the 1970s and 1980s (Kalaitzandonakes 1997). Multinationals, like Monsanto and DuPont, were latecomers in the seed industry when they started M&As to vertically integrate their assets in GM and other markets and the seeds assets (germplasm) of a number of medium and large independent seed firms, like DeKalb and Pioneer.

Each of these three waves of structural changes in the seed industry was thus driven by breakthroughs and advances in plant science and plant breeding. M&As thereby often changed the presence of firms in the seed business. Table 1 provides an overview of the top nine seed companies in 1985, 1996 and 2009. This table reveals that as agrochemical and other diversified firms vertically integrated into the seed business, seed genetics (germplasm) assets of seed companies were merged into multinational firms with biotechnology R&D investments. Yet, seed business is not necessarily of equal importance to each of the top nine companies; see Section 3 and Table 4.

The entry of these multinationals changed the ownership structure in the seed industry drastically. In 1985 the top nine seed companies had a share of 12,7% of the global seeds market and only four of these top nine seed companies were (owned by) pharmaceutical or petrochemical multinationals. In 1996 the top nine seed companies had a share of 16,7% of the global seeds markets while one of them was (owned by) a multinational. In 2009 the top ten seed companies had a share of 43,8 % of the global seed markets and five thereof were (owned by) agrochemical multinationals. In the same period from 1998 to 2009 the annual sales volume of the global seeds markets increased from 18 billion US dollar to about 44 billion US dollar.

Table 1: The top nine seed companies in terms of net sales 1985 – 2009 (million US$) business strategies after M&As

1985[1]			1996[1]			2009[2]		
Company	**Net sales**	**Share global seed market**	**Company**	**Net sales**	**Share global seed market**	**Company**	**Net sales**	**Share global seed market**
Pioneer	735	4,1%	**Pioneer**	1,500	5,0%	**Monsanto**	7,297	17,4%
Sandoz	290	1,6%	**Novartis**	900	3,0%	**DuPont-Pioneer**	4,700	11,2%
DeKalb	201	1,1%	**Limagrain**	650	2,2%	**Syngenta**	2,564	6,1%
Upjohn-Asgrow	200	1,1%	**Advanta**	460	1,5%	**Limagrain**	1,155	2,8%
Limagrain	180	1,0%	**Seminis**	375	1,3%	**KWS**	920	2,2%
Shell Nickerson	175	1,0%	**Takii**	320	1,1%	**Bayer**	645	1,5%
Takii	175	1,0%	**Sakata**	300	1,0%	**Dow**	635	1,5%
Ciba Geigy	152	0,8%	**KWS**	255	0,9%	**Sakata**	485	1,2%
VanderHave	150	0,8%	**DeKalb**	250	0,8%	**Land O'Lakes**[3]	?	?
Global Seed Market (GSM)	**18,000**	**12,5%**		**30,000**	**16,7%**		**42,000**[4]	**> 43.8%**

Sources: [1] Louwaars et al. (2009); [2] Annual reports; [3] Land O'Lakes (US) reported $ 3,284 million net sales in 2009 by the 'Crop inputs' division (seeds and crop protection). In 2006 seed sales amounted to $ 550 million, so Land O'Lakes probably ranks between the number 7 and number 10 position; [4] Estimates of the global seed market in 2009 range from nearly $ 32 billion (2010 Global Seed Market Database) to $ 42 billion (International Seed Federation, 2009).

3. GOVERNMENT POLICIES AND BUSINESS STRATEGIES AS DRIVERS OF STRUCTURAL CHANGES IN THE SEED INDUSTRY

This section reviews two other main drivers of structural change in the seed industry: government policies and business strategies. First, government policies, such as science and technology policy, intellectual property (IP) laws, and biotechnology safety regulations, will be discussed. Then, business strategies in the seed industry, like R&D investment, R&D collaboration, management of IP, mergers and acquisition (M&As) and (cross)licensing, will be examined. This section closes with a review of enforcement of competition and antitrust laws in the seed industry.

3.1 Government policies

In the 20th century government policies on plant science and technology in the US, Europe and elsewhere are essentially aimed at supporting and increasing agricultural productivity. They include policies for the funding and development of new science and technology, the protection of intellectual property, but also the management of food and environmental risks from biotechnology research through biosafety regulations.

3.1.1 Science and technology policies

The historical review of the application of plant science and molecular genetics to plant breeding suggests that publicly funded scientific research led to several major technological breakthroughs, e.g. hybridisation, recombinant DNA (genetic modification) and genomics. Each of these technological breakthroughs subsequently drove a wave of R&D investments by existing and new private companies in the seed industry, resulting in technological innovations as hybrid seeds and biotech seeds.

North America and Europe

While these technological breakthroughs were driving innovation in plant breeding, seed production and crop productivity, government policies on science and technology and agriculture in the US and Europe interacted with business strategies of seed companies and (agro)chemical multinationals in intricate ways. Until the 1980s public expenditure on agricultural and plant breeding research substantially outweighed private R&D investment. Since then, private R&D investment began to exceed public expenditure. From 1960 to 1996, when various legal forms of IP rights in plant breeding and biotechnology were introduced, global private spending on plant breeding R&D has increased 14-fold and the growth of public expenditure on agricultural R&D slowed-down or even decreased, according to the European Academies Science Advisory Council (EASAC 2004). The EASAC considers this a serious concern because the public sector under-investment gap has been growing, in particular with a view to public sector R&D for plant breeding of minor crops like oats and barley (that are of less commercial interest to large seed firms) and to public goods such as environmental protection and food safety.

Both in the US and Europe but also elsewhere, one rationale for public investment in agricultural R&D has been to address certain market failures (EASAC 2004). While R&D can enhance yields, lower costs, and provide other benefits to producers and consumers and society at large, it may often not be carried by private sector innovators out due to the inability to secure adequate returns from their R&D investments. The ease of copying successful innovations undermines the incentives of potential private sector innovators to engage in R&D which consequently results in a market failure, in that productivity and social welfare enhancing improvements are not realised. One solution is to invest public funds in R&D. Another is to provide incentives for private sector parties to undertake R&D by enhancing their ability to capture some of the value created through successful innovations, typically, through IPRs.

Governments may also choose to cooperate with the private sector in creating innovation. Agriculture in many countries is still characterised by heavily fragmented seed markets. In many cases the individual private benefit is too small to constitute an adequate incentive to invest the substantial capital required. In such cases, agricultural R&D, including applications in biotechnology and plant genomics, have classic 'public good' characteristics. In the view of the EASAC (2004) and others joint action between public and private sector parties and government intervention may therefore be needed to overcome market failures.

While there is concern about the decreasing public expenditures on classical disciplines, like conventional plant breeding, plant pathology and agronomy (Royal Society 2009), public investment on molecular genetics, life sciences and genomics in OECD countries has increased significantly since the 1980s. In 2005, public expenditure on all types of biotechnology R&D in OECD countries amounted to 28.7 billion US dollar. Europe accounted for 4.1 billion US dollar, other OECD countries for 1.43 billion US dollar, and the United States for 23.2 billion US dollar (81% of the total).

Governments use public funding to encourage various policy goals. Europe, for example, used the 70% of its biotechnology research funds for basic biotechnology research (Enzing et al. 2007), while almost 20% was granted to industry oriented and applied research, 2% was used to support knowledge flow and 8% to assure the availability of human resources. Annex D contains several case studies that illustrate how in the US and Europe public research in plant science and genomics interacts with private R&D in plant breeding. The case studies concern: 1) the R&D collaborations of Limagrain with private and public partners; 2) a large European Commission funded Public-Private Partnership in breeding solaneceaous crops (EU-SOL), and; 3) Public-Private Partnerships for smallholders in developing countries.

Emerging markets in Asia and Latin America

The OECD (2009) further noted that current data on R&D expenditures and trend data for new PhDs suggest that countries such as China, India and Brazil will play a growing role in future biotechnology R&D. Over the last decade, the governments of China and India have made significant investments in biotechnology R&D to support innovation for increasing agricultural productivity. China and India rank third and fourth, respectively, in agricultural R&D spending behind the US and Japan (Linton 2010). In 2000, the US invested about 4.4 billion US dollar, compared to 2.5 billion US dollar for Japan, 1.9 billion US dollar for China and 1.3 billion US dollar for India. By 2003, agricultural R&D spending in China grew to 2.3 billion US dollars, while India's agricultural R&D spending remained relatively unchanged in that period.

Within the general field of agricultural R&D, both India and China have selected biotechnology as one of the top priorities. The Indian government has for instance implemented 481 agricultural biotechnology R&D programmes from 2002 to 2006. According to Lin (2010), there are few published estimates of India's total agricultural biotechnology R&D expenditures across relevant government agencies; one exception –

quoted by Lin (2010) – is a publication by James (2008) on India's public sector investment in agricultural biotechnology R&D, which estimated the public investments at 1.5 billion US dollar over the last five years, or about 300 million US dollar per year.

3.1.2 Intellectual Property

To protect the rights of plant breeders against the risk of imitation, governments have introduced various intellectual property (IP) schemes in order to foster innovation in the seed industry. There are two types of IP rights that are relevant for the seed industry: Plant Breeders Rights (PBRs) and patent rights. While PBRs were introduced in the first half of the 20th century, patent rights became more important with the advent of modern biotechnology in the 1980s.

PBRs provide protection to the breeder of a new plant variety. While a 'new' variety must meet a number of criteria to qualify for PBRs, such as distinctness, uniformity and stability, PBRs protect the variety but not the method used to develop the variety. There are also a few important exemptions to the right granted, like the farmer's privilege permitting to save seed, the research exemption that allows scientist to use the protected variety for research purposes and the breeder's exemption that allows another breeder to use the protected variety as basis for further breeding.

Unlike PBRs, patent rights are granted for 'inventions' described in the claims of the patent application, provided the invention meets a number of criteria, including novelty, non-obviousness, inventiveness and utility. A patent grants the right to the patent holder to prevent other parties to produce, use or sell the patented product(s) and process(es) without his permission. In contrast to PBRs, patent rights systems do not provide for a farmer's or breeder's exemption but, depending on the territory, do provide for a (very strict) research exemption. Notably, French, Swiss and German patent legislation also do allow further breeding and product development with patented materials, although a license is needed for commercialisation.

Both IPR systems have been reviewed extensively by Louwaars et al. (2009) and other authors. The Louwaars et al. (2009) analysis of the PBRs granted in Europe up to 2009 showed that the number of applicants for PBRs on cereals, oilseed rape and vegetables has been decreasing over the last few years, resulting in an increase of the share of the top five companies to above 50%. The number of applicants for PBRs on ornamental crops and fruits showed an opposite trend with more applicants and a smaller share for the top five. Large international companies, like Monsanto, DuPont-Pioneer, Syngenta, KWS and Limagrain were all present in the European top.

Trends in patents of enabling transformation technologies, biotech traits and products were also analysed (Table 2). Of the patent applications to the European Patent Office (EPO) from 1980 to 2006, 41% was made by US-based companies, 41% by Europe-based companies and 18% by companies from other countries. Of the patent applications to the US Patent Office (USPTO), 75% were made by US-based companies, 15% by European companies, and 10% by companies from other countries. In 2007, the share of the top ten companies was estimated at about 75% of all patents applications at the USPTO and 43% of all patent applications at the EPO. Notably, in the field of genetic modification, it was estimated that two companies held more than 50% of the patents. For public research institutions, it was shown that from

1986 to 2006 they had a share of 24% of the patent applications to the EPO, and 25% of the patent applications to the USPTO between 2001 and 2005.

Table 2: Distribution of patent applications to the EPO and USPTO 1986 - 2006

	patent applications to	
	the EPO	the USPTO
Europe-based companies	41%	15%
US-based companies	41%	75%
Companies based in other countries	18%	10%

Source: Louwaars et al. 2009

According to Louwaars et al. (2009), it was not clear whether the number of PBRs obtained by a company would be a solid measure of the innovative strength of a company. Whether the number of patents obtained by a company would be a solid measure of a company's innovative strength was not discussed as such.

In emerging commercial seed markets in China and India, the introduction of IP legislation in plant breeding and biotechnology has also been key to attract R&D investments from the major international seed firms. It should also be emphasised, however, that there are specific limits to IP protection in seeds both in China and India. Farmers always have the ability to make 'gray-market' versions of seeds through seed saving, seed exchange and seed sales. For example, in the case of Bt cotton hybrid seeds, a 'stealth' economy emerged in India, in which not only farmers but also seed growers, seed companies and distribution agents worked together (Ramaswami et al. 2008); see Annex E with case studies on China and India.

When IP rights granted are too broad they can stifle rather than stimulate innovation. Several examples on licensing agreements in this study (see Annex B) show that such agreements have only been achieved as a result of IP litigation procedures. In essence, the biotechnology sector faces the need both to protect innovations and to open them up. Consequently, for patent holders, including agricultural biotechnology and seed companies as well as public research institutions, managing IP wisely is no small challenge, as it also requires reconciliation of the needs of the industry with those of government grant-makers and public sector researchers.

There is little doubt that pressure is building to do something to assuage concerns that patents are stifling, not stimulating, innovation (Cukier 2006). A report by an international expert group on biotechnology, innovation and intellectual property, hosted by McGill University in Montreal, Canada, argued that the current system of 'Old IP' rests on the belief that if some IP is good, more IP is better. It also suggested that this thinking increasingly risks becoming counterproductive in sectors like health care and agriculture (TIP 2008). The expert group therefore argued for implementation of 'New IP' models that focus on collaboration and co-operation. Such new IP approaches include open-source models, like BIOS and PIPRA; see Annex F for a review of these open-source models.

3.1.3 Biotechnology safety regulations

Before commercial seeds may be brought to the market, they have to meet a series of agronomic, technical and phyto-sanitary standards and regulations. In the case of biotech seeds, they also need to be 'deregulated' in the countries they are produced and consumed. This means that biotech seeds must undergo safety assessment and obtain market approval under various national regulations for genetically modified organisms (GMOs). Such regulations were shaped in the 1980s and 1990s and are meant to protect the environment and human health against unintended risks that may be associated with organisms whose genetic material had been changed with recombinant DNA techniques. Changes in government policies have led to evolving regulatory frameworks for biotechnology.

So far, the term biotech seed or biotech trait has been used in this study without a proper description or definition. Given the emphasis of this section on biotechnology regulations, the terms need to be described more precisely. A biotech trait can be 'genetically modified' (GM) as determined by the current legal definition within EU law. Other biotech traits can be: 1) traits obtained by marker-assisted breeding (MAB), 2) so-called 'native traits' discovered by genotyping and phenotyping technologies, or; 3) traits obtained by a novel plant breeding technique (NPBT), like RNAi, oligo-nucleotide mediated mutation induction, Zinc-finger nuclease induced mutation, agroinfiltration, reverse breeding, and epigenetic modification; discussions on whether each of these novel plant breeding techniques (NPBTs) results in a GM organism (GMO) requiring regulatory oversight in the EU are currently going on between the European Commission and the EU member states.

While scientific and public discussions on the governance of potential risks associated with the use of GM plants in agriculture have been controversial since the late 1980s, particularly in Europe, public and private parties with interests in GM plant breeding R&D and commercialisation of GM crops have pointed that biosafety regulations imply substantial costs for data collection and regulatory approval. For the first generation of GM crops with a single trait for herbicide-tolerance or insect-resistance, the costs of obtaining market approval have been estimated to vary between 4 million € to 10 million € (Kalaitzandonakes et al. 2007; Schenkelaars 2008). It has been argued that these regulatory compliance costs would discourage public research institutes and small companies to engage in the development and commercialisation of GM crops (COGEM 2008).

Table 3: Number of field trials with GM maize, soybean, cotton and tomato by entity type in the US, the EU, India, Australia and Argentina

Entity type	US	EU	India	Australia	Argentina
CropLife companies	10684	1181	25	40	1061
Other private entities	2067	599	6	14	324
Public institutions	3167	449	20	40	86

Source: compiled by the authors

An analysis of data on field trials with GM maize, soybean, cotton and tomato in the US, EU, India, Australia and Argentina indicates that in terms of numbers, the 'CropLife' seed companies (BASF, Bayer, Dow, DuPont-Pioneer, Monsanto and Syngenta) are, in fact, dominant. Table 3 provides an overview of the numbers of field trials by type of entity in the US, EU, India, Australia and Argentina. Overall, Monsanto ranks first in numbers of private sector field trials with GM maize, GM soybean, GM cotton and GM tomato in these countries. In the case of GM rice, BASF and Bayer rank first in numbers of private sector field trials, followed by Monsanto. Annex J provides more detailed information about field trial applications.

It should further be noted that in some countries regulatory approvals of GM crops also require post-market release monitoring and measures to mitigate adventitious presence of GM material in non-GM crops and in foods and feeds derived from them. As a consequence, seed companies that commercialise GM crops develop so-called 'Product Stewardship' programmes, which should be followed by growers and other users of GM crops, in order to comply with regulatory monitoring requirements and minimise liability risks.

3.2 Business strategies

Business strategies are often interlinked with government policies and shape the structure of the various seed industries. In competitive markets, companies essentially aim to grow and profit from their operations. In dynamically competitive industries like biotechnology, innovation and the development of new products and/or services are essential elements of competitive rivalry. This need for innovation has led seed companies to deploy an array of business strategies. For accessing technologies, germplasm and markets, business strategies deployed by seed companies include in-house R&D on plant breeding and biotech, R&D collaboration with private and public partners, M&As and (cross)licensing of IP.

3.2.1 R&D investment and IP

As indicated earlier, many of the structural changes in the global seed business have been related to business strategies and investments incentivized by some form of IP protection. The first wave of structural change in the (US) seed industry occurred in the late 1930s, when several new commercial seed firms took over the publicly supported research efforts in maize breeding. This public research had resulted in a major technological breakthrough that enabled production of hybrid maize seed. While hybridisation allowed plant breeders to enhance crop yields, they could also protect their intellectual property from the threat of easy imitation. From the perspective of the farmers, hybrid maize had advantages, like higher yield potential, greater uniformity in maturity, and tolerance to lodging, enabling large-scale mechanisation. From the perspective of the seed firms, hybrid maize also had advantages. First, simple examination of a hybrid seed did not reveal its lineage, thus offering companies proprietary control over the seeds they developed. Second, the enhanced vigour is not transmitted to its offspring, requiring farmers to purchase new seed every season to ensure continued vigour. Hence, hybridisation technology provided built-in IP protection and as a result began driving R&D investments and product innovations in the (US) maize seed industry in the 1930s.

The second major wave of structural change in the US seed industry began after the introduction of the Plant Variety Protection Act (PVPA) of 1970 (Fernandez-Cornejo 2004; Cowan et al. 2010). By 1982, 50% of the PVPA certificates were held by 14 conglomerates of companies (Drew 2010). However, IP protection was somewhat limited because the seed market was still dominated by varieties produced from public breeding programmes, farmers were still practicing seed saving for the replanting of open pollinated varieties, and competition between major seed companies was very intense as exemplified by the many close substitutes offered for every variety (Drew 2010).

The development of so-called recombinant DNA techniques in the 1970s, promising rapid and targeted engineering of the genetic make-up of living organisms, brought stronger IP protection and greater amounts of private investment. In the early 1980s several multinationals began investing in (agricultural) biotechnology R&D, boosted by the US Supreme Court ruling of 1980 in *Diamond vs. Chakrabarty* that allowed granting of patent rights on biotechnological inventions. This, in turn, drove further M&A activities (Fernandez-Cornejo 2004).

3.2.2 M&As

The introduction of various schemes for IP in plant breeding and biotechnology, in particular utility patents, drove R&D investment and M&A activities by petrochemical and pharmaceutical multinationals in the seed industry in the 1970s and 1980s. As noted before, this wave of M&As had little discernible impact on the structure of the seed industry. The multinationals mainly acquired and merged small and medium sized regional seed companies that lost market share over time and both independent market leaders, e.g. Pioneer and DeKalb, and smaller regional and local seed companies maintained their market position. Despite the significant capital resources of the new multinationals entering the seed industry, the cost advantages of operating at higher production levels (i.e. economies of scale) were limited and barriers to entry were rather low. In principle, large investments in breeding research and specialised know-how implied that potential scale economies could be significant. Indeed, only a few large seed companies maintained extensive breeding efforts and developed proprietary varieties. Further, substantial time lags between genetic research and commercialisation of improved varieties created potential entry barriers. Yet, the need for geographic adaptation of all new seed varieties placed bounds on R&D scale economies. Importantly, it also created commercial opportunities for specialised breeding (foundation seed) companies, which minimized entry barriers. They developed and broadly licensed proprietary varieties to a large number of small regional and local seed companies, which in turn adapted them to their local conditions.

By the early 1990s, many of the multinational firms that led the M&A activity in the previous two decades had divested their seed assets. For example, British Petrol (BP) divested Rijk Zwaan and Shell divested Nickerson Zwaan. However, a few multinationals maintained or expanded their presence in the US seed industry and continued making significant investments in biotechnology R&D. In the late 1990s a third wave of structural changes in the seed industry took place, when these few multinationals implemented business strategies, like M&As to vertically integrate GM assets and seed assets to increase and consolidate market share and distribution capacity and acquire access to high quality proprietary seed germplasm, or put differently, to achieve economies of scale for return on R&D investment. (Kalaitzandonakes et al. 1997; Graff et al. 2003; Fernandez-Cornejo 2004; Drew 2010).

Notably, in most of these multinational firms, net sales of (agro)chemicals still dominate the net sales of seeds. Other companies, such as Limagrain and Land O'Lakes, have a cooperative background and are more diversified. In these companies, sale of seeds is a part of a range of agricultural services, including food production, sales of agrochemicals and even machinery. Finally, firms like KWS from Germany and Sakata from Japan have remained more specialised in seed production and distribution. Hence, seed business is not necessarily of equal importance to each of the top ten companies; see Table 4.

Table 4: The share of the seed business in the total operations by company, 2009

Company	Net Sales by Division						
	Total	Agriculture & Health/Nutrition		Seeds & genomics		Pesticides	
	in mln. $	in mln. $	share	in mln. $	share	in mln. $	Share
Monsanto	11,724			7,297	62.2%	3,527	30.1%
DuPont-Pioneer	26,109	8,300	31.8%	4,700	18.0%		
Syngenta	10,992			2,564	23.3%	7,116	64.7%
Bayer	8,351			645	7.7%	6,958	83.3%
Dow	46,644	4,537	9.7%	635	1.4%		
Limagrain	1,582			1,155	73.0%		
Land O'Lakes*	10,409			3,284*	31.5%		
BASF	65,032					4,677	7.2%

* Land O'Lakes (US) reported $ 3,284 million net sales in 2009 by the 'Crop inputs' division, which includes both seeds and crop protection.
Source: Annual Reports

According to Chataway et al. (2004), one of the reasons of agro-chemical firms to enter the seed market was that the agro-chemicals market had reached maturity and sales and profits were declining. Indeed, biotechnology and the adoption of GM crops significantly contributed to such declining profits and sales. Agro-chemical companies increased their technological diversity in order to introduce new crop protection products and sought to achieve economies of scale to offset the high costs of biotechnology R&D (Wield *et al.* 2010). Insufficient patent rights drove many mergers of large and small firms in agricultural biotechnology (Kalaitzandonakes and Bjornson, 1997, Rausser et al. 2008) and acquisitions of seed companies by agricultural biotechnology firms allowed access to (elite) germplasm of many different crop species (Fernandez-Cornejo 2004; Moss 2009). Though, companies differed in the extent to which they invested in genetic modification (GM) technologies as a replacement for non-GM technologies or as an addition to other technological trajectories. Chataway et al. (2004) distinguishes three strategies:

1. Investment of large shareholder funds in acquisitions, a strategy performed by Monsanto and DuPont, thus 'buying the channel to the market' for their seeds. This also included heavy investment in building up a technological base in biotechnology. Monsanto's approach was based on a large number of acquisitions spread over many years, whereas DuPont invested $ 7.7 billion in the acquisition of Pioneer in 1997/1998, thus buying itself into the seed business in one blow.
2. A great deal of investment in technology and some acquisitions, a strategy applied by Zeneca and Novartis Seeds, later Syngenta, Dow, and AgrEvo, later bought by Aventis and subsequently by Bayer. This gave them a reasonable 'route to market', but they did not invest in seed companies to the same extent as Monsanto and Dupont. To some extent, a similar strategy was deployed by the cooperative Limagrain.
3. A late starter such as BASF (late 1990s) bought itself into biotechnology bypassing the earlier innovation phase of other companies. In 2007 BASF signed a $ 1.5 billion strategic

R&D collaboration with Monsanto to develop higher yield maize, soya, cotton and oilseed rape (third-generation plant biotechnology), adding another $ 1.0 billion to the deal in 2010.

Companies thus differed in the extent to which they invested in GM technology as a replacement for non-GM technology or as an addition to other technological trajectories and product lines. Monsanto demonstrated the most significant early commitment to the GM technology. The R&D strategy of developing GM crops tolerant to glyphosate and GM insect-resistance crops fitted well with its significant share in the herbicides market and its minimal presence in insecticides. Monsanto's technological leadership was bolstered by its rather aggressive acquisition strategy. From 1996 to 1999, it acquired a group of seed and biotechnology companies with an investment of more than 8 billion US dollar.

Most other multinationals had more to lose from a technology whose main marketing attraction was lower chemical use, since they were predominantly chemical firms with broad portfolios of agro-chemicals whose sales volumes would decrease if the claims for GM technology turned out to be valid. These companies moved more slowly than Monsanto and in different ways. Annex A presents two case studies on the evolution of Monsanto and Syngenta in the seed industry and one case study on the evolution of Limagrain, the world's largest seed cooperative.

3.2.3 Licensing

Another commonly used business strategy to gain access to new markets and increase market share of GM traits and seeds is licensing IP for GM traits and seed assets. Licensing has frequently aimed at stacking GM traits developed in house with traits developed by third parties including partners or competitors in the private sector and/or public sector partners, like universities and research institutions. In most cases seed companies agree (mutual) access to proprietary biotech traits. As a result, markets can be provided with seeds that combine different GM traits, for instance herbicide-tolerances and/or insect-resistances. Several of these IP agreements result from long legal disputes on infringement of IP claims. In some cases, agreements are also reached on (mutual) access to proprietary enabling (transformation) technologies. Finally, licensing agreements of germplasm and traits in particular are important business strategies for smaller seed firms that have limited breeding and R&D activities as they specialize in regional marketing and distribution. Annex B examines a series of such licensing agreements among major biotech seed companies.

3.3 Competition and anti-trust laws

Neoclassical economic theory defines 'perfect' competition as an equilibrium situation where there are many enterprises, each with limited market power, each charging the same price for a homogeneous good in a market characterised by costless entry and exit. Perfect competition is assumed to lead to maximum consumer welfare. Anti-competitive practices are business actions that prevent or reduce competition in particular markets and are assumed to reduce consumer welfare. Examples of such practices include the creation of barriers to entry for firms, dumping of products on markets below production costs, price fixing, linking product together to limit customer/consumer choice. Such practices are considered suspect especially when firms engaging in them have market power (a large share of the market).

Governments use competition laws or antitrust regulations to prevent anti-competitive practices. Nevertheless, the realities of modern markets are likely to be more complex than static theories of perfect competition suggest. This is especially true in industries where competitive rivalry is driven by the investments in R&D and the introduction of new products, like in the case of biotechnology. The entry of large multinational firms into the seed industry has been the subject of much debate, often suggesting possible monopolisation (Fernandez-Cornejo 2004; Murphy 2006; Hubbard 2009; Moss 2009; Cowan 2010). What speaks in favour of their entry is that large firms enjoy scale economies. Firms with significant market share for example can achieve scale economies in R&D as well as in IP, deregulation, production or marketing. As a result, they could be more efficient in developing new technology than smaller firms. Because of their market size, they can also generate (temporary) profits by charging prices above marginal costs in order to pay for R&D and other fixed expenses (see section 5). Alternatively, they may also be able to invest (temporarily) in seed research with resources and revenues from other corporate divisions. Large diversified firms may also be able to increase their efficiency through opportunities for economies of scope, i.e. producing several products together at a cost less than producing them separately. For example, once a specific gene has been identified and isolated, this gene can be used in a number of crops. The entry of large multinational firms has also expanded markets, from domestic or regional to global, thereby increasing sales volumes and profits supporting R&D for smaller and more fragmented markets around the world. But the entry of large firms may also have drawbacks. The presence of large firms in the industry raises concerns about increasing market concentration and the presence of market power. If market power is exercised, it may raise industry profits and margins, and farmers may pay higher-than-competitive prices for seeds.

It is interesting to note that government policies often may seem at odds with each other when it comes to motivating R&D and innovation. Patent law, like competition policy, seek to benefit the public by granting a temporary monopoly on an invention with substantial utility. On a simplistic level, antitrust law seeks to limit a potential market monopoly, often achieved through patent grants. In reality, the relationship between antitrust and patent law is multidimensional (Leslie 2009). In some contexts, particularly in the short run, antitrust and patent law can be in tension. For instance, a patent holder can exclude (infringing) competitors from the market, even if the competitors can make the product more effectively and/or efficiently. In the long run, patent laws promote discovery and new product development leading to economic growth and social welfare gains. Finding a balance between antitrust and patent law thus involves a series of trade-offs: 1) To what extent should competition be suppressed in the short run in order to encourage innovation in the long run?, and; 2) Are there instances and industries where intellectual property rights are unnecessarily expansive, such that competition is suppressed more than needed to incentivise innovation?

Antitrust law and patent law should therefore be discussed in conjunction with the recognition that they both are components of an overall innovation policy that seeks maximising both static and dynamic competition.

Over the last decade two major actions by the US Federal Department of Justice (DoJ) included Monsanto's acquisition of DeKalb in 1998 and Delta and Pineland in 2007. In both of these cases the DoJ recognised both the importance of innovation in markets and rival access to Monsanto's patented technology to competition.
In 1998 the Monsanto's 2.3 billion US dollar acquisition of DeKalb raised concerns of the DoJ Antitrust Division about competition in the biotech maize seed market (DoJ 1998). The

combination of Dekalb's IP of the leading method of maize transformation, so-called 'biolistics', and Monsanto's IP claims in the emerging *Agrobacterium*-transformation technology led to concerns about competition for maize transformation. In the view of the DoJ, other parties in biotechnology needed access to transformation technology, on competitive terms, for introducing new traits in maize seed. Monsanto had to spin off its IP claims on *Agrobacterium*-transformation technology to the University of California at Berkeley, which as an independent entity with experience in the exploitation of such IP would ensure that other parties would not be deprived of future competition in maize transformation technology. In addition, Monsanto had to enter into binding commitments to license maize germplasm of its subsidiary Holden to over 150 seed companies that were Holden's customers. This would ensure that the merger with DeKalb did not reduce competition in biotechnology and seed germplasm developments in maize. One year before, in 1997, Monsanto had acquired Holden with a share of over 30% of the maize hybrid seed market in the US.
The DoJ had similar concerns about the acquisition of Delta and Pineland, a major US cotton seed company, by Monsanto in 2007. The DoJ essentially required Monsanto to eliminate stacking prohibitions in its cotton trait licenses. Under terms of the agreement, Monsanto had therefore to divest various assets; see Annex I for details.
Furthermore, in October 2009, the DoJ confirmed it had started antitrust investigations into allegations that Monsanto would be using anticompetitive tactics with regard to its patented genetic seed traits and the emergence of generic versions of the Roundup Ready biotech trait after its patents expires in 2014. At this point in time it is uncertain whether the DoJ will bring a case against Monsanto; see for details Annex C, which examines the future of generic biotech seeds in the light of a dispute between DuPont-Pioneer and Monsanto.

Moreover, in 2006, the government of the state Andhra Pradesh in India brought a case to the antitrust authorities, because Monsanto-Mahyco would have exercised monopoly power in setting its prices for Bt cotton hybrid seeds. The antitrust authorities agreed with the state government, which led Monsanto-Mahyco to appeal to the Supreme Court. Meanwhile, the state government negotiated with the seed companies to set the prices for Bt cotton hybrid seeds, which was followed by the state government of Gujarat and Maharashtra that adopted similar pricing policies (see further Annex E).

Finally, in the summer of 2010, the European Commission announced investigations under the EU Merger Regulation No. 139/2004 into Syngenta's proposed acquisition of Monsanto's global sunflower seed business. In November 2010 the European Commission cleared the acquisition. However, the European Commission required Syngenta to divest Monsanto's sunflower hybrids, commercialised or under official trial in Spain and Hungary, including the parental lines. Otherwise the transaction would have removed a considerable and innovative competitor to Syngenta, reinforcing the latter's market leader position. The transaction also raised concerns about the activities of exchange and licensing sunflower varieties, insofar as the merging parties would be in a position to restrict the access of competitors to input necessary for the commercialisation of sunflower seeds. In the light of the commitments of Syngenta, the European Commission concluded that the transaction would not significantly impede effective competition in the internal market or any substantial part of it.

4. INDUSTRY ASSESSMENTS OF STRUCTURAL CHANGES AND INNOVATION IN THE GLOBAL SEED INDUSTRY

This section presents the main findings from interviews with eleven top executives from leading seed companies (see Annexes G and H). In these interviews industry executives described in detail the ongoing market pressure to invest in R&D in order to remain competitive and trends in R&D spending and new product introductions.

4.1 Ratings of drivers of structural change

Prior to discussing the consequences of structural changes in the seed industry, interviewees were asked to rate a number of possible drivers for concentration in the seed industry. The results are listed in Table 5.

Table 5: Rating of possible drivers of concentration by interviewees (1 = low, 5 = high)

	Possible drivers					
Company	Changes in seed industry's profit margins	Changes in commodity markets	Increase in plant breeding R&D cost	Cost of applying GM technology	Adoption of patent rights for plants	Regulatory requirements for GMOs
1*	4	1	3	5	5	2
2	-	-	5	-	-	-
3	1	1	4	4	2	5
4	1	1	1	1	5	5
5	-	-	Main driver	-	-	-
6	3	2	5	-	-	4
7	4	2	5	4	3	4
8	-	-	5	5	5	4
9	4	1-2	5	2-5	2-5	2-5
10	2	1	5	4	-	3
11	5	5	4	5	4	4

* Company No.1 identified two additional drivers: 1) Costs of access to genetics (finished lines) and germplasm for breeding uses (rating - 4), and; 2) Legal costs (rating - 4)

There was meaningful diversity in the perceived relative significance of the various potential drivers of structural change. For some of the interviewees, especially for those specialised in vegetable seeds, the cost of applying GM technology is not relevant for the simple reason that they do not apply GM technology in their products. Nonetheless, with few exceptions, the interviewees ranked the increase of plant breeding R&D cost, the cost of applying GM technology and regulatory requirements for GMOs as the main drivers of industry consolidation in recent years. The cost of pursuing patent rights was considered a major driver by a number of interviewees, too, but a number of interviewees rated this driver of low to moderate importance.

The importance of R&D in gaining competitive advantage was highlighted by several interviewees. R&D costs have increased and are expected to increase further, at least proportionately to the growth rate of annual turnover. Increasing R&D costs require sufficient critical mass for return on investment. This business strategy and its effects are described in the following two sections. The third section discusses the effects of regulatory costs, which were classified by most interviewees as another major driver for concentration. In the fourth section, the perspective of the industry executives on access to germplasm IP rights and legal costs are discussed. The final section discusses the concepts of open innovation, public-private partnerships and the development of new GM quality traits (output traits) and their implications for the industry's future innovation.

4.2 Competition and the need to invest in new technologies

Almost every one of the collaborating industry executives identified the increase in plant breeding R&D costs as one of the major drivers for concentration in the seed industry. Genetic improvement is a major driver in the competitive seed business, which can only be safeguarded by investing in the technology. Therefore, most interviewees think that R&D investment will continue at the same (high) level in the coming years and R&D costs will grow at least proportionately to the growth of the total turnover.

One of the interviewees indicated that the growth in R&D spending in vegetable seeds will increase due to investment in technology and patents. Table 6 provides a range of the expected R&D cost share and the IP and legal cost share in the industry. Current R&D spending ranged from 10-30% of turnover and similar ranges were expected in the future.

Another interviewee noted that in markets where GM traits have a large market share, such as maize seed in the United States, companies must offer products with GM traits to compete. Working with GM traits is labour intensive and requires higher skilled personnel, which forces companies to put more of their R&D budget into GM technology and spend less for germplasm improvement.

In addition, all companies continue to explore non-GM interventions such as mutant breeding, TILLING populations, and Marker Assisted Selection (MAS). The strategic choice for non-GM methods is particularly important in Asia where seed prices are generally low making it hard to recoup investments in GM technology, one interviewee said. Moreover, working on GM crops increases market uncertainty. As another interviewee put it "you never know whether and when you will obtain regulatory clearance."

One of the interviewees remarked that the development of MAS, sequencing and more sophisticated genetic modification tools that do not result in a GMO product may make the controversy about GMOs obsolete. Nevertheless, the new technologies for unlocking the potential and diversity of our germplasm such as genomics and bioinformatics also make R&D more expensive. These tools are more costly than conventional breeding methodologies but in the end they are more effective in increasing crop productivity, which makes them profitable for the company's customers. Since there are competitors in the market offering ‘increased crop productivity’, the remaining seed companies have to also invest in R&D in order to stay competitive in the market.

Table 6: R&D cost share & IP and legal cost share of total turnover (or seed business turnover)

Company	R&D cost share	Future R&D cost share	IP and legal cost share	Future IP and legal cost share
1	15%; over last 10 years annual 25% increase of R&D costs due to GM	Annual 10% increase of R&D costs	5%	Up
2	10% – 14%	R&D costs will increase proportionate to growth	Company does not report this figure	-
3	10% - 11%	-	Internal IP and legal procurement costs negligible relative to overall product development costs	-
4	25%	R&D costs will increase proportionate to growth	2%	Up by 15% to 20% per year because of patents
5	20% - 25%	25% is maximum because of costs other business operations	IP and legal costs for utility patents on traits and germplasm are 1% to 2% of R&D budget.	-
6	15%; over last five years annual increase of 0.5%	Up but uncertain how much because of costs of other business operations	-	Up
7	14%	17% - 20%	35% of R&D costs	-
8	Field crops 30%; vegetables 20%	Field crops same; vegetables up	Small fraction	Up
9	14% - 15%	R&D costs will increase proportionate to growth	IP department grew from 1 to 5 persons over last few years	Up
10	9% - 10%	-	Company does not report this figure	Up

Data source: Interviews held by the authors in October 2010

Although the high development costs, the regulatory and market uncertainties associated with GM crops as well as the availability of alternative technologies are reasons why vegetable seed companies or divisions generally prefer not to invest in the development of GM traits, most of them have developed the technology, but according to one interviewee “put it on the shelf”. A few interviewees suggested that for some vegetable seed companies it is becoming difficult to increase the R&D expenditures further as its share to the total turn-over in seed sales continues to increase. One interviewee commented that specialised seed companies may no longer keep pace with competitors that can tap financial and R&D resources from other business operations.

4.3 Competition and the need to create access to new markets

The increasing investment in R&D requires the seed companies to develop new markets in order to have sufficient critical mass and revenue base, almost every interviewee said. Especially the costs of developing a GM crop and bringing it to the market are substantial, according to many interviewees. Seed companies have to recoup those costs from seed markets, which might be large, as in the case of field crop seeds, or from smaller (niche) seed markets, as for most vegetable crops are. These market size considerations plus the potential added value of new traits largely determine which crop species and traits are suitable for GM technology. GM technology has so far been used in product innovations in seed markets for major field crops, like soybean, maize, canola and cotton, where, as one of the interviewees phrased, 'increased productivity' adds value for the company's customers.

M&As often dominate the geographic expansion of seed companies. In addition to mergers and acquisitions, all interviewees explained that their companies continuously seek opportunities for expansion of their business operation into new markets, both geographically and in new crop species through organic entry and growth, joint ventures and other business partnerships.

4.3.1 Emerging markets and the position of China

All interviewees indicated that further growth in the global seed market is to be expected. Nearly all seed companies consider emerging markets in Asia and Latin America to have growth potential, for instance in a major field crop as rice.

In Asia, the concentration of the seed industry is still very modest, so seed (distribution) companies are expected to continue to grow in size, many through M&As. This restructuring will likely be shaped by government policies. In China for instance, the government policy on M&As in seed markets intervenes at two levels. At one level, the Chinese government is pushing domestic seed companies to merge among themselves. Today, there are about 3,000 domestic seed companies in China, and the government's goal is to have 30 – 50 big companies in ten years from now. Moreover, the Chinese government imposes limitations on foreign companies for taking shares in Chinese companies. Foreign companies are allowed to have the majority of shares in R&D, but not in seed production and distribution, where the maximum level of allowable ownership is set at 49%.

Given the ongoing fast economic growth in China, it is expected that Chinese seed companies will also seek to invest in major seed companies outside China. In the next ten years, according to one interviewee's predictions, there will be one Chinese company in the top ten of seed companies in the world, or at least controlled by Chinese.

4.3.2 Expanding markets in new crops: rice and wheat

Several industry executives expect that rice and wheat could be two potentially interesting new crop species for future growth of their seed business. The seed market for rice is still very modest in size. However, it was thought that the development of hybrid rice could provide sufficient value to the farmer and adequate protection to the seed companies, both of which are needed for further growth in this market. Hybridisation in rice is already well underway and in the next ten years more *Japonica* types will become hybrids. There is also significant experimentation with GM traits for rice, though issues of consumer acceptance and market uncertainty will still need to be resolved.

In wheat about 50% of the global market consists of farm saved seed. One of the interviewees pointed out that, due to its low productivity, wheat production is slowly retreating from the original wheat production regions in the US. Maize has become a more productive and profitable crop because of its genetic improvement (including GM) during the past decade. Farmers therefore tend to grow maize instead of wheat. According to another of the interviewees, farm saved seed is a barrier to innovation as the market is commercially unattractive to invest in. During the past decades, genetic improvement in wheat has been only been half of the genetic improvement in maize. In the US, where wheat is mainly only bred by universities, genetic improvement has been even lower. As with rice, the availability of hybrid technology could be an important driver of innovation in the wheat seed markets, since hybrids would enable return on R&D investments in genetic improvements and product innovation.

Whether wheat is going to be the next big GM crop will also depend on the availability of new traits and their added value in wheat, as a few interviewees suggested. A few of the industry executives confirmed that their companies are now investing in wheat breeding. The main markets include Australia, Argentina, Canada and the US. In addition, some interviewees pointed at major trade associations of these countries that have meanwhile taken a (cautiously) positive stance on wheat seed with GM traits.

4.3.3 Licensing and strategic alliances

All interviewees explained, albeit in different words, that licensing (out-licensing and in-licensing) is just another valuable business strategy for accessing enabling technologies, traits and germplasm. One of the interviewees provided Table 7 that shows the number of plant-related license deals of its company in 2010.

Table 7: Number of Plant-Related License Deals of Syngenta (2010)

OUT-LICENSING (number deals)			IN-LICENSING (number deals)		
GM-Trait	**Native Trait**	**Technology**	**GM-Trait**	**Native Trait**	**Technology**
158	6	142	26	2	48

Data source: Interviews held by the authors in October 2010

Further, as one interviewee indicated, small seed companies also increasingly need to have access to technology. For these companies, licensing becomes a primary strategy for remaining competitive in the market. However, according to some interviewees, closing deals with companies with major interests in biotech traits has become difficult. Sometimes business models and market interests are not well aligned making negotiations complicated and lengthy. Other interviewees raised the question: How willing are companies to license? Licensing contracts, they pointed out, have become increasingly extensive (“thick”) because of the different types of restrictions license holders seek to impose on licensees.

4.3.4 Biotechnology regulatory costs

The costs of bringing a GM crop to the market is considered a major driver for concentration in the seed industry by most of the interviewees. Estimates of regulatory compliance costs ranged widely. Some of the interviewees mentioned figures of 100 million US dollars or even higher, whereas the figures mentioned by others added up to a ‘modest’ 15 to 30 million US dollars. Table 8 summarises the information provided by the interviewees in relation to cost items, including trait discovery, GM event construction, product development, GM seed multiplication, GMO regulations, IP and license costs

Table 8: Breakdown per cost item of total costs of bringing a GM crop to the market

Company	Trait discovery	Event construction	Product development	Seed Multiplication	GMO Regulation*	IP and license costs
1	-	-	-	-	-	-
2	50%; $ 100 - 150 million		-	-	-	-
3	-	-	-	-	80% of total costs of $ 140 million	-
4	-	-	-	-	$ 12 million	-
5	10%: $ 30 – 100 million				80% of total costs of $ 30 million to 100 million	10% of total costs of $ 30 million to 100 million
6	$ 20 million - 100 million US dollar					
7	$ 1 – 3 million	$ 2 million	$ 1.5 million	-	Global $20 – 25 million	$ 2 million
8	$ 0.5 – 10 million	Several millions		$ 1 million	Costs are going up	$ 1 million
9	Minor costs	$ 6 – 7 million			$ 10 – 15 million	-
10	$ 1 – 5 million	$ 5 – 15 million	50 – 60 million			-

* In China, only Chinese companies are allowed to bring a GM crop to the market; deregulation by the government, which bears the costs.
Data Source: Interviews held by authors in October 2010

Only few interviewees were able or prepared to provide a detailed breakdown of the total costs per cost item for bringing a GM crop to the market. Several interviewees noted that it depends on how one attributes the costs to specific activities in the R&D and product development process, an issue that is dependent on internal accounting methods which are unique to each company. A number of interviewees also distinguished between the cost of a single country approval for a GM crop and the total cost of a global approval. Overall, the interviewees with experience in bringing GM crops to the market commonly agreed that regulatory compliance costs for GM crops are substantial but their estimates thereof varied widely, from 10 – 15 million US dollars to more than 100 million US dollar.

4.4 Consequences for access to germplasm

According to the industry executives, ease of access to germplasm primarily depends on the scope and nature of IP rights and the legal costs associated with those rights. In addition, regulatory requirements may substantially hamper access to GM traits.

4.4.1 IP rights

The interviewees showed a divergence of opinions on the impacts of IP laws, especially patent rights, on the structure and innovation of the seed industry.

Several interviewees argued that patents allow 'safe' disclosure of groundbreaking information about the technology, which can be used by other innovators. Patents require the disclosure of an invention in order to be granted, and are therefore one of the best tools to ensure knowledge-sharing and faster innovation cycles. The substantial investments in R&D of the various companies in the industry are tied to the patentability of their innovations , as one interviewee phrased. This is essential for securing an adequate return on their R&D investment. Denying patents on plant-related innovations would have the unintended consequence of stifling innovation by causing a reversion to trade secrets as the sole remaining protection mechanism, another interviewee warned.

Yet, defenders of strict patent protection recognised that, as in any new area of technology, the early phase of application of patent law to plant breeding and biotechnology had been characterised by uncertainty of how to describe these new inventions and how to strike the right balance between the contribution of the inventor and the scope of the granted claims. In the early phase of the biotechnology industry, one of the interviewees said, that patents were usually granted with very broad claims, which led to much opposition and invalidation procedures that eventually resulted in the rejection or narrowing of the patent claims. Meanwhile, patent offices have gained more experience and the present quality of patents in the biotechnology industry is not substantially different from those in other technology areas. According to this interviewee, this demonstrates the self-calibrating capability of the existing patent system.

In the US, there is no exemption under patent law as in France, Germany and Switzerland (see paragraph 3.1.2.) and germplasm too can be protected by patents (so-called 'utility patents'). According to one of the interviewees, this has narrowed access to germplasm for universities, public institutions and smaller breeding companies in the US. It also has resulted in a faster consolidation in germplasm, especially among big seed companies, because these companies prefer utility patents over PVP protection. One of the interviewees pointed to the value of IP as a means of creating incentives for R&D in the US soybean seed market. This market was previously largely farmer-saved seed and attracted limited private interest in breeding and technology development. Utility patents on germplasm and biotech traits enabled the profitability of the company's investments in soybean breeding. One interviewee explicitly argued that the position by the Dutch seed industry association Plantum NL would be detrimental to investment; see position text box below. According to this interviewee, the argument that patents may hinder innovation is not correct. Patents do promote innovation but at the cost that patents may (temporarily) restrict <u>the use of</u> innovations.

Several other interviewees argued that patents on traits can hinder breeding activities, have a negative impact on innovation, and accelerate the process of concentration. One of these interviewees indicated that in the case of tomato breeding, patent applications for about 20 traits have been submitted; if these patents are granted, other tomato breeders will face a serious problem. A few of the interviewees speculated that this development had contributed to the decision by De Ruiter Seeds to sell its assets to Monsanto, although the company itself was also trying to acquire strong patent positions, in order to stay in business.

The Plantum NL position on patents and plant breeders' rights

Plantum NL, the Dutch association for breeding, tissue culture, production and trade of seeds and young plants, has proposed to amend patent law. By inclusion of a breeders' exemption into patent law, genes and genetic components in plants could be made freely available for the development of new varieties. Patented biological material (germplasm) should be freely available for breeding new varieties and the use of these varieties should be consistent with the breeders' exemption of the UPOV Treaty. Availability, use and exploitation should not be hampered by patent law. New methods and techniques should continue to come under patent law, though.

Source: Plantum NL, 6 May 2009

Further, a number of interviewees distinguished between patents on what they called 'native' traits and patents on GM traits. For GM traits, several interviewees commented, it is different because of the level of investment and regulatory compliance costs.

One of the interviewees expected that within less than 5 years the complete genome of about 20 crop species will be fully covered by patents because of the patentability of 'native traits'; traits that exist in nature. There is already a lot of activity in high-throughput sequencing, a fast and cheap technology that provides data about the genotype. "Add to this", the interviewee said, "high-throughput technology for determining the phenotype, the bio-informatics computing power to put all data together, and on top of that, a bunch of lawyers for meeting patenting requirements, what you then in the end get is a 'patent machine for carpet bombing'. This will result in a completely unworkable situation because it will lock access to germplasm and genetic diversity. It will also endanger diversification of germplasm, another interviewee suggested, while there is a lot of breeding potential to unlock germplasm, and plant breeders need broad diversity for improving their gene pools."

Moreover, a number of interviewees believed that a consensus seems to be emerging within the European Seed Association (ESA) and the International Seed Federation (ISF) about the exemption under patent law, similar to the exemption in current French, German and Swiss patent laws, which allows pre-commercial product development. Several interviewees argued that such an exemption under patent law will allow more seed companies breeding their products more broadly, as they can test and work with the technology prior to its commercialisation.

4.4.2 IP and legal costs

Several of the interviewees expected their companies' IP and legal costs to increase further while others considered IP and legal costs negligible compared to overall costs of business operations. One interviewee argued that the costs of filing and maintaining patents will continue to increase because competition forces companies to file for patents, even for patents that are not ‘appropriate’. Another interviewee explained that due to a change in the company’s orientation the value of its IP became more important and its IP department grew from 1 to 5 people over the last few years. Yet, another interviewee expected an annual increase of its total costs by 7%, whereas IP and legal costs are expected to increase by 15% to 20% per year because of the increasing use of patents.

One of the interviewees explicitly mentioned the problem of IP litigation procedures that may be caused by seed companies using different technologies for transferring a biotech trait. Since there are different kinds of technologies that help to identify and locate a trait, seed companies that find a way to transfer a trait in a smarter way should also have the right to use those traits.

Another interviewee showed concern about the raising IP and legal costs, as this takes money away from R&D. Another interviewee commented that not all seed companies are fully equipped to know even what has been patented by other seed companies, as they are mostly not using IP databases. Yet, if they use patented traits, they can face lawsuits because of infringing certain IP rights. Characteristically, one of the interviewees said: “If we have two lawyers behind every breeder that will not lead to innovation in the long run. Instead of using the money to protect certain things and arm-twist each other for patent infringement, everybody should be able to get value, sharing is the real solution here.”

4.4.3 Stewardship programmes and liability

Several interviewees expressed concern about constraints in relation to so-called ‘stewardship programmes’ for GM crops that have already obtained regulatory approval because of regulatory requirements for post-market release monitoring of possible risks to the environment and human health and compliance with government policies and/or market standards for the adventitious presence of GM traces in non-GM products.

A few interviewees pointed out that in cases of licensing the recipient of GM plant material - another breeding company – had to have the appropriate tools to follow the stewardship requirements, because otherwise liability claims would accrue to the developer. One interviewee explicitly indicated that the company did not allow other companies to stack its traits without prior agreement on conditions and requirements for stewardship.

4.5 Consequences for innovation

4.5.1 Open innovation

Innovation in plant breeding is only possible when you invest a lot of money, one of the interviewees noted. In particular larger companies that are successful in the market earn a lot of money that can be invested in innovation. For example, large firms in the vegetable seeds industry spend about 20% to 25% of their revenue on R&D. In contrast to the potato breeding industry, which is dominated by cooperatives that hardly invest in R&D, one of the interviewees said. As a result, there is little innovation in potato breeding; so, one might therefore argue that especially large companies are needed for innovation because of their capability to spend a lot of money on R&D.

Several interviewees considered open innovation –not to be confused with open source- a useful approach. One of the interviewees noted that complex breeding challenges can be solved through open innovation and collaboration networks that encourage multi-disciplinary, “out-of the box” inputs or integration of other innovations, and which augment in-house resources/expertise. They can allow the seed industry to innovate faster and accomplish more in less time and with fewer resources. Open innovation can also be applied to certain breeding assets that are not served well by exclusivity, such as germplasm collections and enabling technologies. One of the interviewees indicated that the company had donated its maize genetic stocks for public research, because everybody benefits when new discoveries are made.

Other interviewees, however, believed that some seed companies have become less willing to share their traits. Other threats to open innovation mentioned by the interviewees were the increasing complexity of IP negotiations and contractual prohibitions of stacking, which reduces the flexibility to use and combine own traits and traits licensed from other companies.

4.5.2 Public Private Partnerships

Public Private Partnerships (PPPs) are viewed by government as a key tool to bridge the gap between public and private sectors’ distinctive competencies. For governments, PPPs are a means to translate shared research outputs into useful, relevant tools for increasing agricultural productivity. PPPs can offer access to a greater variety of technology choices, they can spread and share the financial burden of research and they can create flexible, expert resources for capacity-building. One of the interviewees indicated that public R&D is important for the company, as roughly 10% of the company’s R&D is outsourced to public sector partners.

Nonetheless, opportunities for PPPs can be uneven. One of the interviewees stressed the difference between the US and the Netherlands: In the Netherlands, universities are not allowed to breed final products, whereas in the US and elsewhere universities have the ability to do so and compete with the private sector.

Another interviewee stated that in the EU and the Netherlands, there is strong collaboration in pre-competitive R&D. Not only R&D results that are directly applicable in business operations are important, collaboration also aims at establishing relationships between company scientists and academic researchers, gaining insight in research by universities and opportunities for training and recruitment of highly-skilled research personnel. In the US, collaborations tend to be more bilateral between companies and specific public partners. The interviewee argued that the Dutch way of working together might be driven by necessity, because the seed companies are much smaller than in the US, and also because it historically originates from the typical ‘golden triangle’ between the government, knowledge institutions and companies that already exists for decades in the Netherlands. This has led to a blossoming seed industry in the Netherlands, focus on innovative breeding, thereby more or less forcing the public sector to do fundamental research. How to maintain this knowledge infrastructure, from which everybody benefits, is now a Dutch concern.

By contrast, US universities are more ‘commercial’ in their approach, another interviewee said. He added “how can you teach plant breeding if you do not have a commercial plant breeding programme?” Some interviewees pointed at large seed companies that have so much in-house R&D capacity that they can do their own fundamental research and are therefore less dependent on public research than small companies.

Many interviewees recognised that universities do a good job in basic research but how to collaborate with the private sector does not always seem to be clear to them. Although most research projects initiated by universities are interesting from a science point of view, one of the interviewees said, they should understand better that companies seek solutions for their present problems. The private sector really wants to get something out of it and it does not like to participate in 'blue horizon' research.

Another interviewee suggested that the public research institutions are often afraid that companies just wish access to the 'public sector' gene pool for making a profit. Public research institutions should however understand that these gene pools are used for further improvement of crop productivity, from which farmers will profit in the end. While public plant breeding research institutes have knowledge and skills for further development of gene pools, they lack the competencies for product development. Companies are much better equipped to ensure that improved seeds arrive at the farmer. Public research institutes should therefore share more intermediate material, not only conserve it. In return, the interviewee's company is ready to share the knowledge and the costs (in the form of royalties).

Five years ago, major seed companies did not allow public sector scientists in the US to evaluate their biotech seeds without having first access to the results, one interviewee told. As a consequence, universities could no longer be a third voice of opinion. This situation has recently started to change, several interviewees indicated. Both big and small seed companies increasingly recognise that universities should also be supported for teaching plant genetics and plant breeding as they are not only a source of knowledge but also a source for recruitment of highly skilled research and breeding personnel. In addition, universities in the US have started to understand that they should be patenting and out-licensing but, according to one interviewee, it took them quite a while, as the Bayh-Dole act that allowed universities to patent inventions already came into force in 1980. Another interviewee pointed at issues that are considered strategically important for the US; this has for instance led private and public partners to invest in joint programmes for developing maize and soybean germplasm.

Finally, a number of interviewees pointed at the governments of India and China, which consider increasing agricultural productivity for food security for their own populations a top priority and therefore invest heavily in plant breeding and biotechnology. Some interviewees argues that the US government may also consider to invest more in public R&D, not only to foster 'molecular' disciplines but also 'classical' disciplines, such as conventional plant breeding and agronomy.
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4.5.3 Generic biotech seeds and traits

Analogous to drugs, generic markets for biotech seeds and traits will emerge after patents have expired. Generics can usually be sold at relatively low prices. Almost all interviewees expect that a market for generic traits will develop in five years from now. Though, they had different opinions about the market-value of generic biotech seeds and traits.

Many interviewees noted that post-patent use of traits and germplasm should be possible for the development of generics. However, in the case of biotech traits, there are other obstacles to overcome, as generic biotech seeds also require access to and maintenance of regulatory approvals before they can continue to be sold in the market place. Seed companies that seek commercialisation of generic biotech seeds need therefore to submit a ‘data package’ to regulatory authorities. So, a generics developer needs to have access to the original data used for the deregulation or have the ability to create a new regulatory data package before the patent expires. However, as long as the patent has not expired, it is not allowed, under most laws, to conduct research on the patented seed or trait for regulatory approval. In the pharmaceutical industry, this has been solved by an exemption under the patent law that allows collecting data on generics for regulatory approvals before the patent expires. In a similar vein, some interviewees said, such an exemption should also be introduced for (utility) patents on biotech traits, because generics also require clear and science-driven policies regarding liability and stewardship of off-patent traits. If the biotech seeds or traits are GM, maintaining and having access to regulatory data packages and stewardship programmes will be vital for the development of a generics market, as a generics market also depends on innovation.

Yet, one of the interviewees argued that the price of seed is only a minor part of the total production costs of farmers. Therefore, farmers will always opt to grow the best available varieties. Since the legal life cycle of a patent is usually shorter than the technical life cycle, there will usually be many other technical solutions available when a patent expires. The value of generic biotech seeds and traits will therefore probably remain marginal.

A few interviewees also expected a future for generic biotech seeds in Asia. Local seed companies in India and China could use generic seeds and breed them into local varieties and germplasm.

4.5.4 From input traits to output traits

In the 1990s there were seed companies that promised that first generation of input (or agronomic) GM traits, like herbicide-tolerance and insect-resistance, would soon be followed by a second generation of output (or quality) GM traits, for example a GM tomato with increased content of lycopene, which may provide protection against cancer. Meanwhile, it is technologically feasible to develop a GM tomato with increased lycopene content. But, as one interviewee explained, there is hardly any economic potential, because it is not possible to substantiate scientifically a health claim that such a GM tomato would help preventing cancer, and without such a health claim it has no added value. Moreover, especially the vegetable seed industry depends on the final link to the consumers, the retailers. However, retailers are generally not much prepared to share in the development of a new trait and to participate in the introduction of a new type of high-value product and to pay a premium to the developer.

Another interviewee called this promise of a shift to GM quality traits ‘the most common false idea in the debate about GM during the last ten years’. Some interviewees argued that their companies’ customers, the farmers are primarily interested in ‘productivity’, because they are paid for the tonnes produced per acre. Since output traits are usually not that high yielding because of the inverse relationship between quality and productivity, someone in the agro-food chain should pay for the higher quality. This means in practice that the added value of a quality trait accrues mainly to operators down the agro-food chain, like food/feed companies and consumers; it is a value chain issue. One interviewee pointed out that quality traits require a good linkage between growers and food/feed processors, including certification schemes, which are lacking in many cases. In addition, it is not smart to grow a crop with a quality trait in the main production areas of that crop, as outcrossing may lead to inadvertent co-mingling of harvests and quality loss. Hence, there is a need for dedicated production areas. Overall, it requires a lot of effort, time and money to develop such vertical links. Nonetheless, one of the interviewees told that the company is working on such a vertical chain integration for a GM crop with a quality trait, thereby admitting that the company considers this a business experiment. Other interviewees pointed at private sector involvement in the development of fortified GM crops for developing countries, like rice and sorghum with enhanced (pro-)vitamin A content, the so-called Golden Rice.

5. ECONOMIC ASSESSMENT OF STRUCTURAL CHANGE AND INNOVATION IN THE US SEED MARKETS FOR SOYBEAN, MAIZE AND COTTON

This section presents the findings from three case studies on the levels of concentration in the US seed markets for soybean, maize and cotton from 1992 to 2009 and the consequences thereof for innovation in these markets.

5.1 Introduction

This section examines the levels of concentration in the US cotton, soybean and maize seed markets. Two types of indicators are used to measure market concentration: 1) The four-firm concentration ration (CR4) – the market share held by the largest four firms, or CR8 – the market share held by the largest eight firms, and; 2) The Herfindahl-Hirschman Index (HHI), which is the sum of squared market shares for all firm in an industry. The HHI takes values between zero and 10,000 and is used as an indicator of the degree of concentration and the presence of market power. As the HHI decreases, it indicates a reduction in potential market power and an increase in market competition. The HHI is used by the Antitrust Division of the US Department of Justice (DoJ) as a trigger to investigate whether a proposed merger would be anti-competitive, i.e. whether it would increase the market power of a few firms within a sector. A market with an HHI of 1,000 – 1,800 is considered 'moderately concentrated', while a market with an HHI of 1,800 or higher is considered 'concentrated'.

This section also examines the consequences of concentration and market power on innovation in the US seed markets for cotton, soybean and maize. There is a continuing discourse in the economic literature about whether competitive or monopolistic market structures offer the best environment for innovation. There are knotty conceptual and measurement issues that complicate the debate. These include: 1) How to effectively measure innovation?; 2) How to measure the level of competition in a market?; 3) How to effectively link the two?, and; 4) How to account for potential tradeoffs between static and dynamic efficiency. All these issues are confronted in this section.

Past studies have used a number of indicators of innovative activity in different sectors, including the stock of patents, R&D expenditures, and the rate of new product introduction. Here two of these indicators - R&D expenditures and the rate of new product introduction - are used to evaluate trends in innovative activity in the US seed industry over the last fifteen years. For this study, the stock of patents, i.e. the number of plant breeders rights (PBRs) and patents, has not been used as an indicator of innovative activity, also because it was not clear to Louwaars et al. (2009) whether the number of PBRs and patents obtained by a firm would be a solid measure of a firm's innovative capacity; see paragraph 3.1.2.

For the empirical analysis three case studies from the maize, soybean and cotton seed industries in the US are used. Since the introduction and adoption of GM seeds have been significant in these markets over the last fifteen years, it was expected that an economic assessment could provide empirical evidence on the role of GM/biotechnology for structural change in the seed industry. In the first case study, the changes in the levels of concentration observed in the US cotton industry are examined and indicators of firm rivalry in the market are analyzed. In the second case study, recent trends in concentration and R&D expenditures in the US maize and soybean seed industries are examined and the extent of dynamic efficiency in these industries is evaluated. More specifically, the relationship between concentration and market power is first analysed, and the extent that market power has been exercised is examined next. Finally, the profits associated with market power are estimated and compared to the level of R&D investments. In the third case study, trends in product innovation in maize seed are examined through analysis of new product offerings and product lifecycles.

5.2 Structural changes and Concentration in the US cotton seed industry

5.2.1 History of US cotton seed industry

Cotton has been cultivated in the US continuously since the 1620s (Smith et al. 1999) and has been an economically important crop for over 200 years for many of the Southern states. US cotton acreage grew from just over 3 million hectares in 1865 to almost 17 million hectares in 1930. As a result, cotton cultivation expanded to new areas where the plant was not native. This expansion created significant selection pressure on heterogeneous cotton populations and while certain plants failed to produce other plants thrived. In this environment, many farmers consistently selected cotton varieties for their superior performance in their fields and shared or sold well performing seeds to neighbouring farmers.

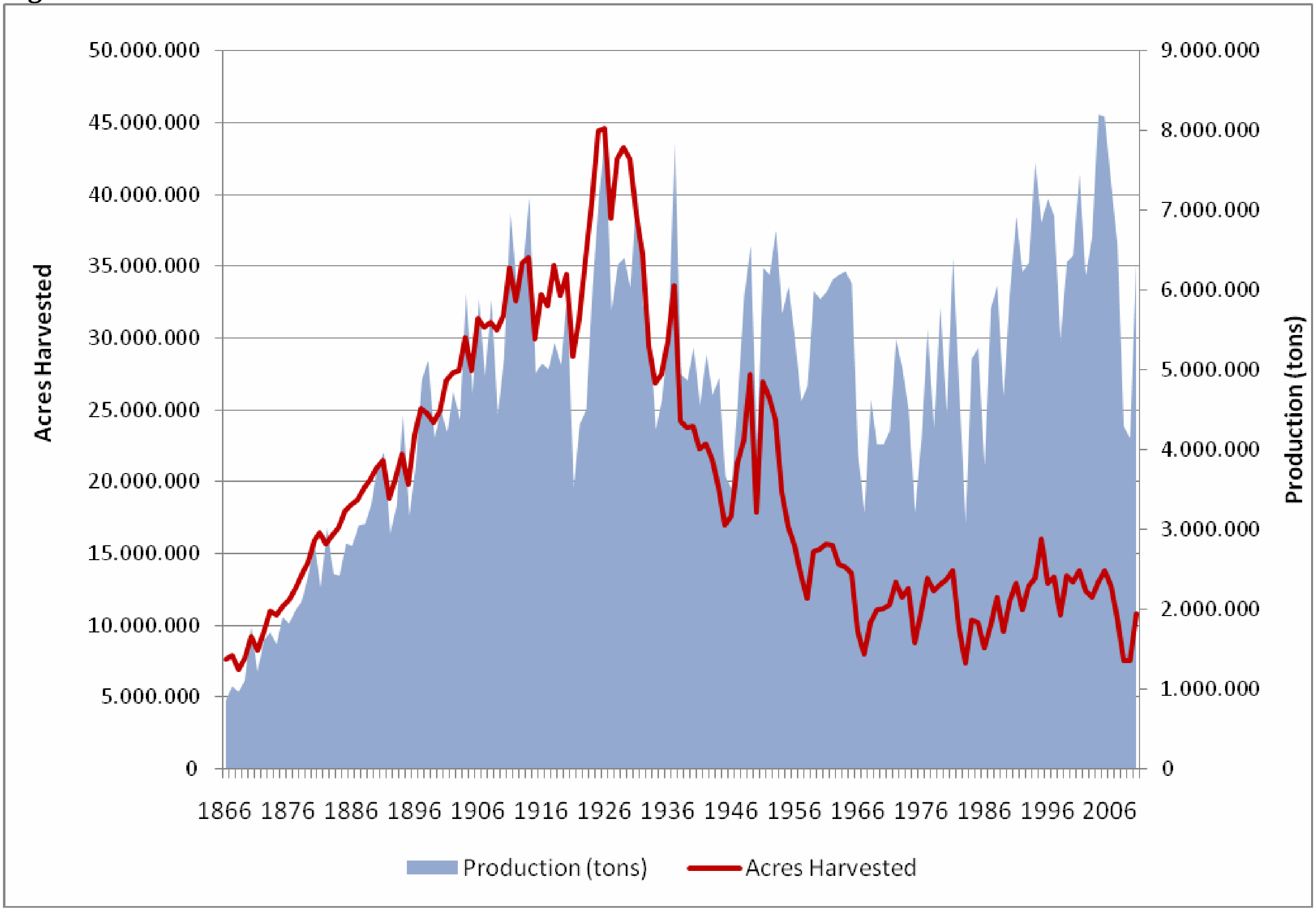
Through the variety selection of seedsmen and farmers as well as through the introduction of germplasm from Mexico, Egypt and other regions, the number of cotton varietiess used in the US increased drastically in the late 1800s. The emergence of the Mexican boll weevil after 1892, however, provided the strongest impetus for new variety development as it caused crop losses up to 90% (Smith et al. 1999). By the early 1900s, science based breeding programs had been established by the US Department of Agriculture (USDA) in a number of southern states. These USDA stations advanced breeding programs for the development of a germplasm base that could produce cotton in the presence of boll weevil.

The public breeding programs contributed both germplasm and human capital in the development of the US cotton seed industry as well. A number of well-known breeders from public programs like H.B. Brown, E.C. Ewing, H.J. Webber and others initiated breeding programs for a number of companies in the private sector many of which became the leading seed firms of the era (e.g. Stoneville, Delta and Pineland, Coker Pedigree and others).

In the early 1930s only 5% of the cotton seeds used by US farmers were purchased from seed companies. Most farmers used gin-run seeds of mixed stock (Smith et al. 1999) As seed firms continued to improve their germplasm and farmers began to appreciate the significance of uniform, good-quality seeds (especially through independent yield trials conducted by USDA stations) seed purchases continued to expand.

The impact of improved variety use on US cotton productivity cannot be overestimated. As illustrated in figure 2, prior to the early 1930s yields were essentially flat, just under 200 pounds per acre. In the mid-1930s yields began to rise, growing up to 880 pounds per acre in 2007. Cotton acreage began to decline in the early 1930s, bottomed out in the mid-1960s and has since been relatively flat. During this same period production rose to the levels last seen in the early 1930s, as much as 8 million tons, but on a third of the land, demonstrating a substantial increase of productivity.

Figure 2: US Cotton Harvested Land and Production 1866-2010



Data source: USDA NASS

5.2.2 Structural changes in the US cotton seed industry since the 1970s

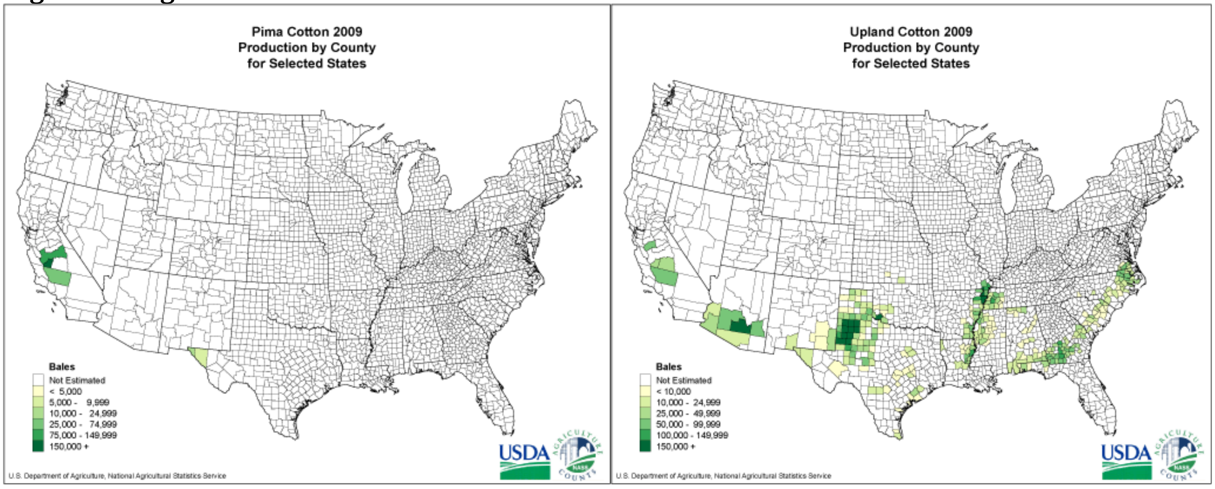
By the 1970s many of the public breeding programs had waned, though some continued to make contributions and offer new varieties into the 1990s (e.g. Tamcot, Pima and Acala breeding programs). As a result, the US cotton seed market was serviced mostly by privately owned companies. The introduction of PVPA in 1970 encouraged the entry of new private breeders but it generally had little discernible impact on structure of the industry as leading cotton seed firms maintained their market position.

Indeed, historically the number of firms in the US cotton seed industry has been relatively small with few leading firms owning large shares of the market. A key factor behind the limited number of seed firms and the concentrated structure of the cotton seed market is its small size. Given the rather small number of cotton hectares cultivated and the fragmented nature of the relevant seed markets (both geographically and variety wise) only a limited number of breeding programs could be effectively supported.

There are 17 cotton producing states that make up the “Cotton Belt” of the United States. These states are often grouped into four regional categories: Southeast, Delta, Southwest/Plains and West. The production characteristics of these regions are different and require different varieties. There are also significant differences in the types of cotton cultivated in each region. For instance, ninety seven percent of the annual U.S. cotton grown in the US is upland cotton, with the balance accounted for by higher quality Pima (extra-long staple) cotton which is grown in four states: Texas, New Mexico, Arizona and California –

with California responsible for 89% of all US Pima production. Acala cotton is also cultivated exclusively in California.

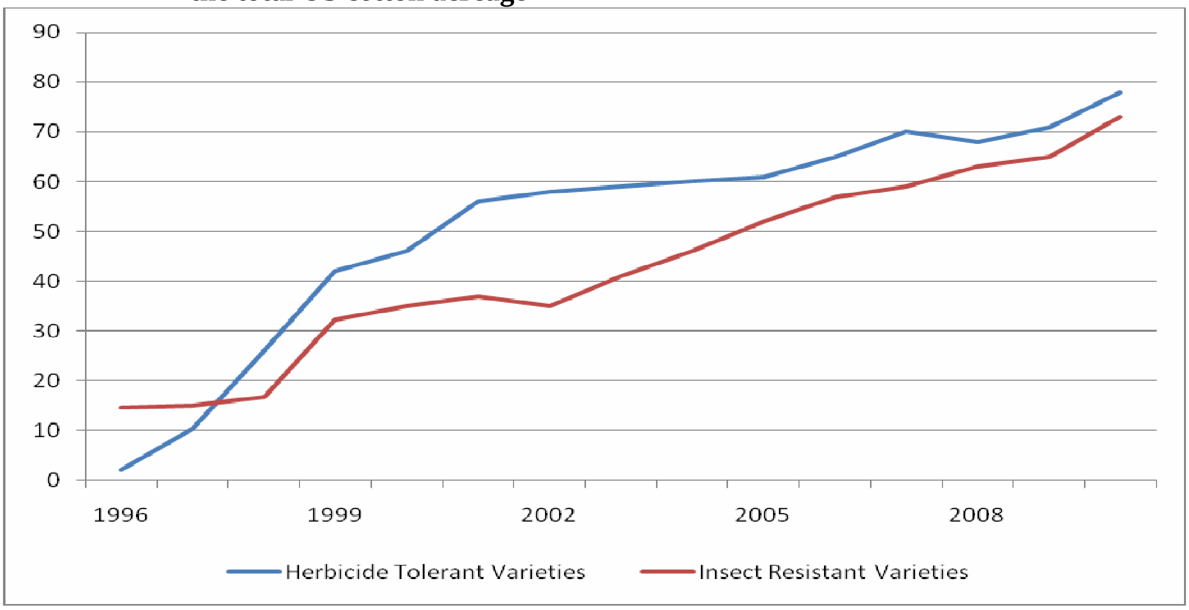
Figure 3: Regional Distribution of US Cotton Production in 2009



Given the small number of cotton seed firms in the US market, the number of M&As was also limited, though a constant stream of new entrants created opportunities over the years. Most of the M&As were "horizontal" and seed firms acquired and merged the assets of other seed firms based on opportunities for synergies. For instance Delta and Pine Land acquired Paymaster, SureGrow, and others while Stoneville acquired Coker, Germain's and others. In most cases, such acquisitions increased the level of industry concentration, at least for some time.

The introduction of GM traits in cotton in 1996 was followed by widespread adoption and by 2010 GM cotton varieties occupied over 93 percent of the cultivated hectares (figure 4).

Figure 4: Adoption of GM Traits in the US Cotton Industry, 1996-2010, as percentage of the total US cotton acreage *



* The figure shows the share of acres in Herbicide Tolerant and Insect Resistant varieties. Some varieties however have both traits ('stacks'). When varieties with a single traits and 'stacks' are all accounted for, the total adoption is 93%.
Source of Data: USDA, NASS

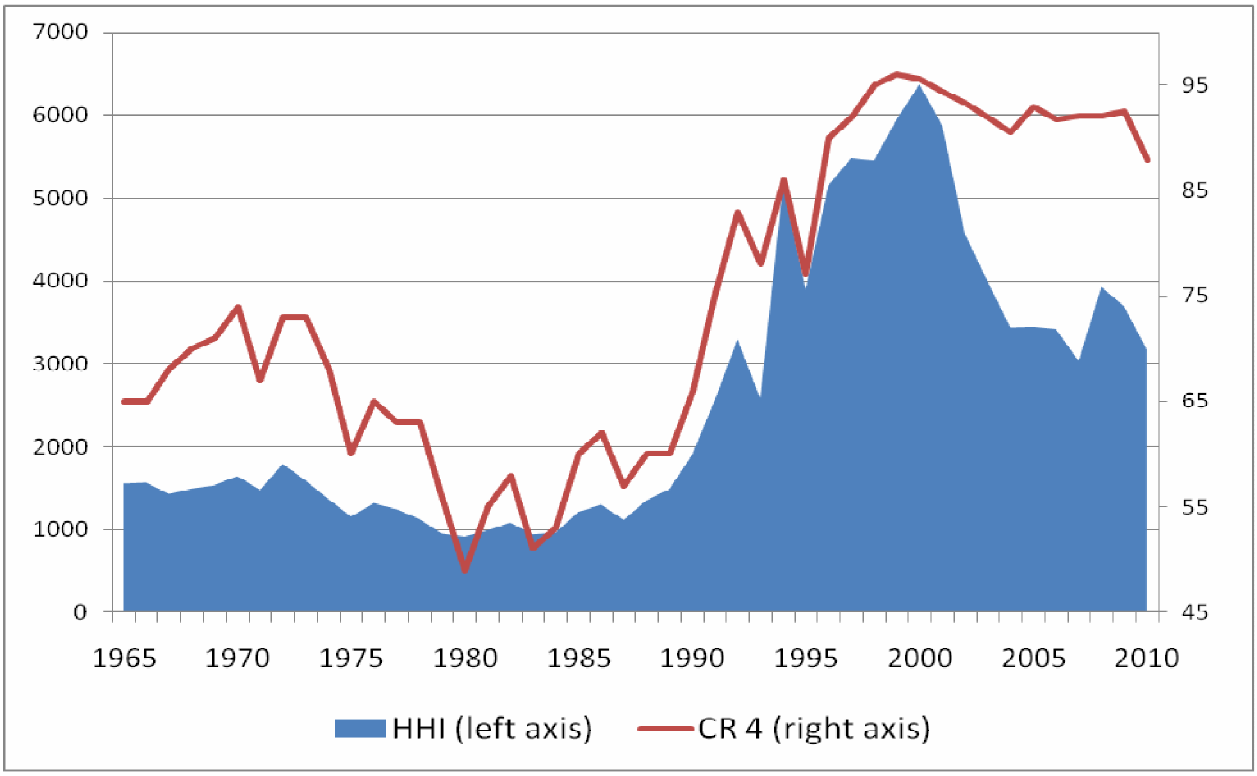
The introduction of biotechnology also had significant structural changes in the industry. Much like it was observed in other seed sectors, the arrival of biotechnology brought about a number of M&As, joint ventures and other strategic alliances. The firms that initiated many of the M&As and joint ventures had significant investments in biotechnology and many of them were multinationals like Agrevo, Bayer, Monsanto and Dow.

M&As led by multinational biotech firms changed the ownership structure of the industry as independent seed firms like Delta and Pineland, Stonevile, CPCSD and others became parts of integrated firms with assets in biotechnology, agrochemicals, and other economic activities. Monsanto acquired Delta and Pineland in 2007 while Bayer acquired Stoneville in 2008.

5.2.3 Trends in concentration and consolidation

The trends in industry concentration and consolidation in the US cotton seed industry can be seen in figure 5. The cumulative share of the top 4 firms (CR4) varied between 60% to 76% from 1965 to 1980, while in the following decade the CR4 varied between 47% to 65%. In the 1990s the CR4 increased steeply from 65% to 95% and stated to decline slightly since the mid-2000s. Another measure of industry concentration, the Herfindahl-Hirschman Index (HHI), has also been relatively high exceeding 1800 in most years since 1965. A market with HHI value of 1800 or more is generally considered concentrated. As figure 5 illustrates, CR4 and HHI both jumped in the early 1990s following the acquisitions of Paymaster and Suregrow by Delta and Pineland.

Figure 5: CR-4 and Herfindahl-Hirschman Index (HHI) for US Cotton Market, 1965-2010

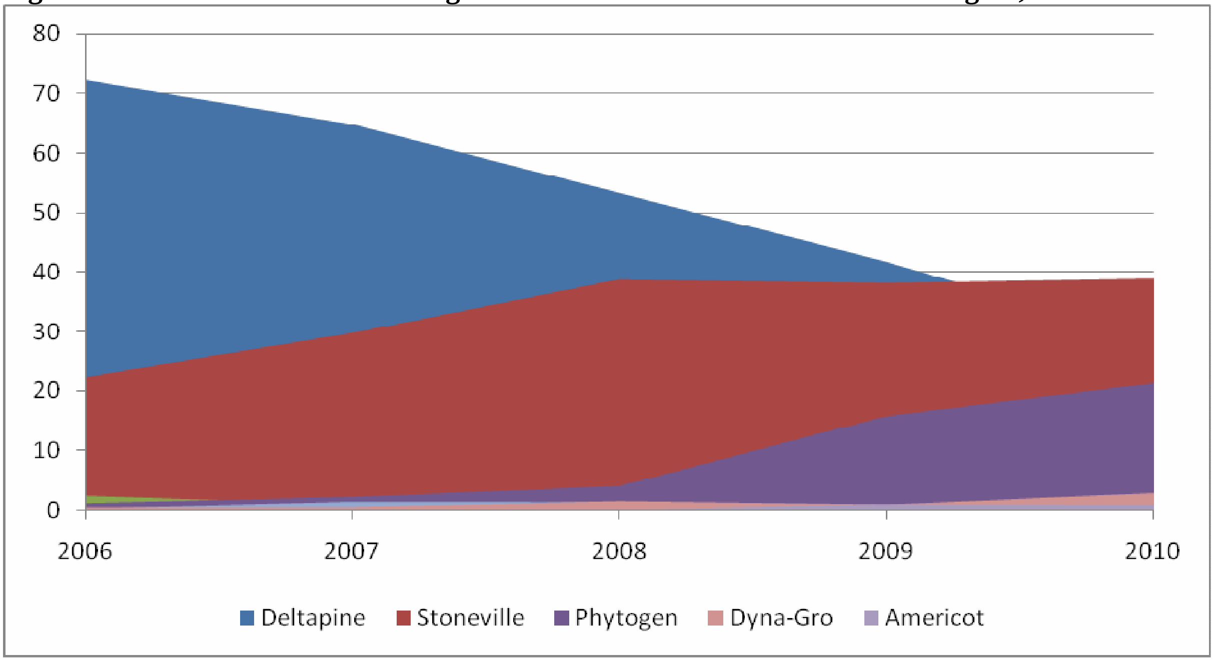


Source of Data, USDA, AMS, various years

While the level of concentration has been high in the last twenty years, it has declined slightly since the mid-2000s. Despite its acquisition of Delta and Pineland in 2007, Monsanto has continued to license broadly its GM traits to large and small competitors. As a result various competitors have been gaining share against the market leader Delta and Pineland and such gains are reflected in the declining HHI of the national market.

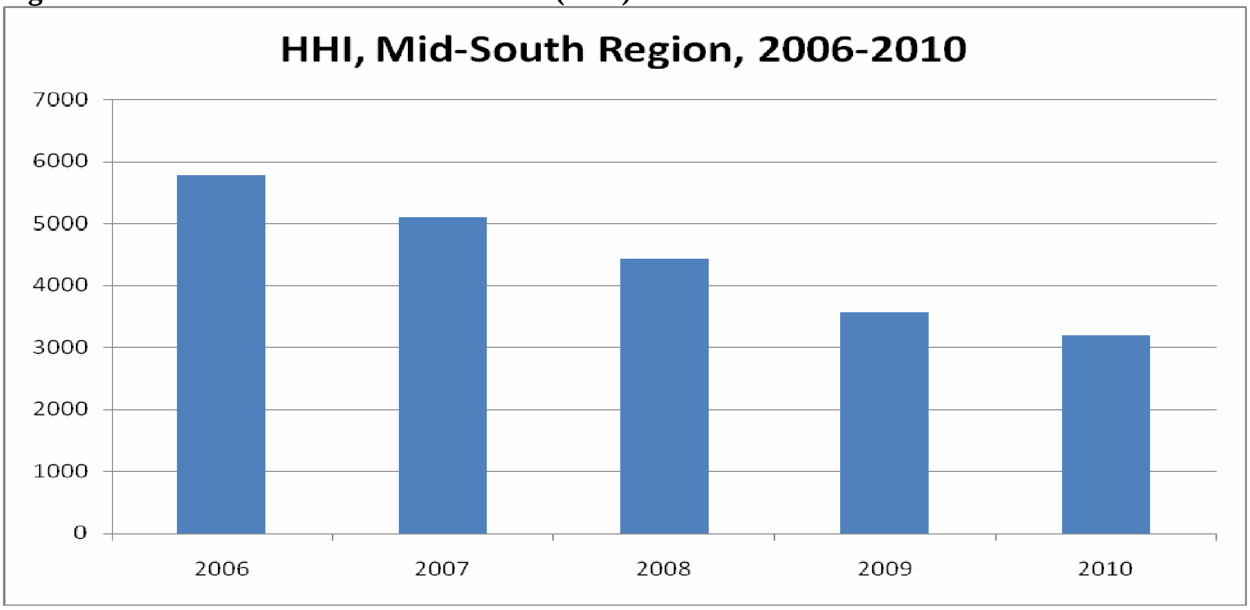
However, such market share gains are even more pronounced in the regional seed markets where firm rivalry is more apparent. In the most important regional cotton seed market of the mid-south (Delta) region, Delta and Pineland's market share has declined from 72% in 2006 to less than 29% while Stoneville (Bayer) and Phytogen have enjoyed large gains and so have smaller companies like Altex, Americot, Dyna Gro, etc. Such changes are also reflected in the regional HHI and both market shares and HHI for the mid-South market are illustrated in figures 6 and 7.

Figure 6: Market Shares of Leading Cotton Seed Firms in the Mid-South Region, 2006-2010



Source of Data: USDA AMS, 2006-2010

Figure 7: The Herfindahl-Hirschman Index (HHI) for the Mid South Cotton Seed Market



Source of Data: USDA AMS, 2006-2010

These measures indicate that the cotton seed market remains concentrated but with significant variation in the competitive position of the firms in the industry. The presence of new entrants and share gains through organic growth of existing firms against the market leader indicate vigorous competitive rivalry.

5.3 Structure, market power and R&D investment in US seed markets for maize and soybean[1]

Markets are said to be concentrated if a few firms hold a relatively large share of the market, and high concentration is one of the criteria used by the federal antitrust authorities when they evaluate the competitive conditions of a particular market. Firms in a highly concentrated market may be able to exert market power and raise prices above a competitive level (to the detriment of buyers). Market power can also influence the firms' interest in innovation. However, high concentration can only serve as a warning sign because market concentration does not necessarily imply the exertion of market power. For example, economic theory predicts that prices may be kept at or near competitive levels under the threat of entry by new suppliers, even in industries that are highly concentrated (Baumol, Panzar, and Willig, 1982). Further, the market may be contestable and remain relatively competitive if potential entrants do not face costs that existing firms can avoid, there are no inherent legal barriers to entry, and entry and exit are relatively costless (i.e., there are no sunk costs).

Several economists have noted that firm entry in the US seed industry may be limited by large entry costs (Fulton and Giannakas, 2001) due to high research and development (R&D) investments and regulatory compliance costs (Heisey and Schimmelpfennig, 2006; Kalaitzandonakes, Alston, and Bradford, 2006) as well as by the complexity of intellectual property rights (Lesser, 1998; Pray, Oehmke, and Naseem, 2005). These circumstances could limit market contestability and increase the likelihood that firms exert their market power.

At the same time other authors have noted that presence of some market power in the US seed industry may not be completely undesirable. Seed firms engaged in the development of new genetics and biotech traits are expected to charge prices above marginal costs to recoup the fixed costs of R&D (Shi, Chavas, and Stiegert, 2008). Without the existence or the prospect of earning prices above marginal costs due to market power, the seed firms would have no incentive to improve product quality, or introduce new varieties and biotech traits. Therefore, some authors have proposed that the key question to be addressed is whether concentration and potential presence of market power in the seed industry permits firms to make profits well above those necessary to recoup their R&D investments (Pray et al. 2005).

To examine the balance between market power and investment in innovation in the US seed industry, empirical measures of price markups attributable to market power in the US seed industry between 1997 and 2008 – a period characterized by the vertical integration of leading multinational biotechnology firms in this industry, are reported in the next section. The revenues from the estimated markups are then calculated and compared with approximate measures of aggregate R&D expenditures in the industry. Finally, conclusions are drawn

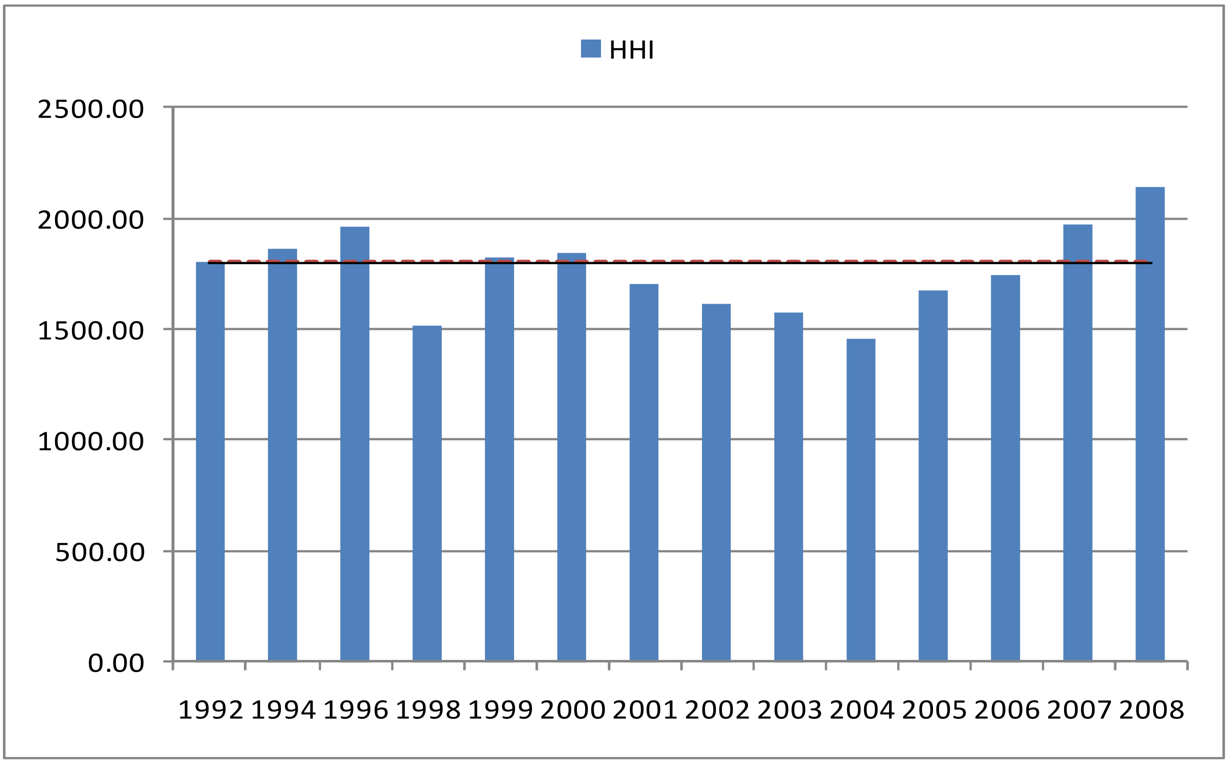
1. A more detailed discussion of the material presented in this section was published as Kalaitzandonakes, N., A. Magnier and D J. Miller "Concentration, Market Power and Dynamic Efficiency in the US Seed Industry" *Regulation* (forthcoming).

about their proportionality over the period of analysis and the dynamic efficiency of the industry.

5.3.1 Concentration levels in the US soybean and maize seed industry

The vertical integration of the biotechnology firms during the third wave of consolidation in the seed industry led to drastic changes in the ownership structure (see Section 3). The Herfindahl-Hirschman Index (HHI) values for the US seed industry in 1992-2008 (Figure 8) have stayed close to 1800, this threshold between 'moderately concentrated' and 'concentrated' was reached or exceeded in 1992, 1994, 1996, 1999, 2000, 2007, and 2008.

Figure 8: Herfindahl-Hirschman Index (HHI) for US Seed Maize Industry, 1992-2008



Data Source: DMR Kynetec, various years

5.3.2 Empirical estimates of market power in the US seed industry

Under the moderate to high levels of industry concentration depicted in Figure 8, two key questions emerge: Do firms in the US seed industry have significant market power? If so, to what extent is market power exercised? To answer these questions, the existing literature on this topic is reviewed, followed by the estimates of market power and the level it is exercised in the US seed industry.

There is limited empirical evidence on the presence of market power in the US industry. A handful of recent studies have examined the pricing decisions of seed firms based on new empirical industrial organization (NEIO)-type models of the firm's profit function. Fernandez-Cornejo and Spielman (2002) constructed a profit function for a representative seed firm and used the profit maximizing conditions to derive an NEIO model of the firm's price-cost margin as a function of the industry HHI statistic, cost indices, the responsiveness of buyers to changes in seed prices (i.e., the elasticity of demand), and the responsiveness of seed firms to the prices charged by other seed firms (i.e. the conjectural elasticity). Based on industry-level data, the authors found that the direct market power effect on the price-cost margin was positive but not significantly different from zero. Also, an increase in market power tended to reduce the processing costs and R&D costs, but the later effect was not significantly different from zero. Thus, the authors concluded that the primary impact of increasing market power on seed margins is the improved processing cost efficiency.

Shi, Chavas, and Stiegert (2008) used farm-level observations on seed price, quantity, and location from 2000 to 2007 to estimate a model of the implicit value associated with individual traits in hybrid seed maize. The model incorporates a generalized form of the HHI statistic to account for the local pricing effects associated with differentiated (i.e. multiple trait) products in the maize seed market. The authors found that three of the four main biotech traits (corn borer and rootworm resistance and two forms of herbicide tolerance) attract significant price premiums and that roughly 8% of the price of seed maize is associated with market power held by the seed companies.

A few studies have examined the possibility of market power by analyzing the seed buyer's decision process, and their findings highlight the importance of farmer-specific and regional difference in the values assigned to particular seed traits. Alexander and Goodhue (2002) used a calibrated model of a representative buyer's decision to adopt seed maize varieties with four specialized traits (high yield, insect resistance, herbicide tolerance, and high oil content). They then used the model to simulate the net revenue and break-even yield for each seed type under various cropping conditions and found that the herbicide tolerant seed was roughly priced at the producer's reservation price, which implies that the seed company could be exerting market power and extracting the full farmer surplus from homogeneous buyers. In contrast, insect resistant seeds were priced below the producer's reservation price so that the farmer captured some of the surplus and the seed company was not exerting full market power. In conclusion, the authors noted that the likely heterogeneity among seed maize buyers/farmers would reduce the seller's/seed company's ability to exert market power and capture the farmers' surplus value from the hybrids.

Producer heterogeneity and the implied differential valuation of seeds and biotech traits have been empirically demonstrated by Useche, Barham, and Foltz (2009). Using a discrete choice model, the authors found that the estimated value assigned to particular biotech traits varied broadly across regions and among individual farms.

Kalaitzandonakes, Magnier and Miller (2010a) have recently constructed models of derived demand for maize and soybean seed that allow evaluation of the presence of market power in these markets. In the estimated models, the price of seed is represented as a function of the quantity of seed purchased and the expected crop price just before planting time (e.g. the average January-March price of the December maize futures contract on the Chicago Board of Trade) plus controls for hybrid life-cycle effects, trait effects, and regional effects. There are 10 distinct biotech traits in maize hybrids aside from conventional maize and these are based on herbicide tolerance (Roundup Ready, Liberty Link, and IMI), maize borer resistance (CB), and rootworm resistance (RW) plus combinations (stacks) of two or more of these traits. Also, there are three distinct soybean variety traits that provide herbicide tolerance (Roundup Ready, sulfonylurea-tolerant or STS, and a combination of these traits).The data used to estimate the derived demand models are annual observations for 6,170 maize hybrids and 4,232 soybean varieties that were sold in the US from 1997 to 2008.

One of the key results derived from the fitted demand models are the price flexibility coefficients for maize and soybean seed, which measure the responsiveness of seed prices to changes in quantity demanded. Under profit maximizing behaviour, the absolute value of the flexibility coefficients provide upper bounds on the Lerner index (Tomek and Robinson), which is the ratio of the product price (P) minus marginal cost (MC) to the price, L = (P – MC)/P. The Lerner index is zero under marginal-cost (perfectly competitive) pricing and increases from zero as the price increases above marginal cost. Hence the Lerner index is a measure of the price markup imposed by firms in the market, and we can use the estimated flexibility coefficient to measure the overall degree of market power exerted by the seed firms in the US market. The key parameters from these estimated models are presented in Tables 9 and 10.

Table 9: Summary Results for the Estimated Model of Maize Seed Prices

Model Component	Estimated Value
Lerner Index (overall price-cost markup for all hybrids)	14.6%
Herbicide tolerance trait	20.1%
Corn borer resistance trait	23.5%
Rootworm resistance trait	29.4%
Corn borer and herbicide tolerance traits	36.4%
Rootworm and herbicide tolerance traits	40.1%
Corn borer and rootworm resistance traits	36.4%
Corn borer, rootworm, and herbicide tolerance traits	53.1%
Corn borer and two herbicide tolerance traits	52.7%
Rootworm and two herbicide tolerance traits	68.6%
Corn borer, rootworm, and two herbicide tolerance traits	77.9%

Table 10: Summary Results for the Estimated Model of Soybean Seed Prices

Model Component	Estimated Value
Lerner Index (overall price-cost markup for all varieties)	17.5%
Roundup Ready trait	53.8%
STS herbicide tolerance trait	-1.2%
Roundup Ready and STS herbicide tolerance traits	56.8%

Notes: The Lerner index value represents the overall markup (price relative to marginal cost) earned by all maize hybrids and soybean varieties. The estimated values for the individual traits represent the expected price premium associated with each trait (or combination of traits) relative to conventional maize hybrids and soybean varieties that do not have biotech traits. All of the reported estimates in Tables 9 and 10 are statistically significant at the 1% level except the STS trait in the soybean seed price model (Table 10).

From Table 9, the estimated flexibility coefficient for the maize seed price is -0.146, which implies that the upper bound on the maize seed mark-up (Lerner index) is roughly 14.6% in the US market. The hybrid life-cycle component in the estimated model indicates that the initial price of maize seed starts low, increases until the hybrid's fourth year on the market, and then declines until the hybrid is removed from the market. Finally, the values associated with the individual biotech traits are positive and statistically significant and positive. For example, herbicide tolerant hybrids earn a premium that is roughly 20% higher than the price of conventional seed maize, and corn borer and rootworm resistant hybrids have premia that are roughly 23% and 29% higher than conventional maize (respectively). Moreover, hybrids with multiple (stacked) traits earn higher premia, but the value of the combined trait is less than the sum of the individual traits, which provides evidence that the seed firms use bundled pricing strategies for hybrids with stacked traits.

From Table 10, the estimated price flexibility for the soybean seed price is similar at -0.175, which implies that the upper bound on the soybean seed markup is roughly 17.5%. The fitted life-cycle component for soybean seed also indicates that the expected soybean seed price reaches a peak price at about the fourth year on the market. Finally, we find that the estimated value for the STS trait is not statistically different from zero, but the Roundy Ready trait earns a premium that is about 54% above the price of conventional soybean varieties. Further, the estimated value of the combined Roundup Ready and STS traits (57% relative to conventional soybeans) is only slightly larger than the estimated premium for Roundup Ready soybeans.

5.3.3 Comparison of revenues from markups and premiums to investment in innovation

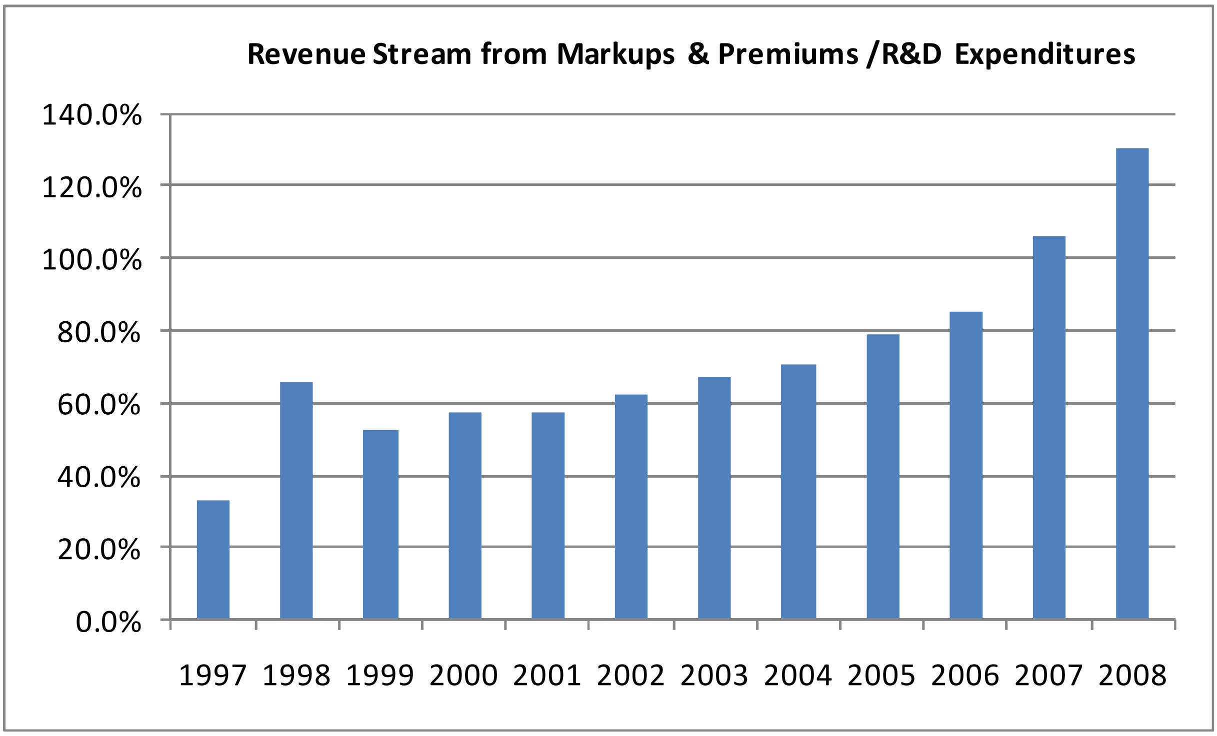
With price markups for germplasm and premiums for biotech traits at hand, one way to examine the potential impact of market power on the level of innovation in the US seed industry is to compare the industry-level revenue stream from those markups and premiums with the levels of R&D expenditures and other relevant fixed costs for the industry. Seed companies incur large fixed costs in the form of R&D expenditures, costs for improvements in quality control systems, regulatory expenses, marketing costs, and legal expenses. The revenue streams from markups and premiums on traits must be large enough to pay for these fixed costs year after year, even though innovations and other efficiencies from such fixed expenditures may be realized many years later. Although complete data for such fixed expenditures is not available, an approximation is used by comparing the revenue streams from markups and premiums associated with biotech traits to the R&D expenditures incurred by all seed companies with meaningful breeding and biotech research activities in the maize and soybean seed segment.

By necessity, the comparison is somewhat crude. The revenue from markups and premiums in the US maize and soybean seed market does not represent the total revenue inflow for the companies examined, some of which have meaningful sales in other seed markets (e.g. cotton, canola, sugar beets) and other countries. However, the US maize and soybean markets are by far the largest and most profitable seed markets in the world and exhibit the most significant penetration of biotech traits. As such, they contribute an estimated 75-87% of global agricultural biotech revenues for the companies examined (Cropnosys) and hence the revenue stream from markups and premiums in the US maize and soybean seed markets provide a good first approximation of the relevant revenue stream. At the same time, R&D expenditures represent only a portion of the fixed expenses seed companies incur, though this portion is likely large. Finally, R&D expenditures are lumpy in nature and cannot be easily allocated among crops. As such, aggregate R&D expenditures overstate those incurred for maize and soybeans alone. Despite these limitations, a comparison of the revenue stream from markups and premiums in the US soybean and maize seed markets with the aggregate R&D expenditures incurred by the leading seed germplasm and biotech traits in these markets provide valuable insight on their proportionality and their overall direction over time. In turn, these insights help to address the question on the degree market power that is exercised in these seed markets.

The estimated markups and premiums from the fitted models presented in the previous section are used to estimate the revenue stream over the 1997 to 2008 period. Specifically, for each year of the analysis, the estimated markups are applied on the total gross annual seed sales and the estimated premiums on the gross annual revenues of seeds with different biotech traits. As a result, the revenue stream from markups and premiums increases over time as traits become more numerous, more valuable, and more broadly adopted.

R&D expenditures for all major developers of germplasm and/or biotech traits in the US maize and soybean seed markets and for each year over the 1997 to 2008 period have been included in the aggregate figures used here. R&D expenditures of firms that were previously independent but were acquired or exited the industry are reflected in the aggregate. All R&D figures were compiled from industry reports (e.g. Phillips and McDougal), financial reports of individual companies and other secondary sources. The resulting R&D expenditures are compared to the revenue stream from markups and premiums of biotech traits by constructing a ratio of these revenue components to R&D investments, and this index is illustrated in Figure 9.

Figure 9: Comparison of Revenues from Markups and Premiums to R&D Investments in the US Maize and Soybean Industry, 1997-2008



Data Source: DMR Kynetec, various years

The size of the constructed index varies over the period of the analysis from a low of 33% (in 1997) to a high of 130% (in 2008). The upward trend is expected as agricultural biotechnology entered its commercial phase in 1996 and matured over the next thirteen years through the introduction of various biotech traits, especially in maize. Until 2005, ten years into the commercial phase of agricultural biotechnology, revenues from markups and premiums from the US maize and soybean seed markets were less than 80% of R&D

expenditures. Over this period of time, almost all of the revenues of the biotech industry were generated from these two seed markets, so these figures suggest that R&D investments were probably financed, in part, through other productive activities of firms, speculative capital investments and other sources.

In more recent years, the introduction of more valuable traits (new traits and stacks) as well as their broader adoption has resulted in increased revenues that closed the gap with R&D expenditures (which were $2.4 billion in 2008). However, it appears that the seed industry did not reach a point where revenues from markups and premiums could be large enough to fully finance R&D and maybe other fixed costs until 2008. Given that trait markets were already quite saturated by that time (i.e., adoption of biotech traits exceeded 87% and 92% in the US maize and soybean markets, respectively), these levels suggest that revenues from markups and trait premiums in the maize and soybean seed markets approached R&D expenditures only during the later stages of the commercial life-cycle for first-generation biotech traits.

The balance between firm profits and investments in product quality and innovation is an important indicator of dynamic efficiency in the market place and an effective gauge of competition in dynamic and innovative industries. Due to the complex supply and demand structures of R&D focused industries, estimation of market power and associated price markups is not straightforward. Nevertheless, from the empirical evidence presented here it appears that in the case of the US seed industry concentration, moderate market power and dynamic market efficiency coincide over the period of analysis.

5.4 Product introduction, Product Lifecycles and innovation[2]

New product introductions have increased while product lifecycles have declined in the US seed industry in the last fifteen years. Data from GFK Kynetec shows that between 1997 and 2008 the number of maize hybrids offered annually in the US seed market grew by almost fifty percent --from 3,060 to 4,300-- while the number of soybean varieties almost doubled --from 650 to 1130. At the same time total acreage planted to maize and soybeans as well as the number of firms in this industry remained largely unchanged suggesting that increase in product offerings was not driven by an expanding market or an increase in the number of participants.

In a working paper in the early 2000s, Dooley and Kurtz proposed that the introduction of agricultural biotechnology had induced steep increases in the number of hybrids offered in the market. Dooley and Kurtz (2001) did not provide supporting empirical evidence for their proposition but described the principle behind the potential increase in product offerings. From a product management point of view the introduction of a single biotech trait could, theoretically, double the number of hybrids/varieties that firms would handle if they chose to keep both the biotech and the conventional versions in their product line. When more traits were available, the number of possible bundles of traits as well as the corresponding number of different hybrid types could increase exponentially.

2. A more detailed discussion of the material presented in this section was published as Magnier, A., N Kalaitzandonakes, and D J. Miller "Product Life Cycles and Innovation in the US Seed Corn Industry" *International Food and Agribusiness Management Review Volume 13, Issue 3,* 2010.

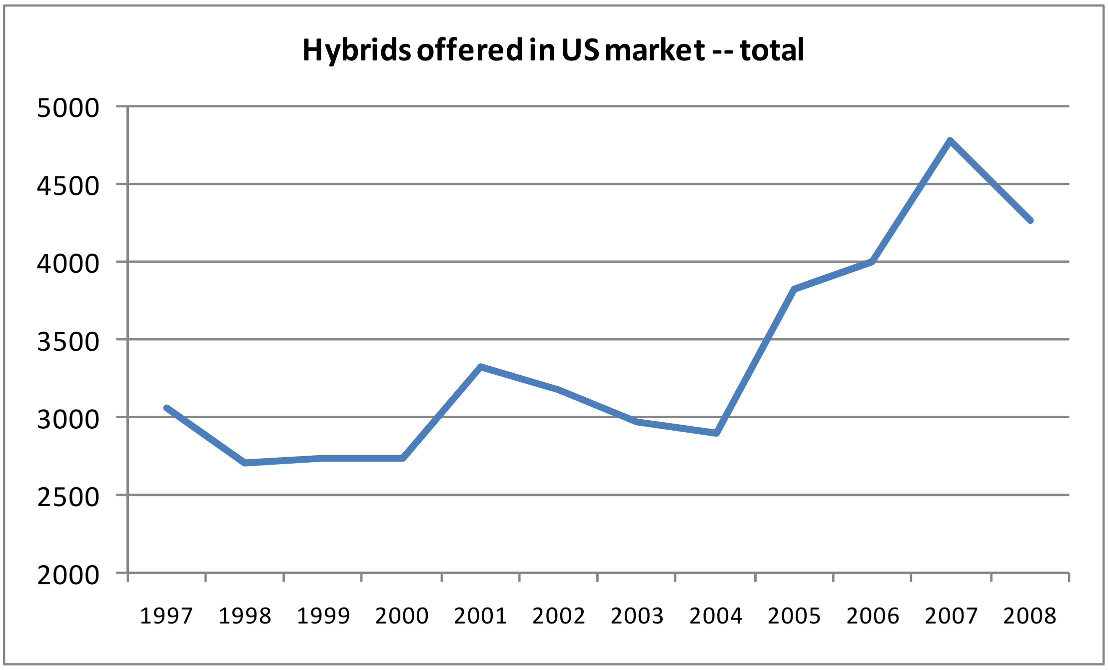
Firms could have an inherent interest in developing and supplying the market with a larger number of hybrid/trait combinations. The performance of hybrids and biotech traits generally depends on such factors as soil types, temperature and moisture ranges, as well as pest populations (Heisey, Morris, Byerlee, & Lopez-Pereira, 1998). The availability of different types of traits and the possibility to combine them into stacks offered seed firms the means to adapt their products to a greater number of specific growing environments and further optimize their performance. Improved performance could increase the demand for the seeds of innovative firms and expand their market share.

At the same time, farmers have different needs and preferences (Giannakas & Kaplan, 2005; Oehmke & Wolf, 2004) and hence different willingness to pay for traits (Marra & Piggott, 2006). For instance, the value of traits that reduce pesticide use is higher for environmentally conscious farmers and traits that save labour are valued higher by farms owned by families whose members provide a large share of the labour (Useche, Barham, & Foltz, 2009).

Hence, a greater number of new biotech traits and a larger number of hybrids offered in the market would generally be expected to translate into a greater flow of innovation and therefore of interest to this study.

5.4.1 Number of product offerings in the US maize seed market

Figure 10: Product offerings in the US maize market, 1997-2008



Source: GFK Kynetec, various years

Figure 10 shows the number of hybrids offered in the US maize market between 1997 and 2008. The figure indicates that there has been a significant increase in the number of product offerings during that period. There is some year to year variation which is expected as both the number of new products brought to the market and the number of existing products removed can be influenced by various factors. For instance, new product introduction is affected by the level of biotech innovation (e.g. number of new traits), structural shifts in demand for seed (e.g. mandates for maize-ethanol production) and other factors. Similarly, existing product withdrawals are affected by the rate of obsolescence, shifts in carryover inventories from one year to another and other factors. Such variations aside, the number of hybrids sold in the US market display two separate cycles of growth: a slower one between 1997 and 2001, and a faster one from 2004 on.

Similar increases have been observed in the number of biotech traits introduced in the US maize seed market. Table 1 lists all of the biotechnology traits and products placed in the US seed maize market by their year of introduction. The information in Table 11 indicates that there have been two separate waves of biotech product introductions between 1997 and 2009. From 1997 to 1999, a total of nine new biotech products were introduced conferring combinations of ECB resistance and tolerance to IMI, Liberty and Roundup herbicides. No new biotech products and traits were introduced until 2003 when a second wave of offerings started. From 2003 to 2007 a total of twenty four new biotech products were introduced in the US seed maize market and included new traits (Rootworm resistance), competing products for traits already in the market (Agrisure CB and GT, Herculex I), second generation traits (Roundup Ready II) and various combinations.

Table 11: Timeline of Biotechnology Traits Introduced in Seed Maize Hybrids

Year of introduction	Product	Biotech Trait	Product Supplier
1997	YGCB	Corn borer resistant	Monsanto
1998	I MI	Herbicide tolerant imidazoline	BASF
1998	LL	Herbicide tolerant glufosinate	AgrEvo
1998	RR	Herbicide tolerant glyphosate	Monsanto
1998	SR	Sethoxydim resistant	BASF
1998	YGCB-IMI	Herbicide tolerant resistant - Corn borer resistant	BASF/Monsanto
1998	YGCB-LL	Herbicide tolerant glufosinate - Corn borer resistant	AgrEvo /Monsanto
1998	YGCB-RR	Herbicide tolerant glyphosate - Corn borer resistant	Monsanto
1999	YGCB-IMI-LL	Herbicide tolerant glufosinate resistant - Corn borer	BASF/AgrEvo /Monsanto
2000	IMI-LL	Herbicide tolerant imidazoline / glufosinate	AgrEvo /BASF
2001	RR2	Herbicide tolerant glyphosate	Monsanto
2003	Herculex I-LL	Herbicide tolerant glufosinate - Corn borer resistant	Bayer/Dow
2003	YGCB-RR2	Herbicide tolerant glyphosate - Corn borer resistant	Monsanto
2003	YGRW	Rootworm resistant	Monsanto
2004	YGPlus	Corn borer/Rootworm resistant	Monsanto
2004	YGRW-IMI	Herbicide tolerant imidazoline - Rootworm resistant	BASF/Monsanto
2004	YGRW-RR	Herbicide tolerant glyphosate - Rootworm resistant	Monsanto
2004	YGRW-RR2	Herbicide tolerant glyphosate - Rootworm resistant	Monsanto
2005	Agrisure CB-LL-GT	Herbicide tolerant glufosinate/glyphosate - Corn borer resistant	Bayer/Syngenta
2005	Agrisure GT	Herbicide tolerant glyphosate	Syngenta
2005	Herculex I-LL-IMI	Herbicide tolerant glufosinate / imidazoline - Corn borer resistant	BASF/Bayer/Dow
2005	Herculex I-LL-RR2	Herbicide tolerant glufosinate /glyphosate - Corn borer resistant	Bayer/Dow/Monsanto
2005	YGPlus-RR2	Herbicide tolerant glyphosate - Corn borer/Rootworm	Monsanto
2006	HX RW-LL	Herbicide tolerant glufosinate - Rootworm resistant	Bayer/Dow
2006	HX RW-LL-RR2	Herbicide tolerant glufosinate /glyphosate - Rootworm	Bayer/Dow/Monsanto
2006	HX XTRA-LL	Herbicide tolerant glufosinate - Corn	Bayer/Dow
2006	HX XTRA-LL-RR2	Herbicide tolerant glufosinate /glyphosate - Corn borer/Rootworm resistant	Bayer/Dow/Monsanto

2006	YGCB-GT	Herbicide tolerant glyphosate - Corn borer resistant	Syngenta/Monsanto
2007	Agrisure CB-IMI-LL	Herbicide tolerant glufosinate / imidazoline - Corn borer resistant	BASF/Bayer/Syngenta
2007	Agrisure CB-LL	Herbicide tolerant glufosinate - Corn borer resistant	Bayer/Syngenta
2007	Agrisure CB-RW-LL	Herbicide tolerant glufosinate - Corn borer/Rootworm resistant	Bayer/Syngenta
2007	Agrisure RW	Rootworm resistant	Syngenta
2007	Agrisure RW-GT	Herbicide tolerant glyphosate - Rootworm resistant	Syngenta
2007	YGPlus-IMI	Herbicide tolerant imidazoline - Corn borer/Rootworm	BASF/Monsanto
2007	YGVT RW-RR2	Herbicide tolerant glyphosate - Rootworm resistant	Monsanto
2007	YGVT3	Herbicide tolerant glyphosate - Corn borer/Rootworm	Monsanto
2008	Agrisure 3000GT	Herbicide tolerant glufosinate /glyphosate - Corn borer/Rootworm resistant	Bayer/Syngenta
2009	YGVT3 Pro	Herbicide tolerant glyphosate - Corn borer/Rootworm	Monsanto

Overall, the number of product offerings --hybrids and biotech traits-- has grown at a faster pace over the 1997-2008 period and indicates that innovative activity in the US seed industry accelerated over this period of time.

5.4.2 Product Life Cycles

In addition to the number of product offerings, the rate of innovation in a sector is generally related to the length of its product life cycles. Observers in technologically dynamic sectors have regularly suggested that shrinking product life cycles go hand in hand with rapid product innovation. In this context, trends in the length of product life cycles in the US seed industry are of interest to this study.

Product Life Cycles in the US seed industry

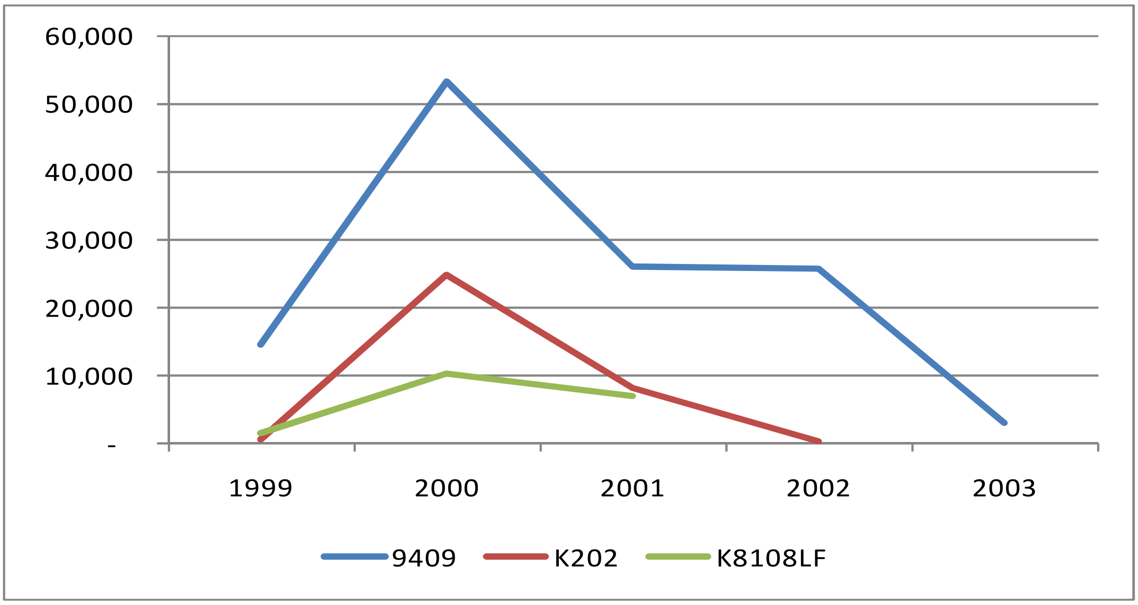
The study of product life cycles (PLCs) has a long history in the economics and marketing literatures on consumer demand and product innovation, adoption and diffusion. The basic ideas underlying the PLC were originally derived from the biological life cycle and were adapted to describe the observed pattern of product sales between the introduction and removal of a product from the market. Although researchers have used different characterizations for the components of the PLC, most view the life cycle as having four distinct stages: introduction, growth, maturity, and decline. Early adopters buy the product in relatively low volume during the introduction stage, but sales increase rapidly during the growth stage as the early adopters become repeated buyers and information about the product diffuses in the marketplace. As new products become available to buyers and enter their own introduction phase, the mature product experiences a slow decline in sales. When the new products enter their growth phase, sales for the existing product decline at a more rapid rate and the product enters the decline phase. At some point, the diminished sales cannot support the costs of production (i.e., there are fixed costs or economies of scale), and the product is completely removed from the market. The adoption and diffusion of various product innovations have been thoroughly investigated in the economic literature, and Mahajan, Muller, and Bass (1990) provide a review.

In the case of the seed industry, there are two studies that have explored the duration of PLCs. Dooley and Kurtz (2001) did not measure the length of PLCs in the US maize seed market. Instead, they used anecdotal information from industry participants and proposed that between the mid-1990s and the early 2000s the average PLC in the US seed maize industry declined from 8 to 5 years. Taking these PLCs as given, Dooley and Kurtz then focused their analysis on the potential cost implications of this decline.

Magnier, Kalaitzandonakes and Miller (2010) measured the duration of PLCs in the US seed maize industry. This study was enabled by data from GFK Kynetec collected through annual surveys of over 5,000 US maize farmers between 1997 and 2009. The complete data set is composed of more than 260,000 farmer responses. These responses were aggregated to form hybrid-specific observations. For each hybrid, the data set included the name of the seed company marketing the hybrid, the maturity zones in which the hybrid is marketed, the type of seed technology/trait (e.g., conventional, insect resistant, or herbicide tolerant hybrid), and the annual sales of the hybrid over its lifetime. Because the farmer panel is large and it is selected every year to be representative of the US maize industry, the data set provides a nearly complete census of the hybrids sold in the market in any given year.

There is significant variation in the observed product cycles of individual hybrids. For many hybrids the transition from introduction to growth, maturity and decline is gradual while for others it is abrupt or non-uniform. Figure 11 illustrates typical PLCs for specific hybrids introduced in the US market in 1999. Like those in Figure 11, most hybrids reach their maximum sales within 2 or 3 years from their introduction. Large acreage hybrids are typically sold and planted in multiple maturity zones and tend to have longer PLCs, in a few instances extending to 10 or more years. Smaller acreage hybrids tend to have more limited geographic scope and shorter PLCs.

Figure 11: Typical Product Life Cycles in the US seed maize industry



Source: GFK Kynetec

In order to estimate the length of PLCs of the various hybrids marketed in the US maize industry, survival or time failure analysis that allows for right censoring of observations is necessary. In evaluating PLCs, hybrids are considered that have completed their cycles, like the ones in Figure 11, and others that are still actively marketed. The hybrids that have not completed their PLCs are right censored and if censoring is not taken into consideration, their life cycle would appear artificially shorter. The magnitude of this bias would be larger for more recent hybrids. For instance, the observed maximum PLC length of all hybrids introduced in 2008 would be two years while in reality a large share of the hybrids could ultimately remain on the market long after that.

Then, survival or failure-time analysis is used to model the factors that influence the observed length of time seed maize hybrids remain on the market and estimate the length of PLCs. A number of the explanatory variables included in the statistical analysis were found to have a significant conditioning effect on PLCs.

The analysis indicates that hybrids with broader market reach would tend to have longer lifecycles. For instance, since the average hybrid in our sample was seeded on approximately 20,000 acres per year, a hybrid with twice that size would be expected to have a PLC roughly 12% longer than the average.
Similarly, the average length of PLCs for all maize hybrids marketed by medium size firms was found to be roughly 9% longer than those of smaller firms (which serve as baseline). Similarly, the length of the average PLC for all hybrids marketed by the top five firms is roughly 18% longer than that of hybrids marketed by small firms. Given that smaller seed firms cater to more regional markets and their hybrids tend to be planted on fewer acres, our results indicate that product turnover tends to be significantly higher among smaller seed companies.
Further, conventional maize hybrids have PLCs that were found to be roughly 13-17% longer than for stacked hybrids over the period of analysis. For the Insect Resistant hybrids, the PLCs were roughly 5-11% longer than for stacked hybrids, and the PLC length was 6-15% longer for different Herbicide Tolerant hybrids relative to stacked hybrids.

The dynamics of PLCs in the US maize seed industry
The dynamics of the PLCs in the US seed industry are of direct interest in this study. PLCs for all maize hybrids generally decreased since 1998. The decrease in the average PLCs was relatively modest until 2003 but accelerated after 2004. Indeed, the annual decrease in the average length of PLCs for hybrids introduced in 2005-2007 was 15.7% to 25.6% lower relative to seed maize hybrids introduced in 1998, and the estimated decline in the expected hybrid lifetime was largest for 2006.

The changes in hybrid PLCs can be illustrated across the trait categories and over time by plotting their estimated average lifetimes over the period of analysis. The plots are presented in Figure 11 and they show that while there are variations, the average hybrid lifetime across the different technologies is similar over the sample period. The average PLCs of conventional, Insect Resistant and Herbicide Tolerant hybrids declined only slightly from 1998 to 2003. The decline was larger for stacked hybrids but by 2003 all hybrids had, more or less, the same expected lifetime.

Importantly, these results indicate that the average PLC duration for Insect Resistant, Herbicide Tolerant and stacked trait hybrids declined between 1998 and 1999 and stabilised or recovered slowly in the following years until average PLC durations for all types of hybrids converged in 2003. Hence, the initial observed decline in the duration of PLCs coincides with the first wave of biotech product offerings. Additional GFK Kynetec data further suggest that the duration of PLCs for all four types of hybrids declined once more between 2004 and 2007 and the decline coincides with the second wave of biotech product innovation. Hence, there is evidence of a close link between biotech product innovation and the length of PLCs in the US seed maize industry. The timing and length of the decline in

PLCs coincides with that of biotech product innovation (when new product introductions begin and end). Similarly, the rate of the decline increases with the rate of the innovation (number of new products per year placed in the market).

5.5 Synthesis of findings from the three case studies

The data and analysis presented in the three case studies suggest that the US seed market for cotton has been highly concentrated since 1965 and that the level of concentration has increased significantly since the early 1990s, while the high level of concentration in the US seed markets for soybean and maize has changed only slightly over the last seventeen years. Detailed time series data on market shares also indicates that over time there has been significant variation in the competitive position of firms. Indeed, as the case study on the US cotton seed industry illustrates, significant shifts in competitive position of companies, the presence of new entrants and share gains through organic growth of existing firms against the market leader, often in very short periods of time, imply vigorous competitive rivalry despite high market concentration.

Moderate to high concentration have enabled US seed firms to exercise some market power and charge prices above marginal costs allowing for markups and premiums. As the second case study on the dynamic efficiency of the US maize and soybean seed industries illustrates, however, such economic profits are in turn reinvested in R&D thus leading to increasing research expenditures throughout the period of analysis. This result suggests that market competition has been rigorous enough to keep economic profits in the US seed industry in line with R&D expenditures and it is consistent with the view of industry executives presented in the previous section who described strong market pressures to remain competitive through R&D investments and product innovation.

Increased R&D expenditures implied the possibility of faster product innovation in the US seed industry over the last seventeen years. This possibility was further examined in the third case study where trends in product innovation, measured through new product introductions and the length of product life cycles in the US maize seed industry, were analysed. The analysis confirmed that the number of product offerings increased and the average length of the product lifecycle in the industry declined over the period of analysis– both indicators of increasing product innovation. Hence, it was concluded that over the last seventeen years, the US cotton, soybean and maize seed industry has experienced increased innovative activity while it has remained highly concentrated.

6. MAIN FINDINGS AND CONCLUSIONS

The question posed by the Commission on Genetic Modification (COGEM) for this study was whether the plant breeding sector worldwide is monopolised by large multinationals, due to the application of genetic modification, and if so, what might be the possible consequences for innovation in this sector? To answer this question, the key findings from a literature review are summarised and compared to those from interviews with eleven top executives in the seed industry for a perspective from "within" and those from an economic assessment of the industry concentration, market power and innovation in US seed markets for the three major genetically modified crops: Soybean, maize and cotton.

6.1 Findings from the literature review

6.1.1. Three waves of structural change

Over the last one hundred years the global seed industry experienced significant structural changes. Three major waves of structural changes in the seed industry were indentified:

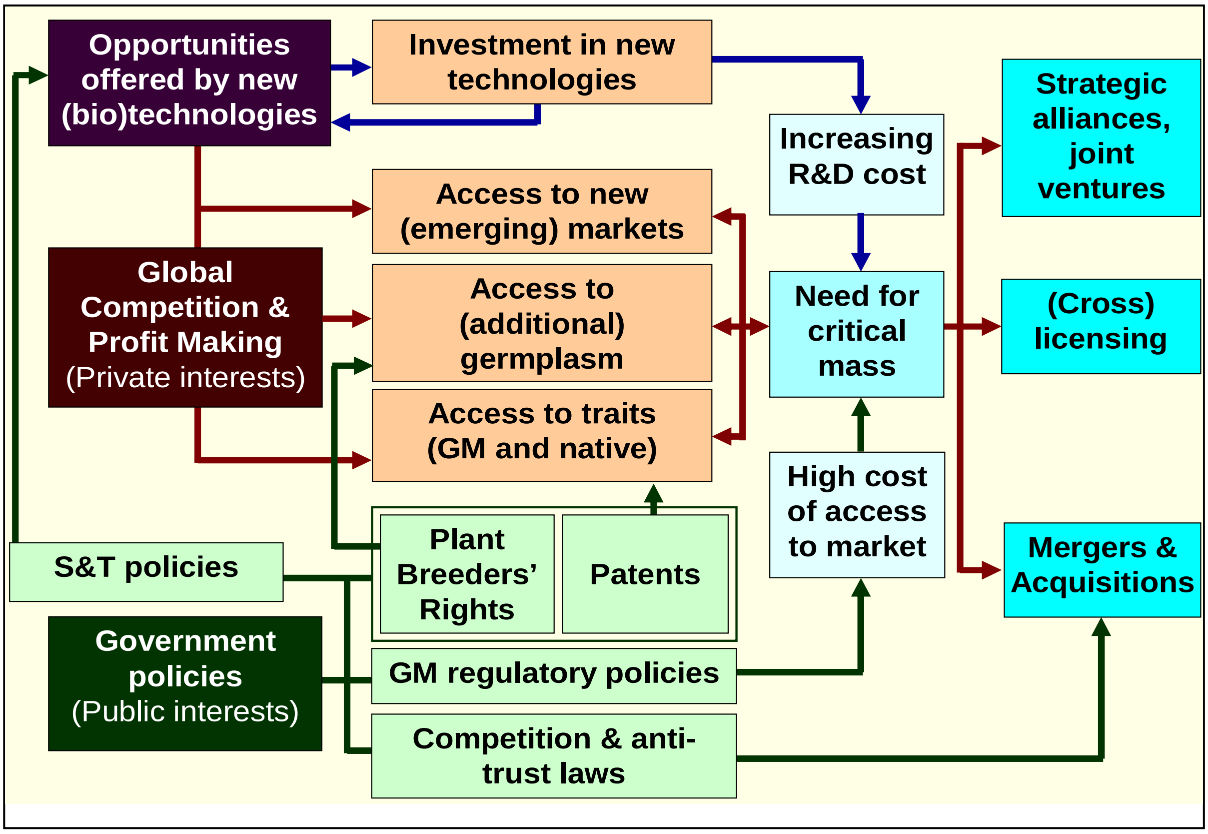
1. The first wave started in the early 1930s when new commercial seed firms were established and continued to adapt public research on hybridisation, leading to innovations and growth in maize and other seed sectors.
2. The second wave started in the 1970s fostered by the introduction of various intellectual property (IP) rights such as plant breeders rights (PBRs) and patents, which promised to increase returns from investments in plant breeding research and development (R&D). While historically seed germplasm assets had primarily been traded among seed companies until the 1960s, the introduction of stronger IP rights set off a wave of mergers and acquisitions (M&As) activities by R&D-minded pharmaceutical, petrochemical and agrochemical companies from the US and Europe. In the US, for example, multinationals mainly acquired and merged mainly small and medium sized regional seed companies. However, independent market leaders and smaller regional and local seed companies generally maintained their market position in spite of the significant capital resources of the multinationals and by the early 1990s many of the multinationals that led M&As activities in the 1970s and 1980s had divested their seed germplasm assets. In the end, a limited amount of consolidation was observed in a few seed sectors in the US and elsewhere.
3. The third wave started in the 1980s, when a handful of agrochemical multinationals from the US and Europe with substantial investments in genetic modification (GM) and other biotechnologies maintained and expanded their presence in the global seed industry. For the commercial introduction of a new GM or biotech seed to be successful, biotechnology know-how, access to seed germplasm and IP had to be coordinated. This need for coordination led to a strong wave of strategic M&As activities by these few multinationals which vertically integrated seed germplasm assets and GM/biotech assets.

The entry of these multinationals changed the ownership structure in the seed industry drastically. In 1985 the top nine seed companies had a share of 12,7% of the global seeds market and only four of these top nine seed companies were (owned by) pharmaceutical or petrochemical multinationals. In 1996 the top nine seed companies had a share of 16,7% of the global seeds markets while one of them was (owned by) a multinational. In 2009 the share of the top nine seed companies had had explosively grown to 43,8 % of the global seed markets and five were (owned by) agrochemical multinationals. In the same period from 1985 to 2009 the annual sales volume of the global seeds markets had increased from 18 billion US dollar to about 44 billion US dollar.

6.1.2. The dynamic interplay of scientific breakthroughs, government policies and business strategies

The literature review further revealed an ongoing dynamic interplay between scientific breakthroughs, government policies and business strategies. Figure 12 provides a schematic overview of interactions between government policies and business strategies that drive structural changes in the seed industry.

Figure 12: Dynamic interplay of government policies and business strategies in seed the industry



Scientific breakthroughs: Publicly funded research in plant science and molecular genetics led to scientific breakthroughs in plant breeding, such as hybridisation, GM technologies as well as genotyping and phenotyping technologies. Each scientific breakthrough drove a wave of private investments in the seed and biotech industry, leading to various innovative products such as hybrid seeds and GM/biotech seeds.

Government policies: Governments around the world have generally pursued growth in agricultural productivity through various policies. On the one hand, Science and Technology (S&T) policies and Intellectual Property (IP) laws have sought to create incentives for innovation. On the other hand, biosafety/GMO regulations were implemented to manage food and environmental safety while competition and antitrust laws were implemented to manage market risks.

Science and Technology (S&T) policies have funded and directed public R&D in fundamental and applied plant sciences, plant breeding, biotechnology and genomics. Until the 1980s public investments in plant breeding R&D outweighed private R&D investments and since then these private R&D investments began to exceed public R&D expenditures. Concerns have been expressed about under-investment in public sector R&D for plant breeding of minor crops (like oats and barely) and to public goods like environmental protection and food safety.

Intellectual Property (IP) laws encouraged private investment in plant breeding and biotechnology R&D. From 1960 to 1996, when various IP rights in plant breeding and biotechnology were introduced, private R&D investment increased 14-fold.
Since they ensure seed companies' access to technologies and GM traits, patents have become an important strategic asset. In 2007, the share of the top ten companies was estimated at about 75% of all patents applications at the USPTO and 43% of all patent applications at the EPO. Notably, in the field of genetic modification, it was estimated that two companies, Monsanto and DuPont-Pioneer, held more than 50% of the patents. Yet, it is not clear whether the number of PBRs and patents obtained by a company is a solid measure of a company's innovative strength. Irrespectively, pressure has been building on governments to act that patents do not stifle innovation.

Biosafety/GMO regulations were introduced to protect human health, the environment and biodiversity from technical risks that might be associated with new biotechnologies and to provide consumers and producers with choice. The literature review suggested that for the first generation of GM crops with a single trait for herbicide-tolerance or insect-resistance, the costs of obtaining market approval varied between 6 million US dollar to 13 million US dollar. It has been argued that these regulatory compliance costs would discourage public research institutes and small companies to engage in the development and commercialisation of GM crops. While this point has not been clearly demonstrated in the literature, it remains a fact that no small or medium size company or public institute has commercialised any new GM crop until now. An analysis of data on field trials with GM maize, soybean, cotton and tomato in the US, EU, India, Australia and Argentina indicated that in terms of numbers, the so-called 'CropLife' companies (BASF, Bayer, Dow, DuPont-Pioneer, Monsanto and Syngenta) are dominant. Overall, Monsanto ranks first in numbers of private sector field trials with GM maize, GM soybean, GM cotton and GM tomato in these countries. In the case of GM rice, BASF and Bayer rank first in numbers of private sector field trials, followed by Monsanto.

Competition and antitrust laws were introduced to protect consumer welfare in industries where monopolisation and market power can emerge. Because the seed sectors in the US and elsewhere are generally concentrated, M&As and other competitive strategies have regularly attracted government scrutiny. In the last decade, the US Federal Department of Justice (DoJ) initiated antitrust investigations concerning Monsanto's acquisition of DeKalb in 1998 and that of Delta and Pineland in 2006. In both cases the DoJ pointed to the importance of innovation in the selected markets and to the need for rival access to Monsanto's patented technology and required the company to divest certain assets. Similarly, in November 2010, the European Commission cleared the acquisition of the global sunflower seed business of Monsanto by Syngenta but required Syngenta to divest certain assets.

Overall, these government policies were found to have positively influenced the incentives for seed and biotech firms to invest, merge and expand in the global seed industry over the period of interest. On the other hand, several enforcement actions of competition and antitrust laws in the US and Europe have required biotech firms to divest certain seed germplasm assets before approving certain mergers and acquisitions and the relatively high GMO regulatory compliance costs of 4-10 million € per GM trait/crop combination have probably discouraged small and medium sized seed and biotech firms and public sector institutions to develop and bring GM crops to the market.

Business strategies: Firms in the seed industry and potential entrants seek opportunities to obtain and extend market share, maximise profits and earn adequate returns on invested capital. Scientific breakthroughs, especially in plant biotechnology, and government policies, in particular on IP rights, created profit opportunities for innovations in plant breeding, which firms could exploit. A variety of business strategies were used in the seed industry over the years in response to such opportunities including investments in in-house R&D in plant science and plant breeding as well as R&D collaboration with private and public partners. In addition, M&As and pursuit of IP rights including through (cross)licensing of IP enabled companies to gain access to new technologies, seed germplasm and new markets. As agrochemical and other diversified firms vertically integrated into the seed industry, seed germplasm assets of seed companies were merged into multinational firms with biotechnology R&D investments. In most of these companies, net sales of (agro)chemicals still dominate the net sales of seeds. Other companies, such as Limagrain and Land O'Lakes, have a cooperative background and are more diversified. In these companies, sales of seeds is a part of a range of agricultural services, including food production, sales of agrochemicals and even machinery. Finally, firms like KWS from Germany and Sakata from Japan have remained more specialised in seed development, production and distribution.

Overall, these business strategies were found to have influenced the structure of the seed industry, resulting in increasing levels of concentration and a drastic change of ownership since the entry of agrochemical multinationals into the seed industry in the 1980s.

By 2009, the top nine seed companies together had a share of nearly 44% of the global seeds market representing a total value of around 44 billion US dollar, while the top three together had a share of 34% of the global seeds markets. Five of these top nine seed companies were (owned by) agrochemical multinationals that started entering the global seed industry in the 1980s. Their entry changed the ownership structure in the industry drastically.

6.2 Findings from interviews with executives from the seed industry

6.2.1 Increasing R&D cost and IP and legal cost

Nearly all interviewees identified increasing plant breeding and plant biotechnology R&D investments, the rising costs of GM technologies as well as increasing GMO regulatory compliance costs as key drivers of change in the structure of the seed industry. In addition, a number of interviewees considered the cost of adoption of patent rights a major driver of structural change but other interviewees thought this driver of less importance.

The interviewees described an industry rivalry where investments in the development of new technology and products had become central to a firm's competitiveness. According to the interviewees, companies operating in seed markets for field crops usually invested between 9% to 15% of their turnover in seed sales in R&D. Companies operating in seed markets for vegetable crops invested between 15% to 25% of their seed sales. The interviewees also expected future growth in R&D expenditures to be in line with growth in total turnover.

Several interviewees indicated that over the last five years IP and legal costs as a share of their companies' total seed sales varied from 2% to 5%. These interviewees expected further growth of IP and legal costs for the nearby future. Others considered IP and legal costs negligible compared to overall costs of business operations. All interviewees explained that licensing (out-licensing and in-licensing) is a valuable business strategy for accessing enabling technologies, traits and germplasm. For smaller seed companies licensing has become a primary strategy for gaining access to technologies and traits and remaining competitive in the market. Nevertheless, some interviewees indicated that agreements with companies with major interests in biotech traits had become more difficult, partly because of restrictions license holders seek to impose on licensees.

The interviewees noted that the increasing investment in R&D for GM/biotech seed innovations as well as large regulatory and legal expenditures required the seed companies to grow in size and expand in new markets in order to achieve critical mass and relevant return on investment. Besides mergers and acquisition, all interviewees confirmed that their companies continuously sought opportunities for expansion of their business operation into new markets, both geographically (China, India, Latin America) and in crops (rice and wheat), and through in-licensing and out-licensing IP on GM/biotech assets and seed germplasm assets.

The interviewees showed a divergence of opinions on the role of IP, especially patent laws, on structural change and the level of innovation in the seed industry. A number of interviewees considered patents on GM/biotech traits, enabling technologies and seed germplasm indispensable for private investment in R&D. Other interviewees argued that patents can hinder breeding activities, accelerate the process of concentration and have a negative impact on the overall innovation in the seed industry and the overall availability of innovative varieties for farmers and society at large.

6.2.2 The costs of bringing a GM crop to the market

The costs of bringing a GM crop to the market were also considered a major driver for concentration and a factor that influences the level of innovation in the seed industry by many interviewees. Seed companies have to recoup those costs from seed sales in markets that maybe large, as in the case of field crop seeds, or small, as for most vegetable crops. Market size and potential added value ultimately determines which crop species and traits are suitable for GM technology, several interviewees explained. GM technology has therefore mainly been used in product innovations for major field crops, like soybean, maize, oilseed rape and cotton, where, as one of the interviewees explained, 'increased productivity' adds value for the company's customers, the farmers.

The estimated costs for bringing a GM crop to the market provided by the interviewees varied widely. Some interviewees mentioned figures of 100 million US dollars or more, Others suggested that the total costs varied between 15 and 30 million US dollars per crop/trait combination, which corresponds roughly with the data on regulatory compliance costs from the literature review.. When the interviewees were asked to separate the development costs in terms of trait discovery, GM event construction and selection, product development, GM seed multiplication, GMO regulations, IP and license costs, only few interviewees were able or prepared to provide a detailed breakdown of the total costs. Some noted that such accounting depends on how one attributes the costs to specific activities in the R&D and product development process. A number of interviewees also distinguished between the cost of a single country approval for a GM crop and the total cost of a global approval.

With a view to stewardship programmes for compliance with post-marketing monitoring of GM crops and government policies and/or market standards for the adventitious presence of GM traces in non-GM products, several interviewees pointed out that in cases of licensing the recipient of GM material, e.g. another seed company, had to have the appropriate tools to follow the stewardship requirements to prevent liability claims accruing to the developer. One interviewee explicitly stated that the company did not allow other companies to stack its traits without prior agreement on conditions and requirements for stewardship.

Moreover, as most interviewees noted that post-patent use of traits and seed germplasm should be possible for the development of generic GM/biotech seeds, maintaining and having access to regulatory data packages and stewardship programmes will be vital for the development of a generics market.

6.2.3 Competition and the need to create access to new markets

M&As often dominate the geographic expansion of seed companies. In addition to mergers and acquisitions, all interviewees explained that their companies continuously seek opportunities for expansion of their business operation into new markets, both geographically and in new crop species through gradual entry and growth, joint ventures and other partnerships. All interviewees indicated that further growth in the global seed market is to be expected. Nearly all seed companies consider emerging markets in Asia and Latin America to have substantial growth potential, for instance in a major field crop as rice.

In Asia, the concentration of the seed industry is still very modest and seed (distribution) companies are expected to continue to grow in size, many through M&As. This restructuring will likely be shaped by government policies. In China for instance, the government policy on M&As in seed markets intervenes at two levels. At one level, the Chinese government is pushing domestic seed companies to merge among themselves. Today, there are about 3,000 domestic seed companies in China, and the government's goal is to have 30 – 50 big companies in ten years from now. At another level, the Chinese government imposes limitations on foreign companies for taking shares in Chinese companies. Foreign companies are allowed to have the majority of shares in R&D, but not in seed production and distribution, where the maximum level of allowable ownership is set at 49%. Given the ongoing fast economic growth in China, it is expected that Chinese seed companies will also seek to invest in major seed companies outside China. In the next ten years, according to one interviewee's predictions, there will be one Chinese company in the top ten of seed companies in the world, or at least controlled by Chinese.

6.3 Findings from the case studies on the US seed markets for soybean, maize and cotton

To what extent the application of GM technology might have contributed to structural changes in the seed industry as well as to changes in the level of innovation was studied further through an economic analysis. Given the substantial adoption of GM technology in the US for maize, soybean and cotton over the last seventeen years, this part of the study focused on these US seed markets. More specifically, the relations between concentration, market power, price markups, R&D expenditure and product innovation in US seed markets for maize, soybean and cotton, were examined over the last seventeen years.

It is worth noting that in the economic literature there is continuing discourse about whether competitive or monopolistic market structures offer the best environment for innovation. These are knotty conceptual and measurement issues that complicate the debate about questions such as: (a) How to effective measure innovation? (b) How to measure the level of competition in a market? (c) How to effectively link the two? (d) How to account for potential tradeoffs between static and dynamic efficiency. Past studies have used a number of indicators of innovative activity in different sectors, including the stock of patents, R&D expenditures, and the rate of new product introduction. For this study, two of these indicators were used: R&D expenditures and the rate of new product introduction. The levels of concentration in the US seed markets for cotton, soybean and maize were measured by using Herfindahl-Hirschman Index (HHI).

Cotton: Since 1965 the HHI in the US cotton seed industry in most years has been relatively high exceeding 1,800, which is the threshold between moderate and high levels of concentration in industries. The HHI jumped drastically in the early 1990s but it started declining since the mid-2000s. Despite its acquisition of Delta and Pineland in 2007, Monsanto has continued to license broadly its GM traits to large and small competitors. As a result various competitors have been gaining share against the market leader Delta and Pineland and such gains are reflected in the declining HHI of the national market. However, such market share gains are even more pronounced in the regional seed markets where firm rivalry is more apparent. Measures indicated that the US cotton seed market has remained concentrated but with significant variation in the positions of the firms in the seed industry. The presence of new entrants and share gains through organic growth of existing firms against the market leader indicate a vigorous competitive rivalry in the US cotton seed market.

Maize and soybean: In the US seed markets for maize and soybean, the HHI values for the US maize and soybean seed industry have stayed close to 1,800 from 1992 to 2008. The findings further suggested that firms in these seed markets exercised limited market power and charged markups for their hybrids, proprietary varieties and biotech traits. For all key firms in the industry, the revenue streams from these markups were in line with increasing R&D expenditures over the period of analysis. Firms in these seed industries have thus increased their innovative activities over the last seventeen years as they have reinvested their profits from innovation into more R&D.

The balance between firm profits and investments in product quality and innovation is an important indicator of dynamic efficiency in the market place and an effective measure of competition in dynamic and innovative industries. Due to the complex supply and demand structures of R&D focused industries estimation of market power and associated price markups is not straightforward. Nevertheless, the empirical findings suggested that in the case of the US maize seed industry concentration, moderate market power and dynamic market efficiency coincided over the last seventeen years. Trends in new product introductions as well as in the length of product life cycles in the US maize seed industry were also examined over the last seventeen years. In that period, the number of product offerings increased significantly and the average length of the product lifecycle in the industry declined – both indicators of increasing product innovation.

Overall, the economic evidence suggests that the high levels of concentration in the US seed markets for cotton, maize and soybean have not had negative impacts on innovation over the last seventeen years; a period that coincided with the substantial adoption of GM technology by these US seed markets.

6.4 Concerns

From the literature review and the interviews with the top executives from the seed industry, the following concerns have emerged:

- Under-investment in public sector R&D for plant breeding of minor crops and to public goods like environmental protection and food safety.
- Patents provide essential incentives for R&D investment but can also stifle innovation in the seed industry.
- It is expected that R&D costs will remain at a high level. Since high R&D costs are one of the main drivers, this will likely contribute to further concentration and consolidation in the seed industry.
- GMO regulatory compliance costs that discourage public research institutes and small companies to engage in the development and commercialisation of GM crops and stewardship programmes for compliance with post-marketing monitoring of GM crops and government policies and/or market standards for the adventitious presence of GM traces in non-GM products, particularly in the case of licensing.
- Lack of maintenance of and access to regulatory data packages and stewardship programmes after expiration of a patent on a GM/biotech trait. Access to this information will be vital for the development of a market for generic GM/biotech seeds.

6.5 Conclusions

Over the last hundred years the global seed industry has undergone three major waves of structural changes. The ongoing dynamic interplay between diverse scientific breakthroughs, government policies and business strategies shaped these structural changes. Advancements in plant science and plant breeding, the introduction of IP rights in plant breeding and biotechnology, the increasing R&D costs expended by seed companies and their need to remain competitive by expanding and accessing new markets were all major drivers of structural change, leading to a large consolidation in the world seed business. The third and most significant wave of structural changes began in the 1980s, when a handful of agrochemical multinationals from the US and Europe with substantial investments in GM/biotechnology maintained and expanded their presence in the global seed industry through strategic M&As activities in order to vertically integrate seed germplasm assets and GM/biotech assets. Their entry changed drastically the ownership structure in the seed industry.

This study revealed a number of drivers for structural changes in the plant breeding sector during the last century. Application of genetic modification has been one of the main drivers in the last two decennia. Consolidation has also taken place in seed markets without GM varieties, where many breeders applied other innovative plant breeding technologies and plant biotechnologies. Therefore, the relative importance of GM as a driver varies per seed market.

According to the economic analysis, the high levels of concentration in the US seed markets for cotton, maize and soybean have not had negative impacts on innovation over the last seventeen years; a period that coincided with the substantial adoption of GM technology by these US seed markets.

ANNEXES

Drives of Consolidation in the Seed Industry and its Consequences for Innovation

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This Annex describes the evolution of three major seed companies over the last decades that illustrate the major strategies of investment in genetic modification (GM) technologies as a replacement for non-GM technologies or as an addition to other technological trajectories (See section 3.2.2 of the major report). Monsanto is an example of a US-based chemical company that started applying a strategy of investment of large shareholder funds in acquisitions in the late 1980s, which turned it into the world's largest seed company with an estimated 17.4% share of the global seed market in 2009. Syngenta, a Europe-based company whose major business is pesticides, ranks nr. 3 on the list of the largest seed companies. Syngenta's predecessors, Zeneca and Novartis, invested a great deal in technology and some acquisitions. Limagrain's evolution illustrates a similar strategy applied by the world's largest seed cooperative.

A.1 Monsanto

Before the mid-1980s, Monsanto was primarily a producer of chemicals and optoelectronics (LEDs). As of 2010, it has become the world's largest seed company. This has been achieved by more than fifty acquisitions of seed companies between 1996 and 2010 (Howard 2009; this study).

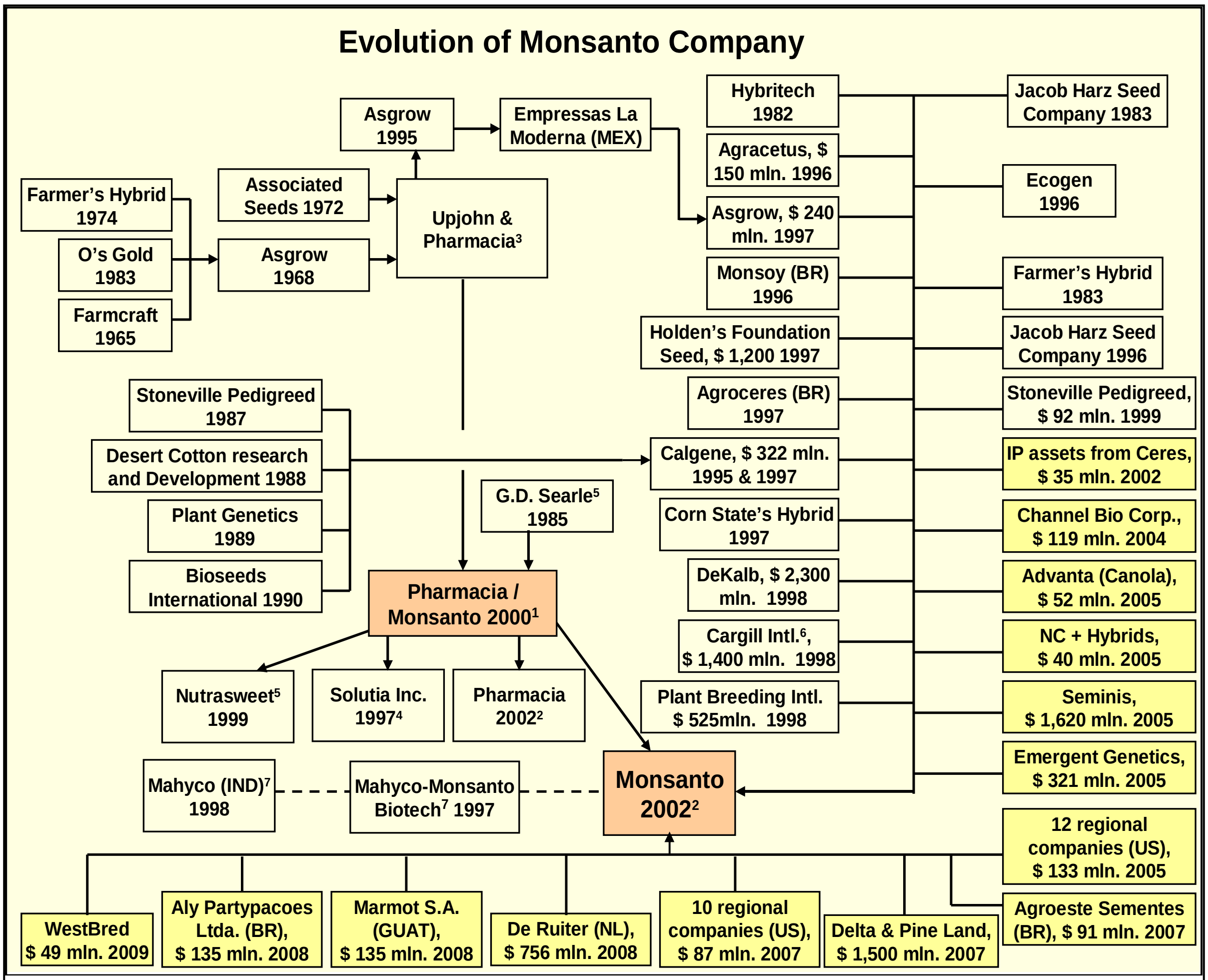


Figure A1: Monsanto mergers & acquisitions

Source|: USDA, Monsanto Annual Reports

- For instance, in 1996, Monsanto acquired Agracetus, a subsidiary of W.R. Grace & Co, gaining access to Agracetus' genetically engineered cotton, and, more important, to its so-called 'Accell=FE gene gun', a proprietary GM technique. This technique uses an electric generator to fire DNA coated micro-projectiles into living cells to introduce new genes; it is an alternative to genetic modification using (the Ti plasmid of) *Agrobacterium tumefaciens*. It is especially useful in monocot crop species like maize and rice (Bijman 1994).
- Subsequent acquisitions of Asgrow and Holden's Foundation Seeds in 1997, DeKalb in 1998 and several other seed companies gave Monsanto access to the maize market, allowing the introduction of RoundupReady technology (herbicide-tolerant) and Yieldgard (insect-resistance) technology into maize (Monsanto 2010).
- Through the acquisition of Plant Breeding International (PBI) from Unilever in 1998, Monsanto gained access to a range of other crop species, including winter wheat, barley, oilseed rape (allowing the introduction of Roundup Ready technology into canola varieties), and potato. Monsanto expected the introduction of new hybrid wheat varieties, resulting from a combination of PBI's conventional breeding capabilities and the advanced breeding techniques developed by Monsanto's Hybri-Tech unit (PR Newswire, 1998).
- Monsanto further added a range of vegetable and fruit seeds to its portfolio with the acquisition of Seminis. Seminis supplies more than 3,500 seed varieties in more than 150 countries in the world. The position in the vegetable seed market was further consolidated in 2008, with the acquisition of De Ruiter Seeds and Western Seeds.
- Moreover, after a first attempt to acquire Delta and Pine Land Company in the late 1990s had failed, Monsanto managed to complete the acquisition in 2007, which gained the company access to the cotton seed market (Monsanto 2006).
- The acquisition of WestBred in 2009 gave the company access to wheat germplasm.
- In terms of net sales, reaching a share of 56%, maize has remained the most important crop for Monsanto. The share of soybean seeds has decreased from almost 40% in 2001 to less than 20% in 2009. Vegetables and cotton seeds have a share of 11% and 6% - 7% respectively.

Table A1: Monsanto's net sales by crop, 2005 – 2009 (in $ million)

	Crop				Total	Remarks
	Maize	Soybean	Vegetable	Cotton		
2009	4,113	1,448	808	466	7,297	
2008	3,542	1,174	744	450	6,369	
2007	2,807	901	612	319	4,964	Acquisition of Delta and PineLand
2006	1,793	960	569	305	4,028	
2005	1,494	889	226		3,252	Acquisition of Seminis and Emergent

Source: Monsanto Annual Reports 2005-2009

A.2 Syngenta

Between 1974 and 1983, three European chemical companies put their first steps in the seeds market. In 1974, three years after the chemical companies Ciba and Geigy from Basel had merged, Ciba-Geigy acquired the US-based company Funk Seeds International in order to expand into the seeds business. Shortly after, Sandoz, also based in Basel, followed Ciba into the seeds market by attaining Rogers, a breeder of hybrid and open pollinated vegetable seeds, and Northrup King, a breeder of maize, sunflower and oilseed rape. In 1980, Sandoz further extended its vegetable seed business by acquiring Sluis & Groot (S&G) of the Dutch Zaadunie group. In the same year, Ciba established a special biotechnology unit. In the UK, Imperial Chemical Industries (ICI) joined the global seed market by establishing ICI Seeds in 1983.

In 1993 ICI demerged its bioscience businesses in pharmaceuticals, agrochemicals, specialities, seeds and biological products. All were transferred into a new and independent company called Zeneca Group (Ipsen 1993). Six years, in 1999, later Zeneca merged with AstraAB to form AstraZeneca PLC.

Meanwhile, in 1996, Zeneca Seeds had started offering the first GM tomato puree to customers. The tomatoes had an extended shelf-life and improved processing properties, which initially was a success on the British market because of its favourable price (GMO Compass). In the same year Zeneca and the Cosun/RoyalVanderHave Group (Netherlands) formed the joint venture company Advanta. A year later Zeneca acquired Mogen, a Netherlands-based plant biotechnology company that developed and patented the *Agrobacterium tumefaciens* plant transformation technology.

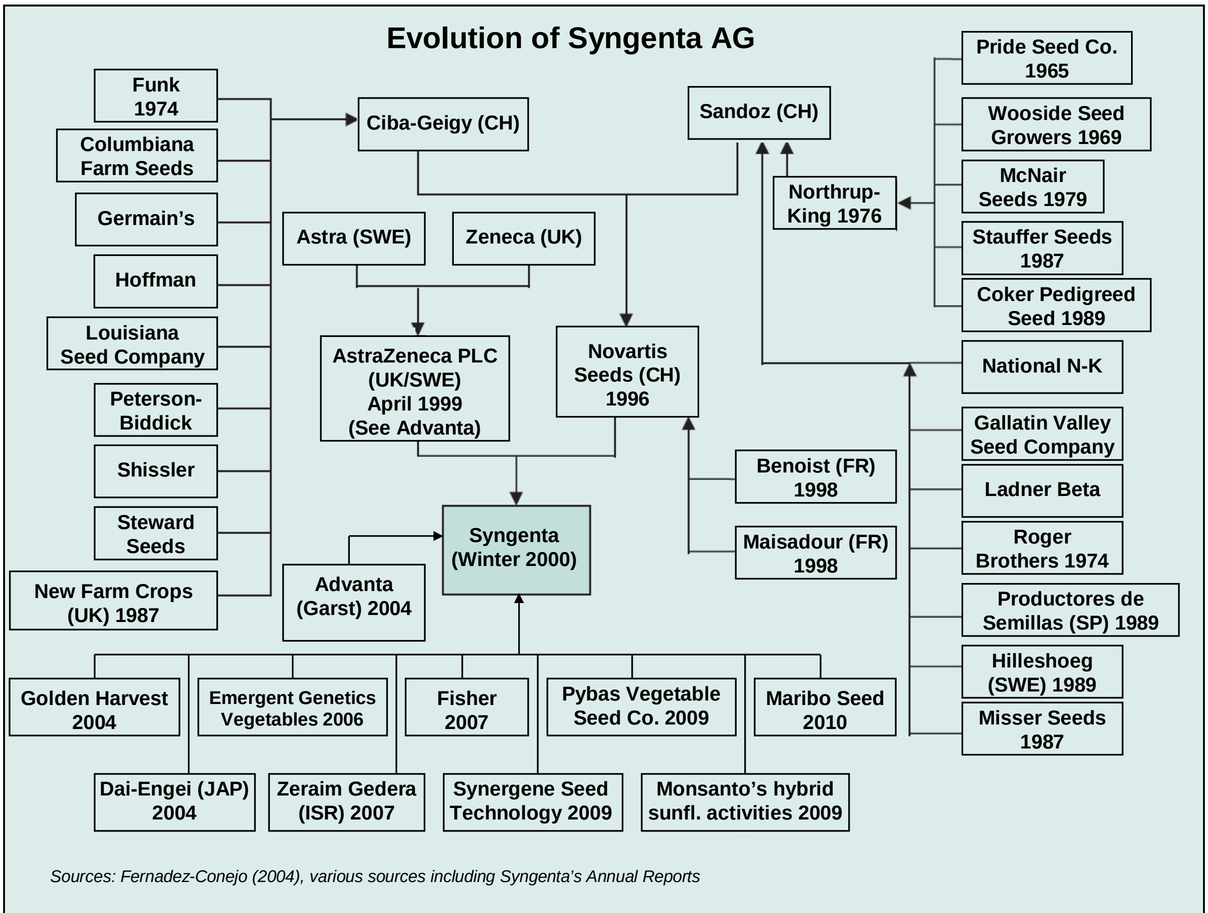


Figure A2: Syngenta mergers & acquisitions

Source: USDA, Syngenta Annual Reports

One of the largest mergers in history took place in 1996, when Sandoz and Ciba-Geigy formed Novartis. Those were the days that companies started to believe in synergistic effects of technologies that could be applied both in pharmaceutical and crop development. "We believe that the fields of human health, crop science and animal health operate today in a common innovation-driven environment. Aventis will have an impressive range of emerging technologies and expertise which will benefit all its businesses," said the chairman of Hoechst AG and the chairman of Rhone-Poulenc SA in a joint statement when they created the chemical companies Celanese and Rhodia, respectively, and merged their remaining operations as Aventis in December 1999 (Hoechst 1999; Thayer 2001). In 1998 the company made headlines with its biotechnology licensing agreement with the University of

California at Berkeley Department of Plant and Microbial Biology. The agreement expired in 2003 (Royer 2004).

In 2000 Novartis and AstraZeneca split their agribusinesses from their pharmaceutical businesses and merged them to form Syngenta. It was not until three years later that Syngenta announced a new acquisition: Dai-Engei, the Japanese leader in producing and marketing seedlings of flowering plants and vegetables (Seedquest 2004b). During the same year Syngenta expanded its maize and soybean business in North America by acquiring a 90% stake in Golden Harvest (180 million US dollar) with a US market share of 4% in maize and 3% in soybean, and Advanta's North American maize and soybean business (400 million US dollar), traded under the Garst brand. Adding to Syngenta's NK brand, these acquisitions enhanced market share in US maize seed to 15% and soybean to 13%. Moreover, Syngenta purchased glyphosate-herbidicide tolerance technology for maize, called GA21, from Bayer, enabling the company to introduce stacked traits with corn rootworm resistance and glyphosate-tolerance (Syngenta 2004a; Syngenta 2004b).

Between 2006 and 2010 Syngenta acquired a number of relatively small seed companies:

- Emergent Genetics Vegetable A/S (EGV) in 2006. EGV focuses primarily on spinach, cucumber, cabbage and cauliflower (Syngenta 2006). Before EGV had acquired the Danish company Daehnfeld.
- Zeraim Gedera (95 million US dollar) and Fischer (67 million US dollar) in 2007. Zeraim Gedera is an Israeli vegetable seeds company focusing on high-value crops, including tomato, pepper and melon. Fischer is a privately held vegetative flowers company specializing in the breeding and marketing of flower crops. (Syngenta, 2007a; Syngenta, 2007b).
- Two lettuce seed companies in the US: Synergene Seed & Technology, Inc., a lettuce seed company with a diverse and proprietary lettuce gene pool, and Pybas Vegetable Seed Co., Inc., well-known for its quality seed production and processing as well as its germplasm (Syngenta 2009b).
- The Maribo Seed sugar beet business from Nordic Sugar, a subsidiary of Nordzucker AG (Syngenta 2010).

Monsanto's hybrid sunflower seed activities (160 million US dollar), which included germplasm, development and breeding of hybrid sunflower seeds, were acquired in 2009 (Syngenta 2009b). Finally, in the summer of 2010, the European Commission announced investigations under the EU Merger Regulation No. 139/2004 into Syngenta's proposed acquisition of Monsanto's global sunflower seed business. In November 2010 the European Commission cleared the acquisition. However, the European Commission required Syngenta to divest Monsanto's sunflower hybrids, commercialised or under official trial in Spain and Hungary, including the parental lines. Otherwise the transaction would have removed a considerable and innovative competitor to Syngenta, reinforcing the latter's market leader position. The transaction also raised concerns about the activities of exchange and licensing sunflower varieties, insofar as the merging parties would be in a position to restrict the access of competitors to input necessary for the commercialisation of sunflower seeds. In the light of the commitments of Syngenta, the European Commission concluded that the transaction would not significantly impede effective competition in the internal market or any substantial part of it.

A.3 Limagrain

Limagrain is the world's largest cooperative seed company. It is a leading producer of maize, wheat, and other seeds in Europe. Limagrain is also the world's leading supplier of seeds to the home gardening market and one of the top suppliers of vegetable seeds to the professional segment. The company is also producing food products, supplying flour and other bakery ingredients through subsidiary Limagrain Céréales Ingrédients. In addition, the company owns Jacquet SA, France's second-largest industrial baking group.

- In 1942, a group of farmers in the Limagne plains area, near Clermont-Ferrand, joined together to create a cooperative to produce and distribute seeds. The new organization was called Coopérative de Production et de Vente de Semences Sélectionnées du Massif Central. The cooperative at first specialized in the production of wheat seed, and began investigating other seed markets in the post-war period. In the mid-1960s, it teamed up with the state-run research institute INRA in order to develop and produce new maize varieties. The cooperative adopted a new name, Limagrain in 1965, and in that year also decided to specialize in the research, development, and production of seeds for new maize varieties
- During the 1970s, Limagrain emerged as a leading seed producer in France and increasingly throughout Europe as well. The cooperative also began seeking opportunities for expansion into other seed markets. In 1975, the group made its first significant acquisition when it purchased Vilmorin-Andrieux, which added an entire new business in seeds for vegetables, fruits, and flowers and other ornamental plants.
- Limagrain's next major acquisition came in 1979, when it acquired Tézier, a prominent supplier of vegetable seeds to the French market in France. and had also developed a strong international presence as well. The combination of Vilmorin and Tézier under Limagrain boosted the cooperative to the leading ranks of European seed producers.
- Limagrain made its first efforts to expand into the North American market at the beginning of the 1980s. After establishing a maize research facility in the United States in 1979, the company added a production subsidiary with the purchase of Ferry Morse in 1981.

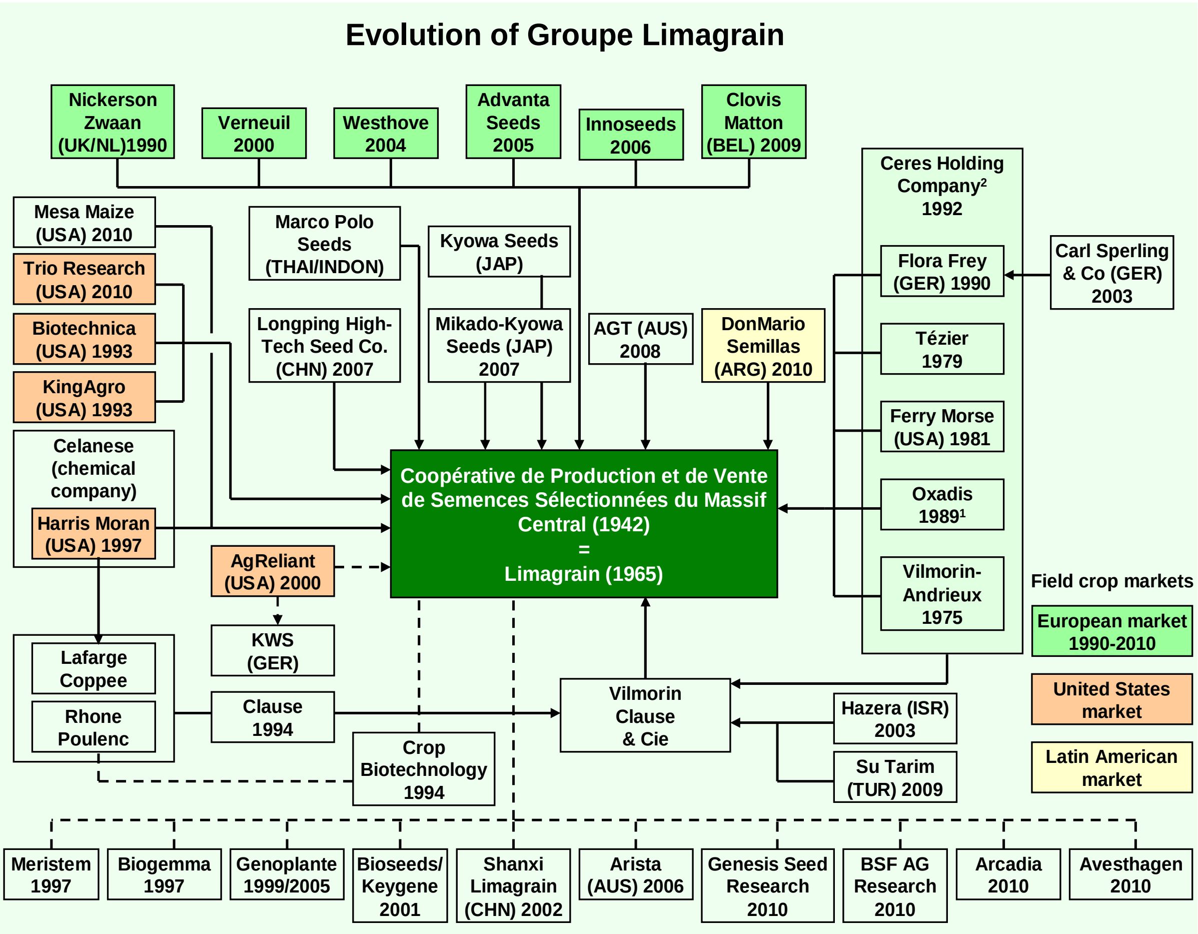


Figure A3: Limagrain mergers & acquisitions

` ....▶ Participations

Between 1986 and 2010 Limagrain made 29 acquisitions, took stakes in 12 companies, and had 24 divestitures (Alacrastore 2010). In the last two decades, Limagrain expanded its European leadership in wheat seeds and expertise in cereal products to an international dimension.

- It started with the acquisition of the European seed producer Nickerson Zwaan. This gave Limagrain prominent positions in the Netherlands and in the United Kingdom. Apart from wheat seeds Nickerson-Zwaan also added a variety of other crop seeds, including sugar beets, cabbage, gherkins, and lettuce.
- Since then, the Group has continuously strengthened its positions by internal growth and acquisitions. Verneuil in 2000 (creation of Limagrain Verneuil Holding). At the end of 2004, Limagrain boosted its grains business with the acquisition of France's Westhove. This purchase was followed by the acquisition of Advanta Seeds Inc.'s vegetable seeds operations in Europe in 2005, as well as that company's sunflower and grass seeds operations in North Dakota and Oregon, respectively. Innoseeds in 2006 (Seedquest 2009).
- In 2000 Limagrain merges its North American maize seeds operations into AgReliant, a joint venture with KWS. At the end of December 2004, AgReliant acquired the Nebraska-based seed company Producers Hybrids, which focuses on producing and marketing maize and soybean seed in its key market of Nebraska and neighbouring US states.
- In 2009 Limagrain also acquired Clovis Matton, a Belgian producers of diverse field crop seeds well-known for cereal varieties with sustainable disease resistance traits (Limagrain, 2009).
- In the early 1990s, the cooperative redoubled its efforts to establish itself in North America. Once again, acquisitions formed a major part of the company's expansion strategy. In 1993, for example, the company acquired Biotechnica, based in Kansas City. This purchase was followed by the purchase of Ontario's KingAgro, a seed company with particular focus on the canola market. The company also began producing maize seed in the United States, launching this operation in 1994. These and other acquisitions transformed Limagrain into a truly global operation. Where previously Europe had accounted for some 95% of Limagrain's revenues, by the middle of the 1990s the North American market already represented more than 35% of the Group's total income. In 1997, Limagrain boosted its North American presence again, this time acquiring one of the market's leading vegetable seeds suppliers, Harris Moran. That company had been formed in the early 1980s under parent company Celanese, a chemical company that had entered the seeds business in the early 1970s. Harris Moran was later taken over by Lafarge Coppee. In 1990, Lafarge Coppee joined with Rhone Poulenc to acquire a French seeds business as well, Clause. Following its acquisition of Harris Moran, Clause too came under Limagrain's control. Clause was then merged into Vilmorin, which became known as Vilmorin Clause & Cie.

Seed companies have increasingly started to pursue other strategies to gain access to new markets and increase their market share of GM traits and seeds. One commonly used business strategy consists of (cross)licensing IP on GM traits and seed genetics. This business strategy is frequently combined with R&D strategies aimed at stacking different GM traits and R&D collaboration with other private partners and/or public partners, like universities and research institutions. In most cases of (cross)licensing strategies, seed companies agree (mutual) access to proprietary biotech traits, which allows the development of seeds with stacked GM traits. As a result, markets can be provided with seeds that combine different GM traits, for instance herbicide-tolerances and/or insect-resistances. In some cases, agreements are also reached on (mutual) access to proprietary enabling (transformation) technologies. Several of these IP agreements resulted from long legal disputes on infringement of IP claims. This Annex provides a brief selection of licensing deals concerning GM traits between the major seed companies.

Figure B.1 is a visual representation by Howard (2009) of (cross)licensing agreements on GM traits between "Big Six" seed companies. As this figure suggests, Monsanto may have obtained a pivotal position in this network, as it is the only firm to have agreements with the other five firms.

Figure B.1 Visual representation of (cross)licensing agreements on GM traits between Big Six seed companies

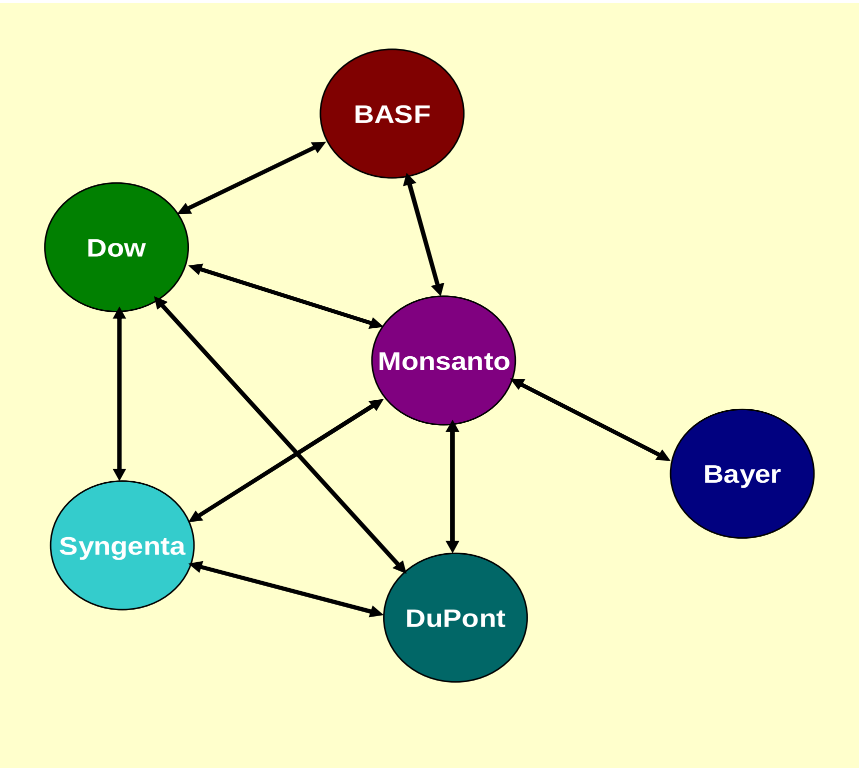


Figure B1: Big Six (cross)licensing agreements on biotech traits

Source: Howard2009

Many licensing agreements provide (mutual) access to proprietary biotech traits (see Annex C). This gives seed companies more options to use each other's inventions for developing plant varieties with so-called ‘stacked’ traits. In 2010 seed companies offered in total 34 different biotech maize varieties to the US seed market, of which 22 had double or triple stacked biotech traits (see Table B1). In the same year, the cotton seed market in the US was supplied with 12 different biotech cotton varieties, of which 6 had double stacked GM traits (see Table B2).

Table B1: Number of commercially available biotech maize varieties in US as of 25 June 2010

Number of stacked traits in maize	Companies					
	Bayer	Dow	Monsanto	DuPont	Syngenta	Total
Single	1	2	4	2	3	12
Double		2	6	3	3	14
Triple		2	2	1	3	8
Total	1	6	12	6	9	34

Source: BIO 2010

Table B2: Number of commercially available biotech cotton varieties in US as of 25 June 2010

Number of stacked traits in cotton	Companies					
	Bayer	Dow	Monsanto	DuPont	Syngenta	Total
Single	1	1	4	-	-	6
Double	1	2	3	-	-	6
Total	2	3	7	-	-	12

Source: BIO 2010

Figure B1 compares the rates of adoption of crops with stacked GM traits and crops with single GM traits in the US over the last five years.

B.1 Monsanto & BASF

- In 2007, Monsanto and BASF announced a long-term joint R&D and commercialisation collaboration in plant biotechnology with a budget of 1.5 billion US dollar to develop a dedicated pipeline of yield and stress tolerance traits for maize, soybean, cotton and oilseed rape (Monsanto 2009). BASF would focus on high-yielding crops and crops that are tolerant to environmental stress conditions such as drought. Monsanto indicated that it had completed all North American and key import country regulatory submissions for the first drought-tolerant maize product. Further, in 2009, the companies disclosed the discovery of *cspB* gene from *Bacillus subtilis* that could help maize plants to tolerate drought and confer yield stability during periods of inadequate water supplies (BASF 2009). Drought-tolerant maize hybrids are currently being tested at over tow hundred test locations in the US. The gene will probably be stacked with other genes. Monsanto mentioned Genuity Smartstax and Genuity VT Double PRO as the most likely platforms for commercialisation (Padgette 2010).

- By mid-2010, BASF and Monsanto further extended their collaboration to the development of biotech wheat and other crops, adding another 1 billion US$ for R&D collaboration on top of 1.5 billion US$ the companies had already agreed to invest (BASF 2010).

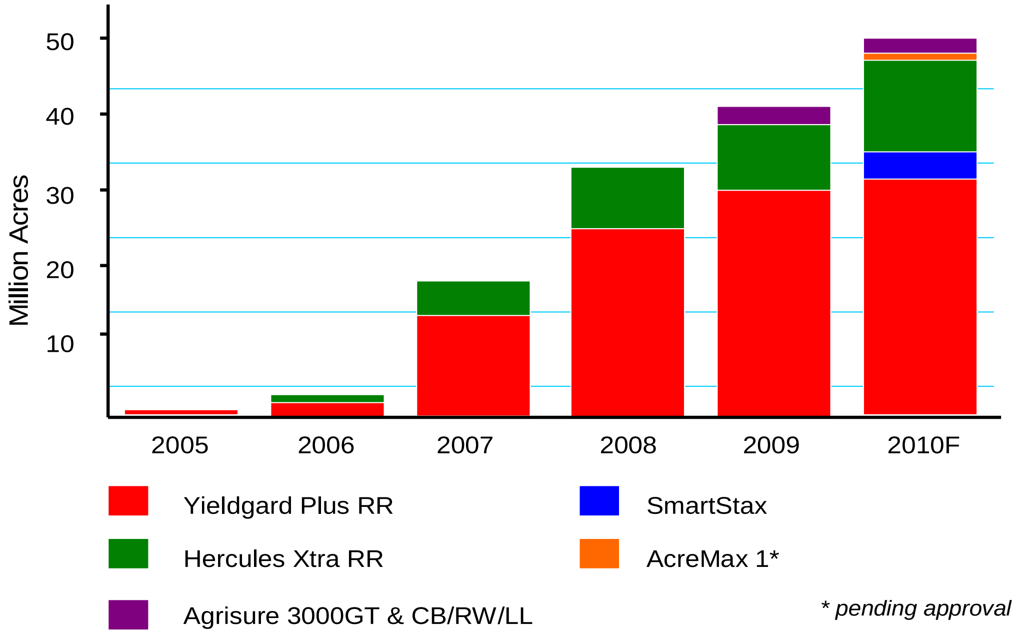


Figure B1: Acreage with Triple Stacked Biotech Traits in the US (2005 – 2010)

B.2 Monsanto & DOW

- In January 2006, Dow received a commercial license to certain Monsanto seed stock and biotechnology traits for both maize and soybean. Dow further received royalty-bearing rights to create and license finished hybrids, combining Monsanto's Roundup Ready Corn 2 technology with Dow's Herculex I and Herculex Xtra technologies, to other licensees of Monsanto's Roundup Ready Corn 2. The companies also established cross-licenses of cotton technologies on a non-exclusive basis. Dow's license includes Monsanto's patent estate for cotton transformation and Monsanto's license includes the patent estate for glyphosate-tolerant cotton of Mycogen, an affiliate of Dow. In addition, Dow received the Monsanto’s IP licenses for Bollgard, Bollgard II, Roundup Ready and Roundup Ready Flex technologies, while Monsanto received the IP licenses for the commercialization of Dow’s Widestrike insect protection technology, including for South America and Mexico.
- The deal also included the mutual use of two important enabling patented technologies: Monsanto's patent estate for synthetic Bt technology and Dow’s patent estate for Bt in plants owned by Mycogen. The companies agreed to settle outstanding legal disputes. Dow’s affiliate Mycogen withdrew its appeal against the U.S. Patent and Trademark Office (USPTO) determination that Monsanto had been the first to invent synthetic Bt genes, while Monsanto withdrew its appeal against the USPTO determination that Mycogen had been the inventor of the Cry1F gene, which is also a Bt gene.
- In June 2010 Monsanto granted a new royalty-bearing license for Roundup Ready 2 Yield to Dow. The new agreement expanded Dow’s GM trait stacking and existing licensing rights across its soybean seed brands and licensing partners (Dow AgroSciences 2010).

B.3 Monsanto & Syngenta

- Monsanto expanded the potential commercial availability of its Roundup Ready 2 Yield soybean technology by granting a global royalty-bearing license to Syngenta for use across its soybean seed brands in 2009. Under the agreement: 1) Monsanto received a royalty-bearing license for

Syngenta's enabling technology related to Monsanto's third generation herbicide (Dicamba)-tolerant technology. Monsanto granted Syngenta a royalty-free license for its herbicide-tolerant GA21 maize technology and insect-protected Bt 11 corn borer technology; 2) Monsanto and Syngenta agreed to settle all patent, antitrust and commercial litigation disputes between them and their subsidiaries. Some of these disputes included Syngenta's antitrust suit, Monsanto's patent infringement suit on herbicide-tolerant maize technologies, and; 3) a dispute between the parties on herbicide-tolerant soybean technology.

- Monsanto and Syngenta also agreed to cross-enable each other to develop and deliver innovative new herbicide-tolerant and Bt insect-protection products in maize, cotton and soybeans. Notably, sales of Syngenta's soybean brands represented approximately 12% of all US soybean sales in 2007, while Monsanto's Asgrow and American Seeds soybean brands collectively represented approximately 27% of US soybean sales. Monsanto estimated that the agreement would increase potential available acreage for the product of 45 million to 55 million acres in the United States, or an increase of more than 10% over its original projection of 40 million to 50 million acres (Syngenta 2009).

B.4 Monsanto & Bayer

- In October 2003, Monsanto and Bayer cross-licensed an enabling technology for herbicide-tolerant crops, allowing broader farmer access to Bayer’s glufosinate-tolerant and Monsanto’s glyphosate-tolerant crops. Bayer further provided Monsanto with a license for its technology related to Monsanto’s corn-rootworm product. The companies also amended existing licenses: Bayer’s existing licenses for use of Monsanto’s herbicide-tolerant and insect-protected technologies for cotton, and Monsanto’s license for use of Bayer’s Dual Bt insect-protected enabling technology (Bayer CropScience 2003).
- In March 2004, Monsanto won a 12-year patent interference dispute against the Max Planck Institute and Bayer about the use of *Agrobacterium*-transformation technology in dicotyle plants such as cotton (US Court of Appeals 2004), as it was licensed exclusively by the Max Planck Institute to Bayer. Less than a year later, the three parties reached an agreement to cross-license their respective *Agrobacterium*-transformation technologies worldwide. Moreover, Bayer and Monsanto agreed to provide each, in selected areas of the world, with non-exclusive licenses for the development, use and sale of specific biotech crops, while Monsanto also provided the Max Planck Institute with a license for research purposes in the US (Bayer CropScience 2005).
- By acquiring Stoneville Pedigreed Seed Company from Monsanto in 2007, Bayer gained access to cotton products with Monsanto’s insect-resistant and herbicide-tolerant traits. Notably, Bayer’s cotton seed business in the US had already been growing strongly over the previous years with its flagship FiberMax brand (Bayer CropScience, 2007).
- Two years later, in 2009, Bayer and Monsanto signed a cross-licensing agreement on herbicide tolerant traits in oilseed rape. Monsanto granted Bayer access to its Genuity Roundup Ready canola trait and Bayer granted Monsanto access to its LibertyLink herbicide-tolerance trait for use in canola. The agreement also included specified rights to access, on a non-exclusive basis, future herbicide-tolerance traits and other agronomic traits that may be introduced by either party for use in oilseed rape (Bayer CropScience 2009).

B.5 Dow & Dupont-Pioneer

Dow and DuPont-Pioneer entered into a commercial cross-licensing agreement that enabled them combine herbicide-tolerance events in soybean in November 2009. Dow licensed its proprietary non-GM herbicide tolerant trait technology, providing tolerance to 2,4-D for soybeans to DuPont-Pioneer, while the latter licensed its proprietary Optimum GAT trait for soybeans to Dow. The Optimum GAT trait from DuPont-Pioneer provides tolerance to glyphosate and the so-called ‘ALS class’ of herbicides. Both companies have given the other rights to stack additional traits with their respective technologies (Dow AgroSciences 2009).

Analogous to drugs, generic markets for biotech seeds and traits are expected to emerge after patents have expired. Generics can usually be sold at relatively low prices. The first post patent generic biotech trait would be Monsanto's Roundup Ready trait. However, the emergence of a generic biotech seeds market might be hindered by anticompetitive tactics. In 2009 the US Department of Justice started an antitrust investigation into allegations that Monsanto would be using such tactics, so as to prevent its competitors from developing generic biotech seeds.

In August 2010, four US senators urged the Department of Justice (DoJ) to "expeditiously complete" its antitrust investigation into allegations that Monsanto would be using anticompetitive tactics with regard to its patented GM seed traits (Kohl 2010). In a letter to the DoJ Antitrust Division the senators pointed out that a swift conclusion of the DoJ's investigation would be "vital to the emergence of generic versions of biotech trait known as Roundup Ready after its patents expires in 2014. Generic entry into the market will promote further competition in the biotech trait sector, enhance innovation and ensure that farmers have access to seeds that are optimised for their growing conditions yielding more food at lower prices."

It should also be noted that a few months before the start of the DoJ's antitrust investigations into Monsanto, on 16 May 2009, Monsanto had initiated a litigation procedure against DuPont, which led DuPont to file an answer and counterclaim to the Monsanto lawsuit, as well as to seek a broad relief under antitrust laws (Monsanto 2009; DuPont 2009).

According to Monsanto, DuPont's Pioneer had publicly touted plans to stack the Roundup Ready trait with DuPont's glyphosate-tolerant OptimumGAT trait since 2006, although Pioneer recently had admitted that the OptimumGAT trait when used alone would present unacceptable risks for farmers; in order to repair these deficiencies, Pioneer would be misusing the Roundup Ready trait to mask problems with its OptimumGAT trait, thereby violating licensing contracts with Monsanto as well as infringing Monsanto's patent rights.

In its counterclaim DuPont maintained that stacking of the OptimumGAT and Roundup Ready traits would be within its rights under the license agreement with Monsanto. DuPont further claimed that Monsanto's patents would be invalid and would therefore not be infringed when OptimumGAT is stacked with Pioneer's germplasm containing the Roundup Ready traits. Monsanto's lawsuit was considered by DuPont as yet another tactic to restrict the availability of competitive products, thereby pointing out that its proprietary OptimumGAT trait combined with the Roundup Ready trait in Pioneer's elite germplasm would be superior to any other product on the market in terms of better yield and broader, more flexible weed control options. In its press release DuPont also indicated that it was seeking broad relief under antitrust laws that would end Monsanto's anticompetitive schemes to unlawfully restrict competition.

The DoJ already started its antitrust investigations into Monsanto in October 2009 but has not yet closed those investigations. At this point in time it is therefore uncertain whether the DoJ will (ever) bring a case against Monsanto. The following paragraphs present the viewpoints, information and data brought forward by in particularly Monsanto (2010a) and DuPont (2010) in their submissions of 2010 to the DoJ. In its submission DuPont essentially argues that Monsanto has engaged in numerous practices that improperly seek to expand the scope of IP rights at the expense of competition, innovation and choice, whereas Monsanto maintain that it does not dominate any of the maize, soybean or cotton seeds markets; competition in these seed markets as well as in innovation would be vigorous.

Both submissions take as starting point a 30-page paper issued by the American Antitrust Institute in October 2009, an organisation sponsored by, among others, DuPont (Moss 2009). In the paper, the AAI points out that over the last two decades the biotech seed industry has undergone a fundamental shift from separate ownership of agricultural biotechnology and seed assets to integrated agricultural biotechnology seed platforms, which comprise three basic elements:

1. genetic transformation technologies;
2. genetic traits, like herbicide-tolerance and insect-resistance, and;
3. state-of-the-art seeds (elite germplasm) containing genetic traits, for which seeds companies are the major distribution channel for sales to farmers.

According to the AAI, Monsanto has created formidable platforms of biotech seeds in cotton, soybean and maize through the control of a large body of patented technologies and systematic acquisition of independent seed companies (ISCs). Citing figures about patents, field releases, regulatory approvals and shares in biotech maize, soybean and cotton seeds markets, the AAI argues that Monsanto possesses market power in markets for biotech traits and biotech seeds. Any antitrust investigation should therefore determine whether Monsanto has shown anticompetitive behaviour through exercising this alleged market power to foreclose competitors from market access, thereby slowing innovation and adversely affecting prices, quality and choice for farmers and consumers of products from seeds. Efficiency defenses, like a quality control rationale for prohibiting the stacking of Monsanto biotech traits with non-Monsanto traits, are unlikely to provide an effective counterbalance to anticompetitive conduct.

Monsanto's submission to the DoJ is a point-by-point rebuttal of the AAI paper, pointing out that:

1. The AAI overstates Monsanto's shares in biotech seed markets and Monsanto's shares of agricultural biotechnology patents;
2. The AAI rather than assessing competition in biotech seeds or traits, primarily focuses on the effects on innovation of concentration, without evaluating any particular Monsanto merger or assessing actual innovations coming to the market, thereby simply observing aggregate changes in number of patents and regulatory permits over the last decade, and;
3. The AAI comes to very certain conclusions and sweeping conclusions not supported by its own analysis.

According to Monsanto, the facts about market shares, regulatory approvals, the number and quality of patents and investment decisions since 2000 demonstrate that competition and innovation are alive and well in agriculture. In order to exemplify competition and innovation in biotech maize, soybean and cotton seed markets, Monsanto prepared Tables C1, C2 and C3.

Table C1: Soybean Trait Profiles

Trait providers →	**Bayer**	**DuPont**	**Monsanto**		
Trait profiles (including conventional)	**Herbicide tolerant glufosinate**	**Herbicide tolerant sulfonylurea**	**Herbicide tolerant - glyphosate**	**Number of trait providers contributing to this product**	**Product includes a licensed trait from Monsanto**
LL					
RR					
RR2Y					
RR-STS				2	X
STS					

Source: dmrkynetec and Monsanto 2009

Table C2: Maize Trait Profiles

Trait providers →	BASF	Bayer	Dow AgroSciences		Monsanto			Syngenta				
Trait Profiles (including conventional	**Herbicide tolerant - imidazzolinone**	**Herbicide tolerant - glufosinate**	**Rootworm protection**	**Corn borer protection**	**Rootworm protection**	**Corn borer protection**	**Herbicide tolerant - glyphosate**	**Herbicide tolerant - glyphosate**	**Rootworm protection**	**Corn borer protection**	**Number of trait providers contributing to this product**	**Product includes a licensed trait from Monsanto**
Agrisure 3000GT		■						■	■	■	2	
Agrisure CB-IMI-LL	■	■								■	3	
Agrisure CB-LL		■								■	2	
Agrisure CB-LL-GT		■						■		■	2	
Agrisure CB-RW-LL		■							■	■	2	
Agrisure GT								■				
Agrisure RW									■			
Agrisure RW-GT								■	■			
Conventional												
Herculex I-LL		■		■							2	
Herculex I-LL-IMI	■	■		■							3	
Herculex I-LL-RR2		■		■			■				3	X
Herculex RW-LL		■	■								2	
Herculex RW-LL-RR2		■	■				■				**3**	**X**
Herculex XTRA-LL		■	■	■							2	
Herculex XTRA-LL-RR2		■		■			■				3	X
IMI	■											
LL												
RR2							■					
YGCB						■						
YGCB-IMI	■					■					2	X
YGCB-RR2						■	■					
YGP1us					■	■						
YGP1us-IMI	■				■	■					2	X
YGP1us-RR2					■	■	■					
YGRW					■							
YGRW-RR2					■		■					
YGVT RW-RR2					■		■					
YGVT3					■	■	■					
YGVT3 Pro					■	■	■					

Source: dmrkynetec and Monsanto 2009

Table C3: Maize Trait Profiles

Trait →	Bayer	Dow AgroSciences	Monsanto					
Trait profiles (including conventional)	**Herbicide tolerant glufosinate**	**Bollworm, Budworm, Armyworms and Loopers protection**	**Bollworm and Budworm protection**	**Bollworm, Budworm, Armyworms and Loopers protection**	**Herbicide tolerant - glyphosate**	**Herbicide tolerant – glyphosate with wider application window**	**Number of trait providers contributing to this product**	**Product includes a licensed trait from Monsanto**
BG-RR								
BGII								
BGII-LL							2	X
BGII-RR								
BGII-RR Flex								
Conventional								
LL								
RR								
RR Flex								
WideStrike								
WideStrike-RR							2	X
WideStrike-RR Flex							2	X

Source: dmrkynetec and Monsanto 2009

Unsurprisingly, DuPont in its 18-page submission to the DoJ largely refutes the arguments forwarded by Monsanto's rebuttal of the AAI paper. Notably, DuPont thereby puts special emphasis on the role of about 200 Independent Seeds Companies (ISCs) in the US that sell maize and/or soybean seed but do not have own biotech trait development programmes or own breeding programs for developing germplasm. According to DuPont's estimates, Monsanto has an overwhelming monopoly in the soybean and maize biotech trait markets, with 98% and 79% share respectively, as well as 60% of the maize and soybean germplasm licensed in the US. This monopoly power, combined with several anticompetitive practices, would require vigorous and timely antitrust enforcement to ensure open, competitive markets. Some of the alleged anticompetitive practices are:

1. Monsanto's license agreements prevent seed companies from stacking different biotech traits in a single seed, including both Monsanto and non-Monsanto technology, and;
2. Monsanto has forced independent seed companies and farmers to switch prematurely from its first generation trait Roundup Ready, present in over 90% of the soybean seed sold in the US, to its second generation Roundup Ready 2 Yield, a new alternative without little, if any, documented added-value to customers; the effect thereof would be to eliminate any prospect for the emergence of generic competition in the first generation Roundup Ready trait, whose patent will expire in 2014, and to extend Monsanto's monopoly for the foreseeable future.

The emergence of generic competition after biotech trait patent expiration seems to be of particular concern to DuPont. While Monsanto's patent on the first generation Roundup Ready trait will expire in 2014, Monsanto would have coerced independent seed companies to convert all of their seed lines from Roundup Ready to second generation Roundup Ready 2 Yield, if they wish to continue licensing the first generation Roundup Ready trait. Because most farmers would not purchase soybean seeds with a proven glyphosate-tolerant traits, this licensing requirement threatened to drive independent seed companies out of the soybean seed market, unless they agreed to switch to second generation Roundup Ready 2 Yield completely. Note that the patent on Roundup Ready 2 Yield expires in 2020 (Fortune 2010).

On the eve of the deadline for submission of public comments to the DoJ, according to DuPont, Monsanto announced it would not force independent seed companies to switch to the Roundup Ready 2 Yield trait and destroy their seed inventories with the Roundup Ready trait. According to DuPont, this comes too late for the independent seed companies that have already switched to the Roundup Ready 2 Yield trait. DuPont was further unaware of whether Monsanto has offered any ISC that had already licensed and switched to the Roundup Ready 2 Yield trait the opportunity to return to a Roundup Ready trait license. In addition, DuPont raised other concerns, such as:

- Will Monsanto continue to improve and out-license Roundup Ready lines for those independent seed companies that rely on Monsanto germplasm for their seed products?;
- Will Monsanto allow Roundup Ready licensees to have continued access to Monsanto's best soybean germplasms, or will they be required to switch to Roundup Ready 2 Yield in order to access those lines?
- Will independent seed companies be allowed to retain and use their breeding material containing the Roundup trait at the expiration of their Roundup Ready licenses?
- Will Monsanto allow Roundup Ready licensees to make stacks with non-Monsanto soybean traits?
- Does Monsanto agree that these same restrictions should be removed for other traits and crops they out-license?

Another serious concern of DuPont relates to the alleged controlled use by Monsanto of the regulatory data packages necessary for import approval for the Roundup Ready trait in all major export markets for US grain producers. While Monsanto has stated that beginning in 2015 Roundup Ready technology will be publicly available and will therefore maintain these regulatory approvals for at least three years, through 2017. But, in DuPont's view, maintaining the regulatory approvals in place for three years post-patent would not give other seed companies sufficient time to obtain regulatory approval for a generic Roundup Ready trait. This leads DuPont to raise two basic questions:

- Will Monsanto agree that licensed trait developers can generate regulatory data to gain regulatory approval of those stack prior to patent expiration, as, unlike for pharmaceuticals, there is no patent infringement defense for companies wishing to prepare for independent regulatory submission?
- Will Monsanto permit that activity starting today, so that generic versions of Roundup Ready can be sold in the marketplace as soon as the patent expires?

Public Private Partnerships (PPPS) are recognised as a key mechanism to bridge the gap between public and private sectors' distinctive competencies. For national governments, partnerships offer a way to translate shared research outputs into useful, relevant tools for their own farmers. PPPs can further offer access to a greater variety of technology choices, spread and share the financial burden of research, and create flexible expert resources for capacity building. This will be illustrated with three examples: 1) The way Limagrain has organised R&D collaborations with several private and public partners; 2) The structure of EU-SOL, a European FP-6 programme on the development of high quality and healthy tomato and potato varieties, and; 3) PPPs for smallholders in developing countries, where the adoption and uptake of GM crops has been slow due to several constraints.

D.1 Limagrain R&D collaborations with public and private partners

In Research (& Development), Limagrain has always collaborated with a wide range of public and private partners. In the mid-1960s, the cooperative company teamed up with the state-run research institute INRA in order to develop and produce new maize varieties.

Later, in the 1990s, developing capacity in the emerging biotechnologies was considered a strategic necessity. According to Joly (2001), Limagrain had limited investment capacity - a R&D budget of approximately 50 million US dollar covering all of its research activities, not just plant genomics. This amount was very modest compared to the R&D investments of agrochemical corporations, such as Monsanto, DuPont, and Syngenta, with an estimated yearly investment of 60 - 70 million US dollar, focussed fully on plant genomics. This led to a change in Limagrain's strategic positioning from 1996 onwards — biotechnology would be one of the central themes for the company; and mastering biotechnology was to be considered necessary if the group was to keep its identity and independence. With this strategic positioning, Limagrain started a number of investments in R&D collaborations and participations in biotech companies.

In 1994, when Limagrain took over the seed production assets of Rhône-Poulenc Agro, the two companies developed common research programs in crop biotechnology within a joint venture called "Crop Biotechnology." Rhobio, a subsidiary common to Biogemma and RPA was formed in April 1998. Rhobio has focused on R&D of disease-resistance, on identifying new genes of interest, and on the improvement of genetic engineering techniques (Joli 2001).

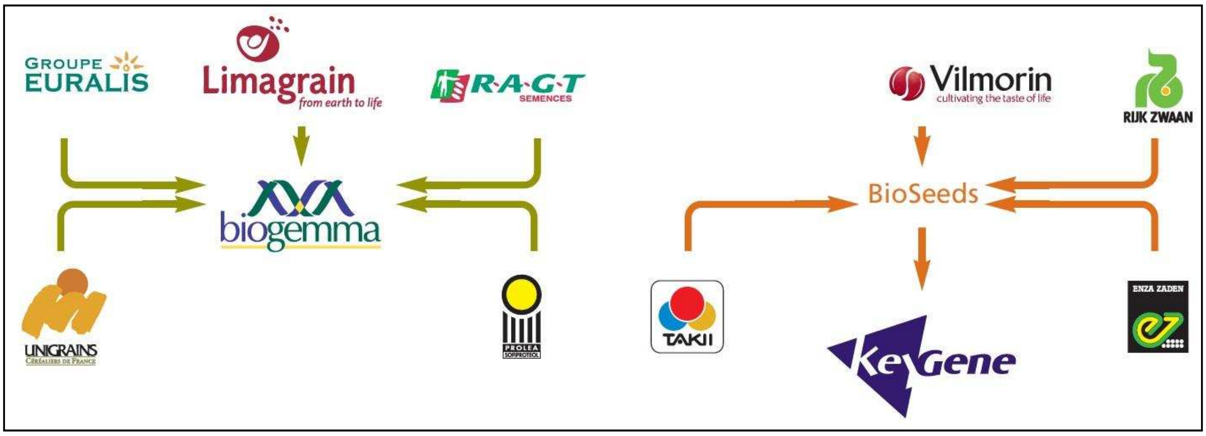
In 1997 the Biogemma company was created by Limagrain with a share of 55%, together with Pau Euralis with a share of 25% stake, Sofiprotéol, and Unigrain. Biogemma's objective was to develop GM crops and to coordinate the research potential of the two companies in order compete with the large companies, such as Monsanto. Biogemma therefore pursued a double strategy: 1) creating a purchasing group that would be able to best negotiate patent licensing contracts; and; 2) to be a source of industrial intellectual property for the exchange of technologies among large industry players. In addition, Limagrain also entered into the development of plants for pharmaceutical uses, creating Meristem in 1997.

In February 1999, several public research institutes and private companies, such as Rhône-Poulenc Agro, Biogemma, and BioPlante, announced the creation of the Genoplante program. This ambitious research effort focused on plant genomics and brought together important French actors, both public and private (Joly 2001). Since its creation in 1999, this programme has made it possible to fund research on the genomes of crop plants (wheat, maize, rice, pea, rapeseed and sunflower) and also on the model genome of the species *Arabidopsis*. Its objective has also been to support research for the creation of tools for genomic research (BAC libraries, microsatellites, SNP, etc.) or functional genome analysis (collections of insertion mutants, TILLING technology, etc.) or in the field of high throughput biology (tools for analysing the transcriptome, proteome and metabolome, etc.). A new six year initiative was launched in April 2005. This initiative, called Genoplante 2010, involved four members from the public sector: INRA, CNRS, CIRAD and IRD, and three members from the private sector: Biogemma (which includes Limagrain), Arvalis plant institute and Sofiproteol. This programme has an annual budget of 30 million € and is supported by the French national research agency with 12 million € annually in the form of grants. Genoplante 2010 is focusing on four strategic objectives:

1. To determine and then validate gene function on a large scale in crop species that are cultivated in France (wheat, maize, rapeseed, sunflower and pea crops) in order to:
   - improve the quality and safety of agricultural products;
   - minimise the impact on the environment, in particular by reducing inputs;
   - increase the agricultural productivity of crop species and their tolerance to climatic variation.
2. To promote widely the use of the tools that have already been developed, and to develop new technologies, in particular in the fields where France is still lagging behind, such as proteomics and metabolomics research.
3. To broaden research and its applications to other important species for which professionals have expressed an interest, for example tomato, potato, grape, trees, cocoa and coffee.
4. To build a genuine partnership at the European level, so that Genoplante can be an important link in the construction of a European biotechnology and plant genomics platform, and to seek new reciprocal alliances at the international level (with Canada, China, USA and Australia).

The programme also aims to increase the efficiency of its policy to protect and exploit results, while still sharing its findings through publication in high quality international journals. The essential aim of the SAS GENOPLANTE VALOR, which was set up in 2001 as an equal partnership between public and private members, is to own, manage and exploit the patent rights of the results obtained from the Genoplante programme. Over hundred projects have been funded by the ministries of research and agriculture during the two first phases.

In the 21st century Group Limagrain continued setting up partnerships. In 2001 Vilmorin Clause & Cie became a shareholder of BioSeeds, a consortium of a number of leading Dutch seed companies. BioSeeds holds all shares of the genomics and biotechnology company Keygene and by participating in BioSeeds, Limagrain acquired 20 % of Keygene's shares (Seedquest 2001).



KeyGene was founded in 1989 by a number of Dutch seed companies, whose goal was and is to create synergy and higher efficiency in their molecular genetic research programs and thus improve their breeding efforts. Today, KeyGene has four strategic shareholders active in the field of vegetable breeding: ENZA Zaden, Rijk Zwaan, Vilmorin & Cie and Takii & Co, Ltd. from Japan. Direct access to the new generation sequence technologies of Roche and Illumina has allowed KeyGene to develop new technologies for SNP discovery, Mutation screening and allele mining in breeding and germplasm collections, gene expression analysis and novel whole genome physical mapping (Whole Genome Profiling) and sequencing.

In 2010 Keygene and Biogemma announced that they will share bioinformatics expertise in a long term collaboration that focuses on data integration and mining of genomics and genetic information applied for sequence based plant breeding (Keygene 2010).

Limagrain also started investing in research outside Europe. Research work in China started with Shanxi-Limagrain, created in 2002. In 2006, in Australia, Arista was created, a joint venture between the CSIRO, the Grains Research & Development Corporation, and Limagrain Céréales Ingrédients. Arista was meant to deliver new high-amylose wheat varieties with improved health characteristics developed by CSIRO and Limagrain.

In May 2010 Vilmorin purchased a 7.25% equity position in Arcadia. In parallel, Arcadia purchased a 35% ownership position in Limagrain Cereal Seeds LLC, a newly formed company that provides the platform for wheat development in the United States. Vilmorin maintained 65% ownership of LCS (Seed Today 2010). LCS also bought the wheat assets of U.S. wheat research companies Genesis Seed Research and BSF AG Research, which focus on genetic material (Reuters 2010).

Limagrain also entered into an exclusive worldwide licensing arrangement with Avesthagen, a Bangalore-based biotech company, for developing and marketing genetically modified seeds such as maize, wheat, barley, rice, sunflower based on Avesthagen's technologies for environment-adjusted crops. Avesthagen will license its patented technologies to Atash Seeds to develop, produce and market seeds nationally and internationally by leveraging Limagrain's domain expertise, knowledge and marketing strengths (Avesthagen 2009).

D.2 EU-SOL: Public-Private R&D collaboration

In 2006 an extensive network of plant scientists from universities, research institutes and industry joined in EU-SOL, a project focusing on the development of high quality and healthy tomato and potato varieties with improved consumer-, processor- and producer-directed traits. The consortium brings together expertise across a wide variety of disciplines, from taxonomy to molecular biology to consumer integration. The potato and tomato breeding companies involved in EU-SOL cover a large percentage of the world market. The consortium has five strategic objectives:

1. To extract the under-exploited natural biodiversity present in *Solanaceae* to improve consumer-driven and environmentally-directed quality of tomato fruits and potato tubers;
2. To map, isolate and characterise genes responsible for quality traits and to dissect the molecular mechanisms underlying these traits by application of state-of-the-art knowledge and innovative technologies;
3. To assemble these genes within new genotypes to boost our knowledge and provide a blueprint for novel high quality varieties to be developed by EU breeding companies;
4. To coordinate and integrate breeding research for quality traits, to provide training in innovative technologies, to disseminate the results and to transfer knowledge and technologies to industry, and;
5. To participate in the international tomato genome sequencing initiative that will tie European Solanaceae research and innovation into the full global activities in this area.

EU-SOL particularly focuses on mapping, isolation and characterisation of genes responsible for traits that are important for consumers and processers, and unravels the mechanisms underlying traits. Traits of interest for consumers include the presence of health components, nutrition, aroma, fragrance, texture, colour, shelf-life, and starch and chipping quality, while traits of interest for producers include plant architecture (long/short plants, branching), fruit set and conservation, tuberisation and cold tolerance. In addition to specific needs of consumers and producers, there is also a need to develop crops with improved yields and better adjusted to a changing climate, including traits for improved yield on poorly fertile soil and for tolerance to situations of reduced water availability or increased salinity.

Table D1: Companies participating in EU-SOL and their status

Company	Status
Tomato breeders	
Semillas Fito (ESP)	Family company
Vilmorin & Cie (FR)	Owned by Limagrain
Gautier Semences (FR)	
Zeraim Gedera (ISR)	Owned by Syngenta
Hazera Genetics (ISR)	Owned by Limagrain
ENZA Zaden (NL)	
Nunhems (Bayer, NL)	Owned by Bayer Cropscience
Rijk Zwaan (NL)	
Syngenta (SWITZ)	
De Ruiter Seeds (NL)	Owned by Monsanto
Seminis (US)	Owned by Monsanto
Potato breeders	
Agrico Research (NL)	Breeding and research station of the co-operative Agrico
HZPC (NL)	
Averis Seeds B.V. (NL)	Division of AVEBE Group
Technology suppliers	
Keygene NV (NL)	Founded by Vilmorin, Rijk Zwaan, ENZA Zaden, De Ruiter Seeds and Takii Seeds
Cogenics GENOME Express (UK)	
BIOPLANT (GER)	Subsidiary of the Böhm-Nordkartoffel-group, the leading german potato breeding enterprise.
Genelab (IT)	

Source: EU-SOL

Several companies made a part of their tomato genetic resources available to the EU-SOL scientific community. These resources are accessible under mutually favourable Material Transfer Agreements (MTAs). One company grew a number of tomato cultivars under optimal greenhouse conditions and provided the fruits for sensory evaluation to partners from the Netherlands, France and Italy and analysed growth and fruit quality of 81 inbred lines from crosses between tomato and a wild relative. One of the potato breeders did phenotyping of diversity in potato for which 15 segregating diploid potato populations had been developed.

The technology suppliers supply a range of services, from sequencing to construction of optimized silencing vectors for the study of the efficiency of silencing and stability of inserts in various vectors and plant organs, including leaves and fruits. One of these companies does the genotyping of a large number of tomato varieties in order to make sub-populations for studying particular interesting traits such as drought resistance or taste and translation of genes that could be important in controlling particular traits into new varieties for the breeding industry.

EU-SOL partners have signed a detailed agreement, which foresees in a complex scheme of dealing with confidentiality as well as ways of sharing, publishing, exploiting and commercialising intellectual property rights related to genetic resources made available by individual partners and the research results and knowledge generated by EU-SOL. Table D1 presents an overview of the companies that participate in EU-SOL.

D.3 Public-Private Partnerships for smallholders in developing countries

According to Escaler (2002) from the International Service for the Acquisition of Agri-biotech Applications (ISAAA), the adoption and uptake of GM crops by developing countries has been slow, because of: 1) the high costs and proprietary nature of modern biotechnology R&D; 2) the absence of regulatory and IPR management capacity, and; 3) a lack of scientific resources and skilled personnel. Escaler (2002) argued that public-private partnerships (PPPs) could help to address these constraints, as partnerships with the private sector are an important route for public research institutes in developing countries in order to gain access to research tools and technologies. Nowadays, many seed companies have entered into agreements with public research institutes with the objective to support smallholder farmers in developing countries. Usually, the companies provide fundamental scientific data, technologies, including genes and traits, scientific know-how to adapt proven technology to crops, and licenses to patented technologies.

On the other hand, public-private partnerships are also expected to benefit private firms by providing access to emerging markets in developing countries, locally specific scientific expertise and genetic materials, opportunities to strengthen corporate social responsibility programs, corporate image, brand recognition among customers and the general public, and investor confidence, as pointed out by Spielman *et al*. (2007) in a discussion paper for the International Food Policy Research Institute (IFPRI).
Syngenta, for instance, established the Syngenta Foundation for Sustainable Agriculture, a non-profit organisation that can access company expertise for projects that support smallholders in developing countries. In one of the projects the Foundation formed a partnership with the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) and Kenya Agricultural Research Institute (KARI) to develop and deliver maize varieties resistant to the major stem borer species to smallholder farmers, and increase maize production and improve food security. The Syngenta Foundation also supports the HarvestPlus Challenge Program to improve global nutrition. The partners aim to make available staple food crops rich in important nutrients. HarvestPlus, which is an initiative of the Consultative Group on International Agricultural Research (CGIAR), began in 2004 and runs until 2019. In an interview with Voice of America, Howarth Bouis, Director of Harvest Plus, explained that the project decided to stay away from using GM technology because regulations would slow progress (Baragona 2010).

Another example is Collaboration on Insect Management in Brassicas in Asia and Africa (CIMBAA). The CIMBAA project is a public-private partnership involving AVRDC, the Centre for Environmental Stress and Adaptation Research of the University of Melbourne, the Natural Resources Institute of the University of Greenwich, Cornell University and Nunhems B.V., now part of Bayer Cropscience. The objective of CIMBAA was to develop varieties with a constant level of resistance against Diamondback moth, based on Bt proteins. The private sector was undertaking the transformation of plant lines and selection of appropriate germplasm in which to release the release the material to breeders. The public sector was involved in selection of the genes for transfer and undertook a range of studies on the suitability, appropriateness, public acceptability, safety, potential environmental impacts, and optimal deployment methods for these plants. Both sides of the partnership would work together to develop the registration dossier for the transformed material and support its passage through the Indian regulatory system. The developed plant material was to be passed into the ownership of a public partner for distribution to vegetable breeders in any country where the material is registered (Russell, 2006). The Research Agreement was signed in 2007, after two years of negotiation. Nevertheless, after four years the Consortium Agreement was not signed because of liability issues and regulatory hurdles.

Another example of a public-private partnership is Water Efficient Maize for Africa (WEMA) formed in 2008 to increase the drought tolerance of white maize in Eastern Africa, where it is a staple crop. The project is led by the Kenya-based African Agricultural Technology Foundation (AAFT), with partners including Monsanto, the International Maize and Wheat Improvement Center (CIMMYT) and agricultural research systems in Kenya, Mozambique, South Africa, Tanzania and Uganda, and funded by the Bill and Melinda Gates and Howard G. Buffett Foundations. Monsanto provides proprietary germplasm, advanced breeding tools and expertise, and drought-tolerance transgenes developed in collaboration with BASF. The varieties developed through the project will be distributed to African seed companies through AATF without royalty and made available to smallholder farmers as part of their seed business. The national agricultural research systems, farmers' groups, and seed companies participating in the project will contribute their expertise in field testing, seed multiplication, and distribution. The project will involve local institutions, both public and private, and in the process expand their capacity and experience in crop breeding, biotechnology, and biosafety (AATF ?).

Monsanto has also public-private partnerships with the Cotton Research Institute in Zimbabwe for the development of bollworm resistant cotton, with KARI in Kenya for bollworm resistance and glyphosate tolerance in maize and with AGERI in Egypt for insect resistance in cotton. Monsanto also delivers technologies in gene cloning and transgenic screening for Papaya Ringspot Virus resistance in a public-private partnership with the Malaysian Agricultural Research and Development Institute (IFPRI-PRRI 2010).

Pray et al. (2006) analysed the history of the sequencing of the rice genome, in particular the competition between private sector an public sector research efforts. In 1998, the International Rice Genome Sequencing Project (IRGSP), led by Japanese government researchers, was launched to take advantage of the advances in sequencing technology and to coordinate the sequencing. An offer made by Celera in 1999 to sequence the entire rice genome was a wake-up call to the Japanese government, which substantially boosted its investment in rice genome sequencing. The announcements by Monsanto in 2000 and Syngenta in 2001 that they had draft maps of the rice genome provided a further stimulus to Japanese government spending. Notably, the initial release of the Monsanto and Syngenta data was not completely unrestricted. When Syngenta published its results in the journal *Science* in 2002, it did not release its rice genome sequencing data to GenBank, which was the norm for articles published in *Science*. Rather, the data were posted on Syngenta's website and access was restricted to academic researchers, who ceded any commercial applications of their research to Syngenta. When Monsanto's data were first released in 2000, they were also accessible only when researchers agreed to certain conditions. Many researchers were wary of signing up for these databases, as they felt that the withholding of information would be contrary to the appropriate conduct of scientific inquiry. Moreover, the demand for access to such data appeared to be low, perhaps because the Beijing Genomic Sciences had meanwhile also started releasing its data to GenBank and IRGSP was also making its data publicly available. The low demand for proprietary information might have contributed to Syngenta's decision to donate its rice genome sequencing data to IRGSP. Also Monsanto decided to donate its data to IRSGP. Disclosure of these data on the rice genome would have clearly accelerated public sector research on the rice genome and in 2005 IRGSP was able to publish the complete rice genome sequence in August 2005 (Pray et al. 2006).

ANNEX E: BIOTECHNOLOGY AND THE SEED INDUSTRY IN CHINA AND INDIA

China and India are interesting markets for global seed companies (see section 4 of the main report). Both countries have made significant investments in agricultural biotechnological R&D. While China remains the world's largest cotton producer, the growing use of GM cotton has shifted India's position from one of the world's largest importers to one of the world's largest exporters of raw cotton. Due to the structure of agricultural production and government policies the dynamics of Indian and Chinese seed business differs from commercial operations in the US and European markets.

E.1 Agricultural biotechnology R&D in China and India

Over the last decade the governments of China and India have made significant investments in biotechnology R&D to support innovation for increasing agricultural productivity; they rank third and fourth, respectively, in agricultural R&D spending behind the US and Japan (Linton 2010). In 2000, the US invested about 4.4 billion US dollar, compared to 2.5 billion US dollar for Japan, 1.9 billion US dollar for China and 1.3 billion US dollar for India. Since 2000, agricultural R&D spending in China grew to 2.3 billion US dollar in 2003, while until 2003 India's agricultural R&D spending remained relatively unchanged in that period.

Within the general field of agricultural R&D, both India and China have selected biotechnology as one of the top priorities. The Indian government has for instance implemented 481 agricultural biotechnology R&D programmes from 2002 to 2006. According to Lin (2010), there are few published estimates of India's total agricultural biotechnology R&D expenditures across relevant government agencies; one exception – quoted by Lin (2010) – is a publication by James (2008) on India's public sector investment in agricultural biotechnology R&D, an estimated 1.5 billion US dollar over the last five years, or about 300 million US dollar per year.

Likewise, the government of China has implemented agricultural biotechnology R&D programmes, which as of 2001 involved more than 150 national and local laboratories in more than 50 research institutes and universities. While agricultural biotechnology R&D funding began with a budget of 4.2 million US dollar in 1986, it grew to almost 60 million US dollar in 2003. In July 2008, the government decided to allocate 584-730 million US dollar per year for R&D on GM crops, with the aim to obtain genes with great potential commercial value whose intellectual property rights belong to China, and to develop high quality, high yield, and pest resistant GM crops.

E.2 Government policies on innovation in China's seeds sector

Since the mid-1990s China's government has tried to encourage new institutional approaches to develop and disseminate new plant varieties (Hu *et al*. 2009). Laws governing intellectual property rights have been passed, new biosafety management approaches are tried, new initiatives have been taken for promoting the commercialisation of the crop breeding system and seed industry and in many efforts the private sector is being encouraged to play a larger role. The following paragraphs provide details of new institutional approaches from China's governments, and in particular its reform of the seed law and adoption of intellectual property rights.

Reform of seed law

In the mid-1990s local and regional state-owned-enterprise (SOE) seed monopolies dominated China's seed industry. In total, 2,700 SOEs operated in their local counties, prefectures and provinces. In many counties only the local SOE was allowed to sell seeds of the major crops. Typically, the county-based SOEs sold their seed through township agricultural extension agents, so-called traditional, non-commercial seed sales channels. In addition, seed also flowed to farmers through other traditional non-commercial channels, such as the cotton office - a state-designated cotton monopoly procurement agency through the late 1990, which was turned into a cotton technology extension and cotton policy administration agency after 1998.

In 2000 China's government passed a new seed law that for the first time legally defined a role for the private sector. Since then, all firms – private, quasi-commercialised SOEs and traditional SOEs – were allowed to apply for permits to sell seed in any jurisdiction. Measures were also implemented that allowed companies to have their seeds certified at the provincial level, which would entitle them to sell the seeds in any county in the province. Since China has 1,464 counties divided over 22 provinces, with populations ranging from 5.4 million to 113 million, those seed markets could be of considerable size. By late 2001 nine companies had permits to sell seed anywhere in the country. For national companies it had become possible to establish their own distribution and retail networks, while at the other end of the spectre hundreds of small seed companies opened up to supply local needs. Moreover, private companies were also allowed to sell (GM or non-GM) seed bred by public breeding institutes. The reform of the seed law thus formally removed the legal protection of the monopoly positions of county, prefectural and provincial seed companies. Consequently, commercial seed distribution channels opened up alongside the networks through which agricultural extension services had traditionally sold to farmers, and new sources of investment in the seed industry emerged. Domestic entrepreneurs started making investments in private seed companies and some traditional SOEs transformed into commercial firms. Furthermore, foreign companies also began investing in China's seed industry, although they are required to sell through a Chinese company.
In the cotton seed industry three fundamental shifts occurred in its structure:

1. The appearance of large commercial seed companies that operate at the regional or national level;
2. The emergence of a small, private cotton seed firms, and;
3. The entry of private foreign companies, although they still play a somewhat limited role.

Mergers and Acquisitions in China

In Asia concentration in the seed industry is still very low, so seed distribution companies are expected to merge. Today, there are about 3,000 seed companies in China, and the government's goal is to have 30 – 50 big companies in ten years from now.

China's government policy acts at two levels. At the first level, the Chinese government is pushing companies to merge between them and the share of foreign companies in Chinese companies is limited. A foreign company can have the majority of shares in research, but in production and distribution they can only have a maximum share of 49%.
At the second level, as we see in other sectors of economic activity, China will probably put money in seed companies outside China. The country has the money to invest in big companies. In the next ten years, among the big ten seed companies in the world, most probably one of them will be Chinese, or at least controlled by the Chinese.

Adoption of intellectual property rights

Prior to the late 1990s seed companies could legally reproduce a variety of another company for the purpose of marketing the new variety. There were neither restrictions of the use of another breeder's variety as parent in the development of another variety, a common practice in the 1980s and 1990s. In 1997 Plant Varietal Protection (PVP) was introduced for most of China's crops. Yet, protection is still not very strong and cotton as a crop was excluded from protection until 2005. Notably, because the PVP law still does not restrict the use of another breeder's variety as parent for the development of new variety, as it has a research exemption explicitly allowing research institutes and seed companies to use PVP varieties for breeding of new variety. In addition, PVP does neither give proprietary protection to genes, although genes can be covered by China's patent law.

Given loopholes in the PVP law and their enforcement, public research institutes and companies have deployed several tactics to prevent their proprietary varieties and novel genes from being used freely. Above all, the seed industry and public institutions have begun using the patent system. For example, the Chinese Academy of Agricultural Sciences (CAAS) obtained a patent on the Bt-gene it had developed. This CAAS Bt gene is used in all of the China-produced cotton varieties sold by a CAAS (fully domestic) joint venture enterprise. In addition, trademarks, another form of intellectual property protection, can also be used to protect technology; in this case, the trademark "Biocentury" has been acquired.

Although Monsanto has patents on several genes, it did not patent its original Cry1Ac Bt gene in China. This Monsanto Bt gene can therefore be legitimately found in cotton seeds sold by two joint venture seed companies originally set up by two foreign companies, Monsanto and Delta and Pineland. Also for China, Monsanto was granted protection for its trademark "Bollgard" on its Cry1Ac Bt gene-based trait.

Six reasons why European and American seed companies wish to invest in China

1. *Currently, the part of commercial seed is very low compared to other markets. Also the margin in the seed sector is very low in China, about 10% per year. Nonetheless, China has a huge potential, in the first place because of the size of the market. Today, China is the 2nd seed market in the world and in the next 15-20 years it can even become the 1st seed market in terms of volume. China started to export rice and probably will start to export wheat in the future. For instance to India, where the growth of yield of wheat and rice is flat, which will cause starvation in India in the next 5 – 10 years. China also try to develop more trade connections with countries in Africa and South America in order to have access to minerals and some products.*

2. *The second reason has to do with the fact that there has been an investment in biotechnologies (and transfer) from North America to China (Asia) in the past few years. Those investments are increasing very rapidly. Lots of Chinese that have made their career abroad are coming back, which is really a booster for creating labs, so there is infrastructure too. That makes the Chinese market more accessible than the North American market.*

3. *It is possible to do more cooperation. There is a huge effort of the government in this area. Official party papers speak of creating labs to produce new types of crops, probably GM, with tolerance to drought etc. China is also intensively involved in sequencing several plant and animal species, such as rice, pig and silk worm. There is now critical mass of experience. This means access to the results of research companies do with their partner in China, which they can use anywhere in the world.*

4. *Adjacent to China, there is Taiwan, which is also developing new technologies in this sector.*

5. *What also makes it attractive is the availability of the rice genome sequence and the fact that Japonica is very easy to transform, so you can test some candidate genes. This is possible in monocot crops, and in dicot crops in the future too.*

6. *China is also cheap. The labour cost of scientific personnel is much lower (post docs in China cost only 1/3 of what they cost in Europe), they work hard and the number of qualified people is increasing rapidly.*

Hu et al. (2009) provide profound insights from their well-researched analysis of the impacts of the adoption of intellectual property rights and reforms of the seed law on China's Bt-cotton industry. While through the late 1990s farmers in China accessed cotton seeds from traditional non-commercial sources, after 1999 farmers could still purchase cotton seeds from those traditional non-commercial sources, save their own seeds or purchase cotton seeds from commercial sources. Table E1 presents an overview of the adoption of GM cotton seeds in India from 1999 to 2001: 56% of the farmers bought cotton seed from commercial seed companies, 20% from traditional, non-commercial channels and 24% self-saved seeds. During these years, 74% of the cotton seed purchased from commercial channels was found to be based on the Monsanto gene, while the 26% was based on the CAAS gene. In addition, examination of plots planted with cotton seed from commercial sources revealed that 56% of the plots had been planted with legitimate cotton seed, whereas on 44% of the plots illegitimate cotton seed had been planted. Notably, the incidence of illegitimate seed types was higher for domestic commercial seed (66%) than for foreign varieties (36%). The conclusion from these findings was that the reform of intellectual property rights did not eliminate illegitimate seed types from China's Bt cotton seed market. Nonetheless, despite the weakness of China's IPR system, the decision to allow foreign seed companies into the nation's cotton industry appears to have brought benefits, as technical efficiency of China's cotton production rose sharply after the introduction of Bt cotton seeds.

Table E1: The Chinese cotton seed market between 1999 and 2001

	Origin of the seeds			
	Bought from commercial seed companies		Bought from traditional, non-commercial channels	Self saved
Percentage	56%		20%	24%
Origin of the gene	Monsanto	CAAS		
	74%	26%		
Legitimacy of the seed	Legitimate	Illegitimate		
	56%	44%		

Source: Hu et al. 2009

Yet, concerns about multinational companies dominating the seed industry persisted. In 2009, the Chinese Academy of Science and Technology stated that the seed industry is of strategic importance to China and that opening of the industry threatens the survival of domestic firms and the security of China's germplasm resources (Linton 2010). Notwithstanding several seed market access restrictions that are still in place, foreign firms have been permitted to undertake several new agricultural biotechnology R&D programmes and new investments are allowed, provided they are limited to research and do not extend to commercialisation of new products. Under such terms, both Syngenta and Bayer have started to collaborate with Chinese research institutions and universities.

E.3 Government policies on innovation in India's seeds sector

Evolution of the Indian seed industry

The evolution of the seed industry in India can be divided into four periods (Pray *et al.* 2009):

1. The colonial period during which the government of British India established a series of agricultural experiment stations and agricultural colleges that first imported crops and plant varieties from other parts of the world and later bred higher yielding sugarcane, wheat, rice and cotton varieties.
2. Green Revolution period during which India's government established agricultural research systems and a series of state agricultural universities and public sector breeders started producing improved varieties if maize, sorghum, pearl millet, cotton, sugarcane and other major crops, while the private sector only played a small role in importing and distributing new vegetable and fruit varieties and tobacco.
3. The Hybrid period which started in the 1980s and in which private firms began to play a major role in the seed industry by producing and distributing hybrid varieties of maize, sorghum,

pearl millet and cotton, while hybrid sunflower varieties from the US and Australia were also introduced. In the 1980s and 1990s the private sector made major investments and public-private partnerships proliferated during the late 1990s, resulting in the introduction of hybrid varieties of rice, wheat and rape seed. For instance, the International Rice Research Institute (IRRI), along with some Indian government institutions and several private firms, have adapted the Chinese hybrid rice system for India.

4. The Biotech period that began at the beginning of the 21st century, starting with the introduction of GM Bt cotton hybrids by Monsanto and a joint venture between Monsanto and Mahyco, one of the biggest Indian seed companies. The GM Bt cotton hybrids were officially approved by India's government in 2001 and about 20 seed companies in India have inserted the Bt gene in their proprietary cotton hybrids. Recently several new Bt genes have been approved – one from China and one from an Indian public research institute. At present, about 80% of India's cotton production is based on GM Bt cotton hybrid seeds. Figure E3 provides an overview of the number of Bt cotton hybrids that were approved for commercial cultivation in 2009.

Policy reforms

In 1966 India's government passed the first seed law, leading to restrictions on private seed companies and seed exports as well as the banning of commercial imports of any agricultural input that was also being produced in India (Pray *et al*. 2001). In 1979, India's government implemented its Industrial Policy Act which restricted investments by large Indian firms and did not allow firms with more than 40% foreign ownership to enter the seed industry. However, in the mid-1980s India's government started reducing barriers to the entry of foreign firms by: 1) including seed and biotechnology industries in the list of 'core-industries' in 1986, which allowed large Indian firms and foreign-owned companies to enter India's seed industry; 2) adopting the New Seed Industry Development Policy in 1988, which allowed seed firms to import commercial vegetable seeds with no quota, to import commercial seeds of foreign varieties of coarse grains and oilseed for two years, after which seed firms had to produce the seed inside India, and to import germplasm for research purposes, and; 3) reducing regulations on technology transfer and foreign investment.

As a result, five large Indian firms, J.K. Industries, Southern Petrochemical Industries Corporation (SPIC), Khatau-Junker Ltd., Godrej, Dunlop and Harrisons, entered the seed business in 1986, although three of them soon dropped out. In addition, large firms that were partially foreign-owned, like Hindustan Lever, ITC, ICI and Sandoz, also entered the seed industry. Other key groups of new entrants were multinational seed companies, such as Cargill, DeKalb and Monsanto, who generally came in as joint ventures or wholly own research or foundation seed companies with local distributors, and small (Indian) seed companies. According to Pray *et al*. (2009), the effects of these entrants was to reduce concentration and increase the competitiveness of the seed industry. The so-called 'four firm ratio', which is a measure for concentration, went down from 69% of private seed sales in 1987 to 51% in 1995. In that period, the large Indian companies went from nothing to a 23% share of private seed sales, while some foreign-owned firms went from 10% to 33%, while government companies' sales were about equal to private companies' sales.

Murgkar *et al.* (2007) have examined competition and monopoly issues in the Indian cotton hybrid seed market and identified several factors that have played a role in the rapid development of the private sector cotton hybrids in the 1990s. First, their growth is the outcome of a process of technology diffusion and learning. Many of the private sector firms that have their own hybrids today entered the cotton seed business by marketing and producing public bred hybrids. Furthermore, the private sector has relied heavily on retired public sector breeders to lead their research efforts. The knowledge spillovers from the public sector R&D activity have therefore been substantial. Second, once the private sector was able to evolve a successful model of hybrid development, production and release, it was also quick to spot the market opportunities left unexploited by the public sector. In particular, the private sector developed early duration hybrids with good fibre quality. The early duration hybrids appealed to farmers in rain-fed areas anxious to minimize their exposure to weather risk. By comparison, the public sector hybrids were middle to late duration crops. Third, as selling one's own proprietary hybrids offered much greater margins than marketing public bred hybrids, private firms reallocated their resources accordingly. On the other hand, the public sector seed corporations were unable or unwilling to invest in the marketing effort to compete with private bred hybrids.

Currently, there are over 250 private seed firms in India, of which perhaps 60 firms have R&D programmes to develop and commercialise new varieties and about 20 firm are major players in a seed market with an annual sales volume of about 1300 million US dollar (Pray *et al*. 2009). The liberalisation reforms have thus led to a shift towards private sector seed industry, while at the same time, from 1995 to 2005, the share of public sector seed sales decreased from 40% to 22%.

Moreover, there is a growing investment of foreign seed and biotechnology companies in R&D and India's seed industry and their use of India as a research base for developing technology for elsewhere in the tropics. Further, Indian firms are expanding into international markets through acquisition by foreign-based multinationals and seed companies in the US, Europe and South America and there are research alliances and contract research between Indian firms and US, European and Chinese research organisations.

For example, Limagrain set up joint ventures with Avesthagen and Devgen that bought the rice, sorghum and millet business in India from Monsanto, while both Monsanto and DuPont have established R&D facilities in India. Moreover, Bayer and its subsidiary Nunhems are expanding their biotechnology and breeding research in India so that India can be a research base for hybrid rice and vegetables seed for South and Southeast Asia. Another example is Advanta that already had two research facilities in India and expanded further in 2008 through the acquisition of the US-based hybrid grain and forage sorghum supplier Garrison & Townsend. In addition, in 2001 the Indian firm DCM Shriram Consolidated purchased Bioseed International, which was primarily a maize seed company that had spun off from Pioneer and had breeding programmes in the US, Philippines, Vietnam and India, while in India it was expanding into hybrid rice, cotton and sorghum. Another Indian firm Krishidhan Seed recently announced its long term agreement with the Dutch biotechnology company Proteios International for the development and application of molecular markers and DNA detection technologies to cotton.

Table E2: Shares of hybrids in total seed sales of the private sector and the public sector in 2008

Crop	Share of hybrids in total seed sales	
	Private sector	Public sector
Maize	98%	2%
Cotton	100%	0%
Millet	82%	18%
Sorghum	75%	25%
Sunflower	100%	0%
Rice	90%	10%
Vegetables	100%	0%

Source: Pray et al. 2009

Notably, private sector companies have introduced a growing number of hybrid varieties of field crops and vegetables, thereby taking a substantial share of the market from the public sector, especially in crops, such as cotton, sorghum and millet, and vegetables. While Pioneer, DeKalb, Pacific Seeds and other contributed to the introduction of hybrid maize and hybrid sunflower, rice hybrids were introduced by Pioneer, Bayer and Syngenta. Finally, Monsanto's has introduced BT cotton as the first

GM crop for commercial cultivation in India, contributing to an increase of the seed industry's value, a change of its structure and increased industry R&D investments. More than 150 Bt cotton hybrids, all developed by the private sector, containing any of the four approved GM events (MON1598, MON531, GFM Cry1A and Cry1Ac Bt-1), are now available for cultivation, covering about 90% of the total cotton acreage in India. Table E2 presents the shares of hybrids in total seed sales of the private sector and the public sector in 2008.

Despite continuing concerns by Indian politicians and non-governmental organisations (NGOs), the few quantitative studies that have looked at concentration in the Indian seed industry found that the entry of large Indian companies and foreign-owned multinationals actually led to reduced concentration rather than greater concentration. For example in the cotton seed industry from 1997 to 2005 concentration declined when measured either by the share of the top five firms (see Figure E1) or by the Herfendahl –Hirschman Index (HHI; see Figure E2), while at the same time the displacement of lower priced public cotton hybrids by higher priced proprietary hybrid seed contributed to the growth in the value of the Indian cotton seed market (Murugkar et al. 2007).

Figure E1: Share of top 5 firms in cotton proprietary hybrid seed market

Source: Murugkar et al. 2007

Figure E2: 5-firm Herfendahl –Hirschman Index for the cotton proprietary hybrid seed market

Source: Murugkar et al. 2007

According to Pray et al. (2009), Monsanto's sales in the early 21st century could have been between 20% to 25% of the private sector seed sales in India. Though, it could also have been less, because Monsanto sold of the Stoneville cotton seed part of Emergent Genetics (acquired in 2005) to Bayer in 2007, when it bought Delta and Pineland and sold the sorghum, pearl millet, sunflower and rice seed business in India to the Belgium based company Devgen.

Another type of concentration occurred in the Bt gene business. The Indian company Navbharat had a brief illegal monopoly on Bt cotton until it was discovered in 2001 (see the subsection *Diffusion of unapproved Bt cotton seeds* for more details). Then, the joint venture Monsanto-Mahyco Biotech was given a temporary monopoly by the Indian biosafety regulators on the 'legal' Bt cotton industry until 2006 when Nath Seed and J.K. Seed were also allowed to sell new Bt genes.

Figure E3 provides an overview of the number of four types of Bt cotton hybrids that were approved for cultivation in India in 2009.

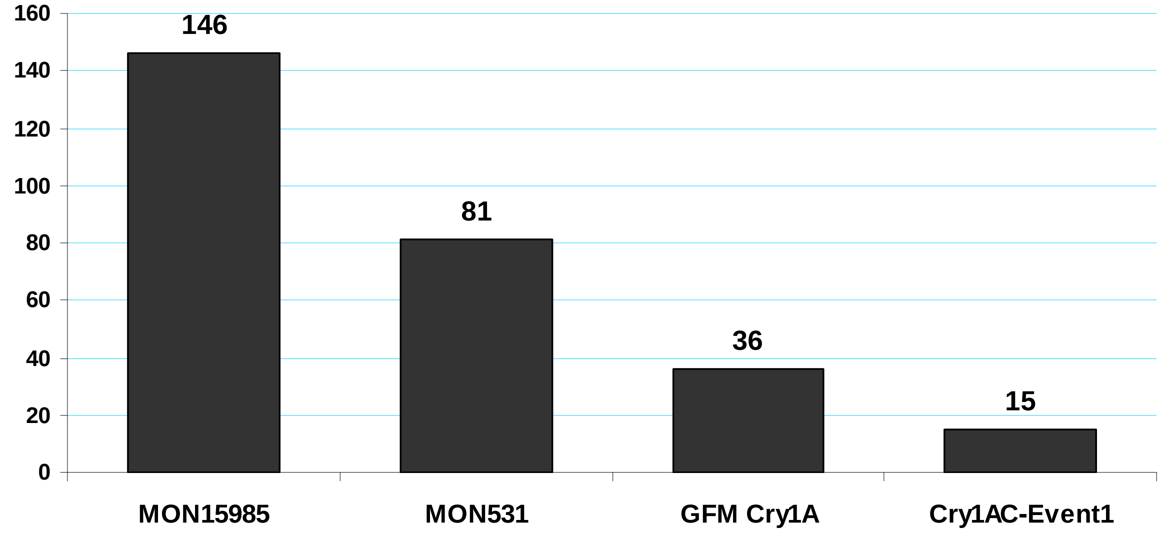


Figure E3: Number of Bt cotton hybrid approved for commercial cultivation in India in 2009

Note: Mon15985 and MON531 have been developed by Monsanto and GFM Cry1A and Cry1Ac Event-1 by Indian public research institutes.
Source: http://igmoris.nic.in/default.asp

Antitrust enforcement

In 2002 the Monsanto-Mahyco joint venture had the first mover advantage because it had the only approved Bt genes for commercialisation in India. Prices for its Bt cotton hybrid seeds were raised four to five time more than for conventional cotton hybrid seed, which attracted a large number of (Indian) seed companies to license the technology from Monsanto-Mahyco as well as to invest in R&D for new Bt genes. For instance, Nath, J.K. Seeds and a consortium of companies led by Nuziveedu, decided to invest in developing their own Bt cotton hybrid programme from scratch.

However, in 2006, the government of the state Andhra Pradesh brought a case to The Monopolies and Restrictive Trade Practices Commission because Monsanto-Mahyco had exercised monopoly power. The antitrust commission agreed with the state government but Monsanto-Mahyco appealed to the Supreme Court. Meanwhile, the government of Andhra Pradesh negotiated with the seed companies to set prices of the BT cotton hybrids. Soon other state governments (Gujarat and Maharashtra) also adopted similar pricing policies for Bt cotton hybrids.

Bt cotton seed price in India

Farmers are willing to pay a higher price for seed if it brings them benefits, for instance in terms of higher yields, lower expenditures on other important production factors such as fertilizers, pesticides and labor, or improved product quality that sells at premium prices. This can be illustrated by the development of Bt cotton in India. When Bt cotton was first introduced in the 2004/2005 growing season, the price for Bt seeds was Rs 3,517 per kg for official Bt seeds and Rs 2,374 per kg for unofficial Bt seeds. In 2006, the state governments of Maharashtra, Andhra Pradesh and Gujarat, which constitute the Indian cotton belt, fixed the price of single and double gene technologies at Rs 1,667 and Rs 2,111 respectively, about 50% lower than the initial price. This was further reduced to Rs 1,445 and Rs 1,667 in 2008 (Murugkar, 2007; HinduBusinessLine, 2010). Although the price was still considerably higher tan the Rs 963 per kg that was paid for non-Bt proprietary hybrid seeds, Bt cotton rapidly became very popular among Indian cotton farmers: the Bt cotton acreage touched 66% in 2008 and grew further to 90% in 2010 (Choudhary, 2010).

The actions led to debates on whether government imposed price controls could have a negative impact on innovation. First, companies may not invest in seeking approval for the release of new GM traits in India; for example, in China where there is virtually no IP protection Monsanto has not even attempted to introduce any other Bt-trait than the one introduced in 1997. Second, price controls may complicate seed companies and technology suppliers, like public or private research institutes, reaching licensing agreements with each other. Third, government price controls may prevent domestic firms seeking entry into the seed industry and harm domestic firms to develop and commercialise GM seeds (Linton 2010).

Diffusion of unapproved Bt cotton seeds

The approval of Monsanto-Mahyco's Bt cotton was preceded by the discovery of an unauthorised Bt cotton hybrid in farmers' fields in Gujarat at the end of 2001. The unapproved seed was a variety registered as a conventional cotton hybrid that belonged to Navbharat Seeds. Later investigations confirmed that the Bt gene was the Cry1Ac gene developed by Monsanto and used in the legally approved varieties. Consequently, Navbharat Seeds has been barred from the cotton seed industry and prosecuted for violating biosafety regulations. Despite this, the multiplication and distribution of unapproved seed continued to spread. While the area under approved Bt cotton hybrids grew from 28 million acres in 2003 to 4800 million acres in 2008, the area under illegal Bt cotton hybrids grew from 30 million acres to 1800 million acres in the same period (Ramaswami *et al*. 2008).

Herring (2006; 2008), among others, has emphasised the limits of IP protection in seeds, suggesting that farmers always have the ability to make 'gray-market' versions of approved seeds through seeds saving, seed exchange and seed experimentation. In the case of unapproved Bt cotton hybrid seeds, a 'stealth' economy emerged, in which not only farmers but also seed growers, seed companies and distribution agents worked together (Ramaswami *et al*. 2008).

ANNEX F: 'OPEN INNOVATION' AND MANAGING INTELLECTUAL PROPERTY IN PLANT BREEDING

While seed companies have diverging opinions about the role of Intellectual Property in plant breeding, a few 'open innovation' approaches for agricultural biotechnology and plant breeding have been initiated: The Biological Innovation for Open Society (BIOS) and the Public Intellectual Property Resource for Agriculture (PIPRA).

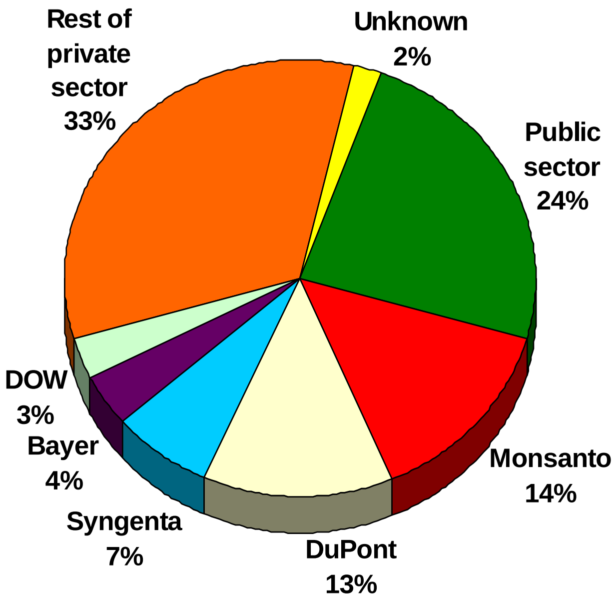
Several examples on licensing agreements in this study (see Annex B) also included deals between seed firms to drop IP litigation procedures against each other, suggesting that the role of IP in (agro)biotechnology might become more, not less, complicated over the next decade. In essence, the biotechnology sector faces the need both to protect innovations and to open them up. Consequently, for patent holders, including agricultural biotechnology and seed companies as well as public research institutions, managing IP wisely is no small challenge, as it also requires reconciliation of the needs of the industry with those government grant-makers and public sector researchers. Moreover, there is a pressure building to do something to assuage concerns that patents are stifling, not stimulating, innovation (Cukier 2006).

In a similar vein, a report by an international expert group on biotechnology, innovation and intellectual property, hosted by McGill University in Montreal, Canada, argued that the current system of 'Old IP' rests on the belief that if some IP is good, more IP is better. This thinking increasingly risks to become counterproductive in sectors like health care and agriculture (TIP 2008). The expert group therefore argued to implement 'New IP' models it saw emerging that focus on collaboration and co-operation.

Meanwhile, a few 'open innovation' approaches for agricultural biotechnology and plant breeding have been initiated. One early example is the Biological Innovation for Open Society (BIOS) started by Richard Jefferson who contributed to the development of a new plant transformation technology as an alternative to the commonly applied *Agrobacterium*-based transformation technology (Broothaerts et al. 2005). In contrast to the complex patent licensing landscape for *Agrobacterium*-based transformation technology, the alternative technology "TransBacter" was made accessible to the international community in a 'protected technology commons'. The open-source-modelled licenses of BIOS are characterised by having no commercial restrictions other than covenants for sharing improvements, relevant safety information and regulatory data and for preserving the opportunity for others to freely improve and use the technology.

Another example of an 'open-innovation' initiative is the Public Intellectual Property Resource for Agriculture (PIPRA), started by Atkinson et al. in 2003. According to the initiators, patented technologies related to agricultural biotechnology have increased dramatically since the 1980s in both the public and private sectors. Public sector research institutions have invented nearly 25% of the technologies in this field – a proportion which is approximately 10-fold greater than most other technology sectors. Figure F1 provides a more detailed breakdown of the shares of patents assigned to private companies and public institutions in the US as of 2003, at the time when PIPRA was initiated.

In spite of the significant size of the public sector technology portfolio, Atkinson et al. (2003) argued that it remains underutilised as a resource in part due to the fact that it is highly fragmented across many institutions. Commonly, these institutions have found that the public research sector is increasingly restricted in its ability to develop new crops with the technologies it has itself invented. Many public/non-profit institutions share a common philosophy supporting broad technology access, but prior to the formation of PIPRA there was no mechanism for collaborative management of patented technologies to further these goals. To more effectively manage patented technologies, 39 universities and non-profit research centers in 10 countries have joined forces to form PIPRA for to the strategic management of intellectual property to enable the broadest commercial and humanitarian applications of existing and emerging agricultural technologies. PIPRA thereby indicated to believe that the landscape of intellectual property could be more effectively managed collaboratively by using a set of shared principles, like: 1) provide a one-stop intellectual property clearinghouse for access to public sector patented technologies; 2) provide a resource for the analysis of patented technologies for implementation of specific projects; 3) develop gene transfer and gene-based trait technologies that have maximum legal “freedom to operate” (FTO); 4) manage pools of public sector technologies to promote availability and reduce transaction costs associated with transfer of rights to patented technologies, and; 5) support the development of intellectual property management best practices and capacity enhancement in developing countries.



University of California	1.7%
USDA	1.2%
Cornell University	0.9%
Iowa State University	0.8%
Michigan State	0.7%
North Carolina State	0.5%
Washington State	0.5%
University of Florida	0.5%
Wisconsin Alumni Research Foundation	0.5%
Massachusetts General Hospital	0.5%
Salk Institute	0.5%
Canadian Ministry of Agriculture and Agri-Food	0.4%
Rutgers University	0.4%
Rest of public sector	14.6%

Figure F1: Shares of patents assigned to private and public entities in the US as of 2003

Source:Graff et al. 2003

Both BIOS and PIPRA have started providing services as ‘patent landscape navigating’ and new open-source tools for healthcare and agricultural R&D especially to public research institutions and small companies in developing countries. At this point in time it might be too early to evaluate the successes and/or failures of both these initiatives. Independent reviews of their activities have not been found, nor information on whether these (or possible, similar) open-innovation initiatives have had an impact on R&D for plant breeding by public institutions and small(er) (family-owned) seed companies in developed countries.

ANNEX G: INTERVIEW QUESTIONS

Note: In the interviews with Alain Bonjean (Limagrain) a separate list of questions focusing on the situation in China has been used. These questions are listed in italics.

1. Drivers

- What has been the **main driver of concentration in the seed industry** over the last twenty years? Rank from 1 to 5.
  - Changes in seed industry's profit margins? 1 – 5
  - Changes in commodity markets? 1 - 5
  - Increase of plant breeding R&D costs? 1 – 5
  - R&D Costs of applying GM technology? 1 – 5
  - Regulatory requirements for GMOs? 1 – 5
  - Access to patented technologies and traits for plants? 1 – 5
  - Other? 1 -5

China: *How has the Bt-cotton seed industry evolved in China? Is concentration/consolidation occurring? If so, what are the main drivers? Is there a GM rice seed industry evolving in China? If so, which public and private (including foreign) parties are involved?*

2. M&As:

Do you foresee any future mergers and/or acquisitions?
If yes, what type of activities/companies would that concern:

- Companies active in field crops, vegetables or ornamentals?
- biotech companies that add new technologies
- seed companies adding new germplasm and/or new crops to the portfolio
- seed multiplication and distribution companies
- companies that extend your commercial activities to other parts of the world, North America, South America, Europe, Asia, Australia, Africa?

If not, why not?

China: *Why is Limagrain present in China? Does Limagrain focus on certain crops and/or traits? Why these crops and/or traits?*

3. [Cross] licensing

- What is the strategic background of the growing number of licensing agreements and R&D collaborations with other seed/biotech companies? Is it a way forward, if growth by M&As is no longer possible?
- What role do breeders' research exemption in some patent laws (France and Germany) play?
- What role do anti-trust limitations imposed by the authorities play?

China: *Are there specific Intellectual Property issues in China? If so, in what respect do IP issues in China differ from the US or EU?*

4. Cost of bringing GM crop to market

These cost are said to be about 100 - 150 million US dollar. Could this figure be broken down into:

- q million for trait discovery
- x million for research (gene construct – event) [(+ possibly licensing costs)]
- y million for development (event – GM crop variety)
- q million for seed multiplication, distribution and sales [(+ possibly licensing costs)]
- z million US dollar (regulatory research, dossier, approval)
- w million US dollar (obtaining and maintaining patent(s), and licenses)

China: *What are the costs of bringing a GM crop to the market in China?*

5. R&D

- What is the **R&D cost share of the total budget** over the last five years? Will this share go up or down the coming years? Why?
- What is the **IP and Legal cost share** of the total budget over the last five years? Will this share go up or down the coming years? Why?

6. Innovation

- **R&D collaborations/open innovation:** To what extent can we talk in terms of 'open innovation' as it concerns the seed industry? What are opportunities & threats?
- **Public-private partnerships**: What is the role of public R&D in plant science and plant breeding versus private R&D?
  China: *Are there public-private partnerships (PPPs) in China? If so, do they also involve foreign companies and under which conditions? What are the key features of Chinese PPPs? What is the role of public R&D in China?*
- **Biotechnology:** Biotech/seed companies are promising a major shift from present input oriented agronomic traits to output traits (e.g. product quality). What can we expect from your company in the short (now – 2 years), medium (2 – 5 years) and long run (5-10 years)?

7. Intellectual Property Rights

Patents are meant to protect the intellectual property and ownership of real inventions and to enable the inventor to get a return on R&D investment In the recent years, there have been a series of legal cases concerning patent infringement, while in some cases the adversaries eventually decided to stop litigation procedures and reach an agreement among themselves. Are these patents important enough to spend huge budget on professional legal advice? Are there any alternatives to protect IP?

China: *Is there a market for 'illegal' (Bt-cotton) seeds or traits in China? If so, how do the Chinese authorities deal with trade in such 'illegal' seeds or traits?*

8. Generic biotech seeds and traits

Do you see a future for generic biotech seeds and/or traits? If not, why? If yes, what would be the conditions supporting the market for generics?

China: *Is there a market for generic biotech seeds and traits in China? Would such generics market differ from those in the US or EU.*

ANNEX H: LIST OF INTERVIEWEES

DuPont-Pioneer	John Bedbrook, Vice President Agricultural Biotechnology
Bayer – Nunhems	Johan Peleman, Managing Director of Research & Development
Illinois Foundation Seed	Tim Johnson, President
KWS	Léon Broers, Executive Board - Breeding & Research
Limagrain	Jean-Christophe Gouache, CEO of the Vegetable Seeds Division Alain Bonjean, Managing Director Limagrain's Greater China
Monsanto	Philippe Castaign, Head of European Corporate Affairs Jim Tobin, Vice President Corporate Affairs
Rasi Seeds	Arvind Kapur, CEO Vegetable Seeds Division
Syngenta Seeds	David Morgan, President
Rijk Zwaan	Ben Tax, Board of Directors
	Pim Lindhout

ANNEX I: TWO MAJOR ANTITRUST CASES IN THE US SEED INDUSTRY

Monsanto, DeKalB and the maize seed market

In 1998 the Monsanto’s 2.3 billion US dollar acquisition of DeKalb raised concerns of the DoJ Antitrust Division about competition in the biotech maize seed market (DoJ 1998). The combination of Dekalb’s IP of the leading method of maize transformation, so-called ‘biolistics’, and Monsanto’s IP claims in the emerging *Agrobacterium*-transformation technology led to concerns about competition for maize transformation. In the view of the DoJ, other parties in biotechnology needed access to transformation technology, on competitive terms, for introducing new traits in maize seed.

Consequently, Monsanto had to implement certain changes to the deal that would ensure that biotechnology developments in maize would remain competitive. On the one hand, Monsanto had to spin off its IP claims on *Agrobacterium*-transformation technology to the University of California at Berkeley, which as an independent entity with experience in the exploitation of such IP would ensure that other parties would not be deprived of future competition in maize transformation technology. On the other hand, Monsanto had to enter into binding commitments to license maize germplasm of its subsidiary Holden to over 150 seed companies that were Holden’s customers. This would ensure that the merger with DeKalb did not reduce competition in biotechnology developments in maize. One year before, in 1997, Monsanto had acquired Holden with a share of over 30% of the maize hybrid seed market in the US.

Monsanto, Delta and Pineland and the cotton seed market

The DoJ had similar concerns about the acquisition of Delta and Pineland, a major US cotton seed company, by Monsanto in 2007. Eventually, Monsanto reached an agreement with the DoJ that allowed it to complete its acquisition of Delta and Pine Land. The DoJ essentially required Monsanto to eliminate stacking prohibitions in its cotton trait licenses. Under terms of the agreement, Monsanto had therefore to divest certain assets including its US branded cotton seed business. Therefore, the company (Monsanto 2007):

- Entered into a definitive agreement to sell its Stoneville cotton seed brand and related business assets, subject to Justice Department approval, to Bayer for 310 million US dollar. As part of this agreement, Monsanto agreed to sell to Bayer certain conventional cotton parental lines that Monsanto will acquire from Delta and Pine Land's cotton breeding program. Monsanto retained a non-exclusive license to these same parental lines. Bayer's FiberMax brand and the Stoneville brand continued to be licensed to use Monsanto's cotton trait technologies.
- Entered into a definitive agreement to sell its NexGen cotton seed brand and related business assets, also subject to Justice Department approval, to Americot for 6.8 million US dollar. As part of this agreement, Monsanto agreed to sell to Americot certain conventional cotton parental lines that Delta and Pine Land acquired from Syngenta in 2006. The Americot and NexGen continued to be licensed to use Monsanto's cotton trait technologies.
- Amended certain cotton licensing agreements so that its other cotton licensees would have the same terms that Delta and Pine Land enjoyed with regard to the use of third-party trait technologies;
- Provided Syngenta certain germplasm in Delta and Pine Land's breeding pipeline that contains VIPCot trait technology. This action was intended to allow Syngenta to continue its development of this technology.

ANNEX J: FIELD TRIALS WIT GM CROP IN THE US, EU, INDIA, AUSTRALIA AND ARGENTINA

This annex provides overviews of the number of (applications for) field trials with GM crops in the USA, EU, India, Australia and Argentina, which can be considered an indicator of the level of activity of countries and companies in GM crops.

These overviews are based on data that have been retrieved from the following databases:

- **USA**: Information Systems for Biotechnology at Virginia Tec (data provided by USDA APHIS Biotechnology Regulatory Services); http://www.isb.vt.edu/cfdocs/fieldtests1.cfm

- **EU**: GMO Register of the European Commission Joint Research Centre; http://gmoinfo.jrc.ec.europa.eu/

- **India**: Indian GMO Research Information System; http://igmoris.nic.in/default.asp

- **Australia:** Office of Gene Technology Regulator; http://www.ogtr.gov.au/internet/ogtr

- **Argentina:** Ministry of Agriculture; http://www.minagri.gob.ar/SAGPyA/agricultura/biotecnologia/

Field trial data from China, as publicly accessible databases have not been found on the Internet.

Notably, the number of field trial applications does not necessarily equate with the number of field trials conducted. Applications might have been rejected by regulatory authorities of withdrawn by applicants, although the number of such cases seems to be very limited.

Moreover, the scope of a (permit for a) field trial might range from one field test at one site for one year to multiple field tests at multiple sites for multiple years.

Further, for this search, companies have been clustered in accordance with findings from literature on mergers and acquisitions in the seed industry from 1990 to 2010. For example, if a company conducted a field trial at a particular point in time but it merged or was acquired by another company later, the field trial has been counted as if the latter company has conducted it.

Table J.2 provides an overview of clusters of companies that have applied for field trials with GM crops in the US, EU and India. Further, Big Six is a notion used in this and some other studies to cluster the following companies: BASF, Bayer, DuPont, Dow, Monsanto and Syngenta. Table J.3 provides an overview of the top ten companies in terms of field trial applications. The figures are split by crop in tables J.4 to J.7.
The tables illustrate Monsanto's dominant position with more than 40% of all field trial applications in the USA, the EU, Argentina, Australia and India. Except for rice, where Bayer is the major applicant, Monsanto ranks nr. 1 in all GM crop field trial applications.

Table J.1: Clusters of companies that applied for field trials in the US, EU, India, Australia and Argentina

Company	Mergers & Acquisitions	Company	Mergers & Acquisitions
Monsanto	Agracetus Asgrow DeKalb Forage Genetics International Holdens NC+Hybrids Upjohn Calgene Delta and Pineland DeltaMax Cotton Jacob Hartz Campbell Petoseeds Seminis Vegetable Seed Bruinsma Seeds (Seminis) Advanta – oilseed rape SES (Advanta; oilseed rape) Sharpes (Advanta; oilseed rape) Cargill Seeds CDM Mandiyú Mahyco	**Syngenta** **Bayer**	Ciba-Geigy Garst Golden Harvest Seeds Hilleshög Northrup King Novartis Seeds Rogers NK S&G Seeds Zeneca Mogen Mahissa ICI Seeds Agrevo Aventis Hoechst-Rouseel Plant Genetic Systems Rhone-Poulenc Sunseeds Sanofi Solavista (Aventis/AVEBE) Nunhem
Limagrain	Advanta; maize Europe Clause Seeds SES (Advanta; maize) SELIA Tézier Emilseme Nickerson Zwaan Maïs Angevin Biogemma	**BASF**	ExSeeds Crop Design Plant Science Sweden Amylogene
DuPont	Pioneer Hi-Bred (Targeted Growth Inc)	**Dow**	Agrigenetics Mycogen

Source: compiled by the authors

Table J.2: Applications for field trials per entity type in the USA, the EU, India, Australia and Argentina

Company	USA (1987-2010)	EU (1991-2008)	Argentina (1991-2010)	Australia (2001-2010)	India (1987-2010)
Big Six	10,684	1,181	1,061	29	25*
Other private entities	2,067	599	324	14	6
Public entities	3,164	449	86	40	20
Total	**15,915**	**2,229**	**1,471**	**83**	**51**

* Including Mahyco Monsanto

Table J.3: Applications for field trials by the ten major companies in the USA, the EU, India, Australia and Argentina

	Company	USA (1987-2010)	Argentina (1991-2010)	EU (1991-2008)	India (1987-2010)	Australia (2001-2010)	Total
1	Monsanto	7,230	536	311	14*	16	**8,107**
2	DuPont	1,331	173	195	1		**1,700**
3	Bayer	752	85	363	5	8	**1,213**
4	Syngenta	710	225	207		1	**1.143**
5	DOW	429	98	21	6	4	**558**
6	Limagrain	159		173	1**		**333**
7	BASF	135	35	84			**254**
8	Associados Don Mario		59				**59**
9	Frito Lay	58					**58**
10	Satus Ager		37				**37**
	Total	**10,840**	**1,248**	**1,354**	**27**	**29**	**13,462**

* Mahyco Monsanto
** Avesthagen

Table J.4: Company applications for maize and soy field trials in the USA, Argentina and the EU

Company	USA (1987-2010)		Argentina (1991-2010)		EU (1991-2008)	Total	
	maize	soy	maize	soy	maize	maize	soy
Monsanto	3,973	1,056	348	137	136	**4,457**	**1.139**
DuPont	992	91	132	24	189	**1,313**	**115**
Syngenta	486	52	202	7	118	**806**	**59**
DOW	353	78	98		17	**468**	**78**
Bayer	325	111	13	26	76	**414**	**137**
Limagrain	102				112	**214**	
BASF	96	4	35	6		**131**	**10**
Frito Lay	58					**58**	
J.R. Simplot Company	36					**36**	
Satus Ager			29	9		**19**	**9**
Southern Seeds			13			**13**	
Associados Don Mario			12	47		**12**	**47**
Nidera				29			**29**
Pau Semillas			5			**5**	
Bioceres			5			**5**	
Total	**6,421**	**1,392**	**892**	**200**	**648**	**7,961**	**1,592**

Table J.5: Company applications for cotton field trials in the US, the EU, Australia and Argentina

Company	USA (1990 -2010)	EU (1991 -2009)	Australia (2001 - 2010)	Argentina (2001 - 2010)	Total
Monsanto	582	24	14	38	**658**
Bayer	181	32	3	24	**240**
Syngenta	77		1	2	**80**
DOW	46	4	4	10	**64**
DuPont	20				**20**
Hexima Ltd.			2		**2**
Cotton Seed Dist. Ltd.			1		**1**
BASF				1	**1**
Total	**906**	**60**	**25**	**75**	**1066**

Table J.6: Company applications for rice field trials in the US, Argentina and the EU

Company	USA (1990 -2010)	EU (1991 -2009)	Argentina (2001 - 2010)	Total
Bayer	56	18	18	**92**
Monsanto	51			**51**
BASF	21	2	25	**48**
Ventria Biosciences	32			**32**
Syngenta	11			**11**
Arcadia Biosciences	9			**9**
RiceTec	6			**6**
DOW	1			**1**
Total	**187**	**20**	**43**	**250**

Table J.7: Company applications for tomato field trials in the US and the EU

Company	USA (1990 -2010)	EU (1991 -2009)	Total
Monsanto	269	12	**281**
Gargiulo (BHN Seeds)	71		**71**
DNA Plant Technology	50		**50**
Syngenta	44	7	**51**
Bayer	6	6	**12**
Limagrain		9	**9**
Lipton	4		**4**
Arcadia Biosciences	3		**3**
DuPont	3		**3**
SME Richerche scpA		3	**3**
Total	**450**	**37**	**487**

ANNEX K: REFERENCES

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