INTERNATIONAL TRADE IN GENETICALLY MODIFIED-SENSITIVE INDUSTRIES: A CROSS-COUNTRY ANALYSIS

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Dedication

To my family. To my family.

Abstract

This dissertation analyzes the effects of *non-traditional* endowments (R&D stock and biotech land) on trade of genetically-modified sensitive industries. The study also explores the effects of differences in *institutional endowments* (intellectual property rights and regulatory regimes) on genetically modified sensitive industries.

In particular, I ask, do the *non-traditional* endowments confer comparative advantage to a country in exporting to the rest of the world (ROW)? I pursue this hypothesis by looking at whether a country's true non-traditional endowments (R&D and biotech land) correspond with net export of embodied non-traditional endowments. I employ the factor-content model of the Heckscher-Ohlin-Vanek (HOV) as the underlying theoretical framework. The empirical implementation and method include examination of this relationship via non-parametric and parametric methods using 2006 cross-section data of three-digit level of the Standard International Trade Classification (SITC).

Further, I examine the causal relationship between non-traditional endowments and countries' bilateral trade of genetically modified-based industries. In addition, I analyze the effect of institutional measures of policy on bilateral trade in GMO-based industries and account for ways in which these institutional factors interact with non-traditional endowments (R&D and biotech land). I employ the Gravity model of international trade to examine these relationships.

Findings show countries with higher non-traditional endowments than the world average have embodied net exports of these endowments. In other words, this finding is an indication that such countries have revealed comparative advantage in goods that make intensive use of these factors. In particular, results show that the causal relationship between trade in genetically modified-sensitive products and biotech land of a country is informative. In aggregate and subaggregates trade, the biotech land factor consistently shows positive and statistically significant parameter estimates indicating that indeed it confers comparative advantage. Accordingly, the relationship between trade in GMO-based industries and GMO land is genuinely causal rather than just correlation. This implies that the variation of trade in GMO-based industries is not attributable to either unmeasured characteristics or the traditional endowments. However, the relationship

between trade in genetically modified-sensitive industries and R&D stock is less definitive. R&D stock confers comparative advantage in one (fats or vegetable related) of the four main subaggregates while it neither confers comparative advantage nor comparative disadvantage in others. There is evidence that R&D stock (knowledge capital) does not fit the traditional immobility assumption. Knowledge capital spillovers may take place. Thus, the importance of knowledge capital is not showing up in the statistical results.

I found mixed evidence on the effect of institutional endowments (relevant regulatory regimes and intellectual property rights) on bilateral trade in GMO-based industries. Using different levels of data aggregations (for comparability and concordance) and estimation methods (for robustness checks), the results showed that strengthening of patent protection in the destination country relative to the source country reduces exports of genetically modified-sensitive products. This demonstrates a market power effect where strengthening intellectual property protection grants monopoly power to economic agents of importing country relative to exporting country. Finally, results show that even when there are marked regulatory differences and policies, there is little evidence of diversion of trade in GMO-sensitive industries.

The dissertation is organized as follows. Chapter 1 provides an introduction and overview of GMO-intensive industries. This chapter also summarizes patterns of international data on trade in GMO-intensive industries, R&D, GMO land use, and policies including regulatory regimes and intellectual property rights. Chapter 2 then analyzes determinants of trade in GMO-intensive industries using the Heckscher-Ohlin model. This analysis focuses on determinants of a country's trade with the rest of the world. Chapter 3 analyzes determinants of trade in GMO-intensive industries using the Gravity model. This analysis focuses on the determinants of a country's bilateral trade with each trading partner. Chapter 2 and 3 both focus on the role of the *non-traditional endowments* as determinants of trade. These non-traditional endowments include: (1) the knowledge stock of countries, (2) the land endowments of countries including the GMO component of land, (3) regulatory regimes of countries related to GMO policies, and (4) the intellectual property right policies of countries. I refer to the knowledge stock variable as an R&D stock through much of the dissertation. I also refer to the two policy variables as '*institutional endowments'* throughout the dissertation. Chapter 4 then provides a conclusion, discussion of policy implications of the research, elucidates the limitations, and proposes areas of further research.

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List of Abbreviations

AgLand	–	Agricultural Land
APHIS	–	Animal and Plant Health Inspection Service
Bt	–	Bacillus thuringiensis
C.I.F	–	Cost, Insurance, and Freight
CAC	–	Codex Alimentarius Commission
CFIA	–	Canadian Food Inspection Agency
COMTRADE	–	Commodity Trade
CRS	–	Constant Return to Scale
EU	–	European Union
F.O.B	–	Freight on Board
FAO	–	Food and Agricultural Organization
FDA	–	Food and Drug Administration
FFDCA	–	Federal Food, Drug and Cosmetic Act
FSANZ	–	Food Standards Australia New Zealand
GATT	–	General Agreement on Tariffs and Trade
GDP	–	Gross Domestic Product
GDPPC	–	Gross Domestic Product Per Capita
GM	–	Genetically Modified
GMO	–	Genetically Modified Organism
HO	–	Hechscher Ohlin
HOV	–	Heckscher Ohlin Vanek
IPR	–	Intellectual Property Right
ISAAA	–	International Service for the Acquisition of Agribiotech Applications
ISIC	–	International Standard Classification
K	–	Capital
L	–	Labor
MERCOSUR	–	Common market of the South (Mercado Comun del Sur)
MFN	–	Most Favored Nation
MLE	–	Maximum Likelihood Estimation
NAFTA	–	North America Free Trade Agreement
POP	–	Population
PPA	–	Plant Protection Act
R&D	–	Research and Development
ROW	–	Rest of the World
RTA	–	Regional Trade Agreement
RTFE	–	Relative true factor endowment
SITC	–	Standard International Trade Classification

SPS	–	Sanitary and Phytosanitary
TBT	–	Technical Barriers to Trade
TRFE	–	Trade Revealed Factor Endowments
TRIPs	–	Trade-Related Intellectual Property
UNCOMTRADE	–	United Nations Commodity Trade
UNESCO	–	United Nations Educational, Scientific and Cultural Organization
WDI	–	World Development Indicators
WHO	–	World Health Organization
WTO	–	World Trade Organization

CHAPTER 1: INTRODUCTION AND OVERVIEW

1.0 Introduction

Within the framework of traditional trade theories, economists have studied comparative advantage of traditional endowments such as capital and labor as the bases of trade for many decades. In the wake of agricultural biotechnology since mid 1990s, countries increasingly utilize research and development (R&D stock) and biotech land in exporting genetically modified organism (GMO)-sensitive industries to the rest of the world (ROW). I term these two factors *non-traditional endowments* throughout the dissertation. *GMO-sensitive industries* consist of products whose principal crops are either genetically modified or are prone to accidental presence of small traces of genetic materials which enter the commodities flow, commonly known as *adventitious presence*. Besides, countries non-traditional endowments interact with *institutional endowments*, including protections offered by strength of intellectual property and relevant regulatory regimes. In explaining GMO-sensitive trade, I also consider these institutional endowments as part of the broader definition of the non-traditional endowments. In this study I argue that while the role of traditional endowments may still be important, countries utilize more non-traditional endowments in leveraging exports of GMO-sensitive industries to the ROW. Until we understand the role of these non-traditional endowments in GMO-sensitive trade, an important aspect of international trade will remain a mystery, especially when agricultural biotechnology appears to affect flow of products across borders.

The specific research questions I asked are (1) whether ‘non-traditional’ endowments confer comparative advantage to a country in exporting to the rest of the world, (2) whether a patent strength of the destination country relative to a source country has an impact on the bilateral trade flows of GMO-based industries (3) whether impact of relative strength of intellectual protection (IPR) on trade in GMO-sensitive industries varies with ‘non-traditional endowments (4) whether countries’ regulatory differences in GMO-based industries distort (divert or create) bilateral trade in GMO-sensitive industries, especially in the wake of heightened consumer shifts associated with potential health and environmental concerns.

In what follows, I provide an introduction and overview of genetically modified organism (GMO) - intensive industries, discuss role of non-traditional endowments (R&D stock and biotech land) in trade, as well as institutional and policy factors which characterize trade in GMO-based industries. As a prelude to the theoretical and empirical work of Chapter 2 and 3, I explain what constitutes GMOs and the current issues surrounding them, the patterns of trade in GMO-based industries, and patterns of land use for GMO-based industries. In terms of land use, I describe how countries that have biotech land utilize this endowment to leverage export to the rest of the world (ROW). In addition, I discuss policies that affect trade in GMO-based industries and compare national and international policies, treaties and arrangements that affect trade in GMO-based industries.

Because the debate surrounding GMO-sensitive trade is literally sensitive, I discuss the factors influencing countries’ positions on and development of GMOs. These factors include policy awareness, level of risk, willingness to undertake, and capacity to conduct risk assessment. For example, countries in North America and the European Union (EU) have taken opposite position on GMOs with former block supporting GMOs. Although initially rejecting GMOs, the EU in the later years eased moratorium on GMOs by marginally increasing tolerance level of GMO content.

1.1 GMO- based industries

Agriculture contributes to output and trade in developed and developing economies alike even though the latter group rely more on this sector. Developed and developing countries export and import agricultural commodities and intermediate products. In the last decade agricultural biotechnology has affected the sector's output and trade within and across countries. This study gives emphasis to GMO-sensitive industries. These industries are made up of products whose principal crops are either genetically modified or are prone to accidental presence of small traces of genetic materials which enter the commodities flow by accident, commonly known as *adventitious presence*. It is often argued that adventitious presence is inevitable and it has been a part of conventional agriculture. This can occur in processing of harvested products in the food/feed chain or at various stages of production of seed or grain. Genetic modification may take place in the fields through outcrossing, in laboratories during trials and testing, or during their use as intermediates to produce marketed final products. Further, GMO-based industries are derived from crops that take substantial resources in terms of R&D investments.

Sampled GMO-sensitive industries/products in the present study include maize seed, other unmilled maize, maize flour, groats /meal of maize, animal feedstuffs (bran, sharp and other residues of maize), oilcake from soybeans, oilcake from colza seeds (rape or colza), soybeans, rape/colza seeds, cottonseeds, soybean oil fractions, cotton oil fractions, maize oil fractions, and rape/colza mustard oil. Table 1.1 summarizes description and categorization of GMO-based industries.

Table 1.1: Description of GMO-based industries

Code	Description
	Cereals, Cereal Preparations
0441	Maize seed
0449	Other maize, unmilled
04711	Maize (corn) flour
04721	Groats and meal of maize (corn)
	Animal feedstuffs
08124	Bran, sharps and other residues, of maize
08131	Oilcake and other solid residues of oil from soybeans
08136	Oilcake and other solid residues of oil from colza seeds (rape or colza)
	Oil seed, oleaginus fruit
2222	Soybeans
22261	Rape or colza seeds
2223	Cottonseeds
	Animal, vegetable, fats and oils
4211	Soybean oil, fractions
4212	Cottonseed oil and its fractions
4216	Maize (corn) oil, fractions
4217	Rape, colza, mustard oil

Source: Compiled from UN COMTRADE Database.

Ingredients in GMO industries are highly likely to contaminate and become part of the general food supply chain and consumers can either choose or refuse (Nottingham, 1998). In the absence of labeling the assumption is that GMOs and Non-GMOs enter the supply chain as mixtures and different countries determine their own GMO content tolerance level. Also, the assumption is that primary crops are used as intermediates in the production of final marketed consumable products.

Such industries, via their being used as intermediate products embody technology arising from intensive use of R&D. It is instructive, therefore, to understand the sources and destinations of these GMO commodities in order to begin to comprehend the ubiquitous nature of GMO content in the processed foods globally. More importantly, this might have far reaching policy implications in terms of regulation. Labeling of genetically modified foods or derivatives containing verifiable transgenic material or unavoidable *adventitious presence* of genetic materials is required by countries using the precautionary principle such as the European Union (EU). However, when GMO ingredients become part of the general food supply chain of processed food, labeling and traceability become extremely difficult and costly given that legislation and regulation might extend to non-GMOs. The implementation and maintenance of the regulations requires analytical methodologies that allow for accurate determination of the content of genetically modified organisms within a food and feedstuffs (Miraglia et al. 2004).

Around the world some countries produce GMOs for domestic consumption while others produce for both consumption and export. In either case such countries rely on trade in conventional agricultural products (Zarrilli, 2005). Some of these products could be GMO-sensitive industries or their derivatives. Such countries face enormous challenges in preserving their export opportunities given that parts of the global market are uneasy with bioengineered products (Zarrilli, 2005). Given that bioengineering involves application of biotechnology to manipulate principal crops or derivatives, the global market is apprehensive of any trade involving these products.

There is also the issue of R&D investment affecting GMO-sensitive industries. A significant percentage of R&D investment takes place in large countries. If such countries are also large enough producers and consumers of tradable commodities in the world market, such production and consumption can have direct implication on world prices. Further, if research conducted in one country is transferable to other countries, technology spillovers can cause further reductions in the world prices. Several studies have developed models for evaluating R&D in the context of trade. Some have exclusively looked at the price spillover effect, while others have examined technology spillovers in which research results of a country or region are readily adopted in other parts of the world. Yet other studies have allowed for price spillovers via impact on production and technology spillover. Emphasis is placed more on the technology spillover aspect of R&D because some parts of the world might be able to adopt R&D results of other countries (Alston et al.1995).

A close scrutiny of countries R&D investment presents interesting insight into variations across these countries.[1] The R&D shown is nominal, that is, actually measured in current United States dollars.

[1] R&D figures reflected here are *flows* as opposed to *stocks*. In the empirical sections of Chapter 2 & 3, I compute stock measures of R&D.

Table 1.2: Nominal R&D activity (US$ millions) and intensity

Countries	R&D 1998	Countries	R&D 2006
United States	228	United States	344
Japan	91	Japan	139
Germany	45	China	87
France	29	Germany	67
United Kingdom	24	France	42
Korea Rep	17	United Kingdom	36
China	16	Korea Rep	30
Canada	14	Canada	24
Italy	13	Russia	20
India	9	Italy	18

Countries	R&D % of GDP, 1998	Countries	R&D % of GDP, 2006
Israel	3.19%	Israel	4.53%
Japan	3.00%	Sweden	3.82%
Finland	2.86%	Finland	3.43%
United States	2.62%	Japan	3.40%
Korea Republic	2.34%	Republic of Korea	3.23%
Germany	2.27%	United States	2.61%
France	2.14%	Germany	2.52%
Denmark	2.04%	Austria	2.46%
Iceland	2.01%	Denmark	2.44%
Netherlands	1.90%	Singapore	2.39%

Source: Extracted from UNESCO Database

Table 1.2 shows that in both 1998 and 2006 the United States and Japan registered the highest R&D investments, in that order. A number of Western European countries such as Germany, France and the United Kingdom also had significant R&D investment. This is consistent with the notion that R&D activities are concentrated in the *triad market* (Japan, North America and Western Europe). Apart from the *triad market* countries, China made a remarkable leap in terms of R&D spending from 1998 to 2006. However, in terms of R&D expenditure as a percentage of GDP (%), the picture is different. Israel topped the pack with 3.19% of GDP spending in 1998 and 4.53% in 2006. Other countries in the triad market had between 2.5% and 4.0%.

Table 1.3: Nominal R&D activity (millions US$) and variations

Variable	N	Mean	Std. Dev.	Coef. of variation	Dichotomies
R&D 1998	69	9,690.00	36,000.00	3.72	Strong IPRs
R&D 1998	22	3,790.00	13,900.00	3.02	Lower middle income
R&D 1998	81	10,600.00	37,200.00	3.01	GMO-Free
R&D 1998	19	0.02	0.06	2.82	Weak IPRs
R&D 1998	30	0.03	0.07	2.57	High income
R&D 1998	7	4,580.00	13,800.00	2.11	Low income
R&D 1998	7	2,670.00	7,540.00	2.03	GMO-Commercializing
R&D 1998	23	0.05	0.10	1.89	Upper middle income

Variable	N	Mean	Std. Dev.	Coefficient of variation	Dichotomies
R&D 2006	80	0.05	0.10	3.67	GMO-Free
R&D 2006	79	<0.01	<0.01	3.51	Strong IPRs
R&D 2006	22	<0.01	<0.01	3.33	Lower middle income
R&D 2006	30	<0.01	<0.01	2.52	High income
R&D 2006	19	<0.01	<0.01	2.41	GMO-Commercializing
R&D 2006	7	<0.01	<0.01	2.39	Low income
R&D 2006	20	441.00	824.00	1.87	Weak IPRs
R&D 2006	23	0.00	0.00	1.85	Upper middle income

Source: Generated from UNESCO Database

To understand fully R&D variations across countries consider categorizing countries into dichotomies on the basis of whether they are developed or not, have strong intellectual property protection or not, and whether they adopt/commercialize GMOs or not. It is clear from Table 1.3 that variation in R&D activity is higher among GMO-free countries than GMO commercializing countries, and higher among countries with stronger intellectual property protection than those with relatively weak protection. In terms of development level, lower middle income countries had the highest R&D

variation, followed by high-income countries, while the upper-middle income countries had the least variation. Over time a clear pattern appears to have emerged that there is downward trend in the variation of R&D activity of all countries. Also, high-income countries and upper middle-income countries had downward trend in variation of R&D activities. This is consistent with the suggestion that there is some convergence in R&D intensity in these countries (Gittleman & Wolff, 1998). Variation in R&D activity in both GMO-free countries and GMO commercializing countries appears to exhibit upward trend, an indication that divergence in R&D investment is taking place. However, given that there is significant difference in sample size of sets of countries along these dichotomies, no significant regularity can be drawn from variation of R&D investments. Therefore, the statistics have to be cautiously interpreted.

Until we understand the role of non-traditional factors in trade, an important aspect of international trade will remain a mystery, especially when agricultural biotechnology appears to affect flow of products from GMO-sensitive industries across borders. Besides, non-traditional factors may not only confer comparative advantage in international trade but also interact with countries' institutional endowments such as strength of intellectual property protection. Products relating to GMO-based industries/sectors are characterized by intellectual property protection because a country's knowledge is generated by its research investment spillover to other countries. Trade as a transmission mechanism of this spillover makes intellectual property rights (IPRs) an increasingly important facilitator of such new technologies and merits the strengthening of such policy. One reason for this important role is that knowledge leading to research flows has to be protected by some form of IPR such as patents, leading to further advances in output and trade. Again, the realization of such advances will depend on both publicly and privately funded research. IPRs are likely to play an important role not only in securing economic returns for the intellectual investments that make R&D possible but also having implications for trade.

In the spheres of trade, it even becomes more compelling to protect innovations because technology spillover may arise when importing countries are able to adopt the results from exporting countries' research (Alston et al. 1995). It is not surprising, therefore, that IPRs have been a subject of intense discussion at WTO negotiations (Doha Round). As part of patent harmonization among member countries, IPRs are included in TRIPS within the WTO framework. TRIPs ensure minimum levels of protection that individual country has to offer to the IPRs member countries. This requires member countries to grant patents to inventions that become part of international trade.[2] However, TRIPs do not require that countries grant patents for plants and animals but they have to under Article 27.3 (b) provide for the protection of plant varieties by way of patents or *sui generis*[3] systems or by combination of the two. Later on in Chapter 3, I discuss whether or not IPRs have any bearing on the kind of trade and form in which GMO-based products flow across international borders.

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[2] There are exemptions however. For example, although the obligations under TRIPS apply equally to all member countries, developing countries were allowed extension time to put in place transitional laws and implement the applicable changes to their national laws. While the transition period for least developed countries was further extended initially to 2013 and then to 2016, developing countries transition period expired in 2005. In principal, these extensions were put in place for fear that developed countries are massive net-exporters of IPRs –related royalties, TRIPs requirement of patent harmonization among members regardless of level of development would hurt poor countries.

[3] Literally meaning of its own kind/genus or unique in its characteristics.

1.2 Agricultural Biotechnology: Overview, Issues, Data, and Policies

1.2.1 Agricultural Biotechnology and History of GMOs

Genetically modified products are produced using a sophisticated form of genetic engineering in which cells are altered. Although the ultimate aim may be to enhance their potential yields, the modern agricultural biotechnology differs from historical genetic manipulations. To highlight this distinction, it is imperative to put the technology in historical perspective in order to understand the issues that surround it in today's global marketplace. Traditional breeding has been a common phenomenon and genetic modification of plant and animal life has been practiced since organized agriculture began. Gregor Mendel (1822-1884) was a pioneer of experiments and research on inherited characteristics of such crops as peas even though little was known about his work. Pushed by the desire to raise plants and animals with preferred traits, a German plant breeder and biologist, Karl Erich Correns (1864-1933) rediscovered and confirmed Mendel's work.

Today, genetic modification involves a much sophisticated form of genetic engineering where cells are altered either by introducing or eliminating altogether certain genetic sequence using some recombinant DNA techniques. Unlike traditional forms of plant and animal breeding, modern biotechnology allows a much wider set of traits to be introduced or altered in relatively shorter time. These traits include tolerance to herbicides in leading crops, pest resistance, cold and drought tolerance, tolerance to salt in soils, and enhanced nutrition and vitamin content, among others. Herbicide tolerance has been developed to allow farmers to apply herbicide to kill weeds that compete with crops with zero or minimum damage to crops. Examples of this include Roundup-Ready®

soybeans that are genetically altered and can withstand application of herbicide glyphosphate.

Practically, the commercialization of the first biotech crops was in North America, notably in the United States. Following the United States' Supreme Court ruling in 1980 that living organisms were patentable material, transgenic organisms have been developed. Europe joined the fray in 1998 authorizing private commercialization in living organisms. In 1987, practical technique to insert genetic material at the cellular level from one plant species to another began in earnest.

The application of the technology and commercialization of GMOs is becoming more sophisticated and widespread around the world. According to the International Service for the Acquisition of Agri-biotech Applications (ISAAA) the global area planted with transgenic crops increased from 1.7 million hectares in 1996 (the first year of commercialization of biotech crops) to 102 million hectares by the end of 2006. In addition, the ISAAA 2007 report noted that the adoption of GMOs was unprecedented given that it was a 60-fold increase between 1996 and 2006, making it "the fastest and highest unprecedented adopted crop technology and indeed for the whole agricultural sector in recent history." What is interesting to note about this technology is that it is being adopted by both developed and developing countries. For example, for the past decade, the share of global area of biotechnology crops grown by developing countries has not only increased but is also trending towards the industrial countries already commercializing agricultural biotechnology. The crops that account for the greatest share of genetic modification include cotton, maize, soybeans, and rape (canola), among others (Pearlberg, Hopkins, & Ladewski, 2007). Almost half of world's soybean crop was genetically modified by 2001.[4] In terms of countries embracing the technology, there were 63 countries that either commercialized, approved for adoption, field tested or conducted research in a laboratory or greenhouse for 57 biotech crops around the world by 2004 (Runge & Ryan, 2004).

1.2.2 Current issues and policy positions regarding GMO-based industries

Despite the continued adoption of biotech crops in many developed and developing countries, the multilateral trade debate over agricultural biotechnology remained acrimonious, as GMO opponents raised regulatory concerns. The use of modern biotechnology to create GMOs through agricultural production has been received with mixed reactions (Nielson & Anderson, 2001b). In the first decade of commercialization of the technology, the sensitivity of the technology and the manner in which some countries align themselves with position of Western European countries (who oppose GMOs) has been more pronounced than the excitement among those who embrace the technology such as producers in the Americas.

The main issue surrounding GMOs is regulation. Regulatory issues of GMOs have been a subject of intense debate. These regulatory concerns relate, first, to consumer health and safety. Although studies conclude no scientific evidence for food safety problems related to GMOs, often two food safety concerns are associated with genetically modified foods are discussed– potential introduction of allergens and toxins and possible negative effects from the consumption of antibiotic resistant marker genes and viral promoter genes used in the transformation process. In addition, objections have been raised over preservation of biodiversity. Genetic engineering has many and varied

[4] Ibid

effects on biodiversity, but the technology's long-term result will be a decrease in genetic variability of crops and other species. Several hazards have been noted - out crossing or gene flow to related crops or wild species, harm to non-target organisms, and the emergence of resistant pests.

The concern regarding consumer health and safety is reinforced by the fact that genetically modified ingredients tend to become part of the general food supply. It is argued that once approval has been granted for GMO crop, the crop can enter one's diet in a number of ways. For example, soybean - one of the leading crops undergoing gene transformation - is used as an intermediate to produce foods such as bread, baby foods, sausages, meat substitutes, ice cream, chocolate, and other candies (Nottingham, 1998). Nearly 60% of all processed foods in industrialized countries contain ingredients of genetically modified soybeans.[5]

The EU remained opposed to GMOs since their commercialization and reacted by ratcheting up regulatory restrictions. The EU supports "the precautionary principle" in regulating GMOs, based on the premise that the potential danger of GMOs should be minimized or prohibited before they are scientifically proven to inflict catastrophic harm. In the past decade, the EU's opposition to GMOs and uneasiness intensified in the aftermath of food safety crises that plagued the region, such as mad cow disease, the presence of dioxin in Belgian farm animal feed, the discovery of *salmonella* in British eggs, and hoof-and-mouth disease.

By contrast, North America has embraced GMOs. The bulk of agricultural biotechnology originated in the United States and Canada, where most of the corporations spearheading this technology are headquartered. In short, North America's

[5] Ibid

view on GMOs is similar to the scientific consensus – the product and not the process should be regulated. This is the principle of 'substantial equivalence,' where GMOs should receive the same regulatory treatment as other agricultural products.

There is also concern that the introduction of GMOs may lead to increases in the price of Non-GMO but GMO-sensitive substitute goods, thereby decreasing consumer welfare. In some countries, the acceptance of GMOs is also associated with moral, ethical, and religious objections to genetic modification. These concerns notwithstanding, proponents argue that GMOs benefits outweigh any known risks. The benefits include reductions in the volume of pesticide spraying, reductions in greenhouse gas emissions because of decreased fuel use and additional carbon sequestration due to reduced plowing and improved conservation tillage, and enhanced productivity and efficiency leading to increases in farm income. Other indirect benefits also exist arising from increased management flexibility, reduced production risk, and improved crop quality.

According to Drezner (2007), the benefits to the economies of developing world countries from the introduction of GMOs were much greater than the benefits to the developed world. For example, in China production costs of *bacillus thuringiensis* (Bt) cottons were reduced by $750 per hectare per season (Huang, Hu, van Meijl, & van Tongeren, 2004).[6] In Africa, yield increases and savings from reduced chemical use associated with Bt cotton outweighed the higher seed costs. In India, average pest-related losses in cotton cultivation ranged from 50% to 60%, and 15% in the United States. However, as a result of introduction of Bt cotton, yields increased by 60%. But overall,

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[6] *Bacillus thuringiensis* (Bt) is a soil-dwelling bacterium that naturally occurs in insects such as butterflies and produces protein that can be used as a pesticide.

the benefits of GMOs are not fully appreciated among policymakers and academic circles. Despite the benefits, agricultural biotechnology is not a clear-cut issue given that research continues to evaluate it, and that improved productivity (more food for less land) may require more agricultural inputs to safeguard the fragility of marginal lands.

1.2.3 Patterns of trade in GMO-based industries

In this section, I analyze countries exports to and imports from the rest of the world (ROW) of GMO-based industries, as well as their growth rates in the first decade of GMO commercialization (1998 and 2006). The two observations provide a picture of the patterns of trade and analyze growth at two points in time. These two years are chosen for reasons that will become apparent in the data section. The pattern of fourteen GMO-based industries is discussed.

Table 1.4: Country exports to the rest of the world by industry, 1998 (million US$)

	GMO countries			GMO-Free countries[7]			All exporters		
Industry	N	Mean	Std.dev	N	Mean	Std. Dev.	N	Mean	Std. Dev.
1	8	57.20	83.70	88	2.99	10.40	96	7.51	29.00
2	8	879.00	1,550.00	88	13.20	60.20	96	85.40	487.00
3	8	4.48	8.26	88	0.45	1.77	96	0.79	3.03
4	8	13.20	24.20	88	0.64	2.66	96	1.68	7.86
5	8	3.15	5.21	88	0.28	0.83	96	0.52	1.81
6	8	426.00	770.00	88	37.70	201.00	96	70.10	304.00
7	8	26.20	69.20	88	2.99	16.40	96	4.93	25.30
8	8	722.00	1,700.00	88	10.50	56.60	95	70.40	507.00
9	8	265.00	432.00	88	3.48	17.10	96	25.30	139.00
10	8	12.20	20.30	88	0.24	1.38	96	1.23	6.57
11	8	332.00	555.00	88	25.60	102.00	96	51.10	199.00
12	8	11.80	20.00	88	0.56	2.27	96	1.50	6.64
13	8	69.80	139.00	88	1.20	3.78	96	6.92	42.50
14	8	93.20	168.00	88	13.60	68.00	96	20.20	82.50

Key to industries: (1) Maize seed; (2) Other maize, unmilled; (3) Maize (corn) flour; (4) Groats and meal of maize (corn); (5) Bran, sharps and other residues, of maize; (6) Oilcake and other solid residues of oil from soybeans; (7) Oilcake and other solid residues of oil from colza seeds (rape or colza); (8) Soybeans; (9) Rape or colza seeds; (10) Cottonseeds; (11) Soybean oil, fractions; (12) Cottonseed oil and its fractions; (12) Maize (corn) oil, fractions; (14) Rape, colza, mustard oil
Source: Data collected by author from COMTRADE database

Table 1.4 shows the value of country exports to the ROW by industry in 1998. It also shows export values averaged over categories of exporters – GMO-commercializing countries, GMO-free and all exporter countries.[8] Across industries and categories of exporters, fewer GMO-commercializing countries exported GMO-based industries' product than GMO-free countries. On average, GMO-commercializing countries constituted 11% of all exporters of GMO-based industries. This is to be expected given

[7] GMO-free do not permit commercialization of GMOs but can have laboratory trials and may trade (export and import) GMO-based industries. See Table (A.45) in the Appendix for list of GMO-free countries.

[8] Grouping of countries into all and exporting countries presents an interesting export variation analysis that informs the model specifications and trade predictions in the empirical section.

that there were few GMO-commercializing countries in 1998.[9] Second, GMO-commercializing countries on average had higher exports of GMO-based industries to the ROW than GMO-free countries. Exports varied considerably across industries. This disparity is not only indicative of GMO-commercializing countries competitive edge in GMO-sensitive industries but points to increased employment of non-traditional factors, such as agricultural biotechnology and substantial investment in R&D, factors that are likely to accord them comparative advantage.

Among GMO-commercializing countries, maize flour, and animal feed including bran, sharps and other maize residues, as well as vegetable fats and oils, such as cottonseed oil and its fractions, constituted the lowest average exports to the ROW. However, other unmilled maize, oil seed, oleaginous fruit such as soybeans, and animal feed (including oilcake and other solid residues of oil from soybeans) constituted the highest average value of exports to the ROW.

There is also considerable variation within the GMO-free countries in terms of the value of exports to the ROW. Maize flour and groats, meal of maize, and animal feed such as bran, sharps and other maize residues constituted the lowest average exports to the ROW while animal feedstuffs like oilcake and other solid residues of oil from soybeans, soybean fractions, rape, colza, and mustard oil constituted the highest average value of exports to the ROW. Overall, there is a pattern that foodstuffs such as maize flour; animal feed such as bran, sharps and other maize residues; vegetable fats and oils such as cottonseed oil and its fractions, and cotton oil seed are consistently the lowest average exports to the ROW. A pattern also emerged in which foodstuffs such as other

[9] Global area of approved biotech crops (hectares) has been used as indicator of GMO-commercialization in a country.

unmilled maize, oil seed and oleaginous fruit such as soybeans, animal feedstuffs like oilcake and other solid residues of oil from soybeans) are consistently the highest average exports to the ROW across the categories.

Table 1.5: : Country exports to the rest of the world by industry, 2006 (million US$)

	GMO countries			GMO-Free countries				All exporters		
Industry	N	Mean	Std.dev	N	Mean	Std. Dev.		N	Mean	Std. Dev.
1	20	35.10	72.80	76	4.88	16.10	76	96	11.20	37.70
2	20	549.00	1,590.00	76	10.80	41.20	76	96	123.00	746.00
3	20	5.10	8.98	76	0.51	1.60	76	96	1.47	4.65
4	20	7.72	17.80	76	0.93	5.01	76	96	2.35	9.53
5	20	2.98	6.24	76	0.16	0.48	76	96	0.74	3.05
6	20	488.00	1,100.00	76	20.40	101.00	76	96	118.00	534.00
7	20	30.00	69.30	76	2.41	8.84	76	96	8.16	33.90
8	20	777.00	1,940.00	76	7.25	36.60	76	96	168.00	923.00
9	20	130.00	359.00	76	6.49	21.50	76	96	32.20	169.00
10	20	7.27	23.20	76	0.88	6.50	76	96	2.21	12.20
11	20	106.00	279.00	76	11.70	46.30	76	96	31.30	137.00
12	20	1.81	5.05	76	0.20	0.64	76	96	0.53	2.42
13	20	21.10	55.80	76	3.29	14.90	76	96	7.00	29.20
14	20	91.60	193.00	76	15.00	49.50	76	96	31.00	102.00

Key to industries: (1) Maize seed; (2) Other maize, unmilled; (3) Maize (corn) flour; (4) Groats and meal of maize (corn); (5) Bran, sharps and other residues, of maize; (6) Oilcake and other solid residues of oil from soybeans; (7) Oilcake and other solid residues of oil from colza seeds (rape or colza); (8) Soybeans; (9) Rape or colza seeds; (10) Cottonseeds; (11) Soybean oil, fractions; (12) Cottonseed oil and its fractions; (12) Maize (corn) oil, fractions; (14) Rape, colza, mustard oil

Source: Data collected by author from COMTRADE database

Table 1.5 shows 2006 value of country exports to the ROW by industry. Like Table 1.4 it shows export values averaged over categories of exporters – GMO-commercializing countries, GMO-free and all exporter countries. However, in the year 2006, the number of GMO-commercializing countries was higher even though the number of GMO-commercializing countries exporting GMO-based industries is less than GMO-free countries. Exports varied considerably across industries. As in 1998, foodstuffs such as maize flour; animal feed such as bran, sharps and other maize residues;

and vegetable fats and oils such as cottonseed oil and its fractions constituted the lowest average exports to the ROW, while foodstuffs such as other unmilled maize; oil seed and oleaginous fruit such as soybeans; and animal feedstuffs like oilcake and other solid residues of oil from soybeans, constituted the highest average exports to the ROW among GMO-commercializing countries. This pattern was similar to the pattern observed in 1998.

Considerable variations also existed within the GMO-free countries in terms of exports to the ROW. Maize flour, cottonseed oil and its fractions, and animal feed such as bran, sharps and other maize residues constituted the lowest average exports to the ROW, while oilcake and other solid residues of oil from soybeans, soybean oil fractions, rape, colza, and mustard oil comprised the highest average exports to the ROW. While the industries comprising the three lowest average exports to the ROW were the same in the GMO-commercializing and GMO-free countries, those industries comprising the three highest average exports to the ROW were different in the two set of countries.

Having seen the patterns of the various industries, I now look at which countries dominated in export values and whether there was a change in the pattern over the years. Tables 1.6 and 1.7 show leading countries that export GMO-based industries to the ROW for 1998 and 2006, respectively. In the interest of space I show selected countries for sub-aggregates of GMO-based industries.

Table 1.6: Exports to the ROW by country, 1998 (millions US$)

A		B	
Country	Cereals, cereal preparations	Country	Oil seed, oleaginus fruit
USA	4,706	USA	4,990
France	1,453	Brazil	2,176
Argentina	1,349	Canada	1,385
China	532	France	710
Hungary	210	Argentina	656
Germany	106	Paraguay	440
Chile	86	Netherlands	293
Indonesia	65	Australia	249
Italy	62	Germany	159
Ukraine	53	UK	71

C		D	
Country	Animal feedstuffs	Country	Animal, veg. Fat & oils
Brazil	1,753	Argentina	1,512
Argentina	1,741	USA	1,459
USA	1,619	Germany	853
Netherlands	531	Brazil	838
Germany	502	Netherlands	574
India	445	Canada	523
Canada	214	Hong Kong	321
Bolivia	101	Spain	298
Paraguay	64	France	219
Spain	38	China	183

Source: Data collected by author from COMTRADE database

For 1998 export data there is a pattern that large GMO-commercializing countries dominate the exports of most GMO-based products. Panel A of Table 1.6(c) shows exports of cereals, cereal preparations sub-aggregate that comprise maize seed, other unmilled maize, maize (corn) flour and groats and other meal of maize (corn). The United States, Argentina and France dominate these industries exporting US$ 4,706, US$ 1,453 and US$ 1,349 million respectively. Panel B shows oil seeds sub-aggregates that comprise soybeans, rape, colza seeds and cottonseeds. As shown, exports of these industries are dominated by the United States, Brazil and Canada. These countries export to the ROW US$ 4,990, US$ 2,176 and US$ 1,385 million, respectively. In terms of animal feedstuffs, Panel C shows that, Brazil, Argentina and the United States dominate the exports in these industries. Other countries that register significant exports in these industries include the Netherlands, India and Germany. Within these industries, while the United States dominates the exports of bran, sharps and other residues of maize, Brazil had the highest export value of oilcake and other solid residues of oil from soybeans. Finally, Panel D shows animal, vegetable fats and oil sub-aggregates that comprise soybean oil/fractions, cotton oil/fractions, maize oil/fractions, rape and colza/mustard oil. Countries such as Argentina, the United States and Germany dominate the export of these industries to the ROW, with Brazil coming close fourth. These countries export to the ROW US$ 1,512, US$ 1,459, US$ 853¸ and US$ 838 million, respectively.

Now turning to export patterns in 2006, Table 1.7 shows the results by countries. Panel A, as described earlier, shows that in 2006 the same countries led the pack in exporting to the ROW. Even within these countries change happened in different directions. While the United States' exports of cereals and cereal preparations (maize seed, other unmilled maize, maize flour and groats and other meal of maize) nearly doubled, France and Argentina exports marginally declined. Panel B shows that, like in 1998, the United States, Brazil and Canada dominated oil seeds sub-aggregates that comprise soybeans, rape, colza seeds and cottonseeds in 2006. Each of these countries registered significant export increases. Other countries that exported products from these industries included France, Argentina and Paraguay among others.

In the case of animal feedstuffs (Panel C) - like in 1998 - Brazil, Argentina and the United States dominated the exports in these industries in 2006, with Brazil more than doubling its exports. Argentina registered modest export increases while the United States' exports declined marginally from US$ 1,619 million in 1998 to US$ 1,315 million in 2006. Other key players in the export of these industries included the Netherlands, Germany, India and Canada. Finally, for animal, vegetable fats and oil sub-aggregates that comprise soybean oil/fractions, cotton oil/fractions, maize oil/fractions, rape and colza/mustard oil, the leading exporters in 2006 remained the same as in 1998, although not much has changed in terms of export volumes. While Argentina nearly doubled exports, exports of countries like the United States, Brazil, Germany and Canada remained the same or declined marginally.

Table 1.7: Exports to the ROW by country, 2006 (millions US$)

A		B	
Reporter	Cereals, cereal preparations	Reporter	Oil seed, oleaginus fruit
United States	7,407	United States	7,072
France	1,377	Brazil	5,664
Argentina	1,265	Canada	1,964
Brazil	496	Argentina	1,775
China	422	France	574
Hungary	408	Paraguay	445
Germany	211	Netherlands	310
Ukraine	180	Australia	250
Paraguay	166	Ukraine	203
South Africa	152	Germany	151

C		D	
Reporter	Animal feedstuffs	Reporter	Animal, veg. Fat & oils
Argentina	4,358	Brazil	1,260
Brazil	2,421	United States	817
United States	1,315	Canada	783
India	1,131	Netherlands	659
Netherlands	853	Germany	590
Germany	569	Belgium	400
Belgium	276	France	392
Bolivia	211	China	240
Canada	206	United Kingdom	209
Paraguay	136	Poland	152

Source: Data collected by author from COMTRADE database

With regard to the question of which countries dominated exports of GMO-based industries, descriptive statistics in Tables 1.6 and 1.7 reveal patterns did not change between 1998 and 2006. However, there were significant increases in export volumes over the same period for most industries. There were instances where exports of specific products in some of these industries declined, but the change was not as dramatic.

Now consider imports. Table 1.8 shows 1998 value of country imports from the ROW by industry. It also shows import values averaged over categories of exporters – GMO-commercializing countries, GMO-free and all exporter countries.

Table 1.8: Country Imports from the ROW by industry, 1998 (000 US$)

	GMO countries			GMO-Free countries†			All Countries		
Industry	N	Mean	Std.dev	N	Mean	Std. Dev.	N	Mean	Std. Dev.
1	8	39,100	47,600	88	7,862	23,300	96	10,500	27,200
2	8	147,000	229,000	88	73,700	249,000	96	79,900	247,000
3	8	2,344	1,959	88	408	900	96	569	1,146
4	8	6,036	7,659	88	1,142	2,518	96	1,550	3,461
5	8	927	1,234	88	822	2,518	96	831	2,433
6	8	177,000	297,000	88	65,400	126,000	96	74,800	148,000
7	8	29,800	60,600	88	3,617	11,100	96	5,799	20,900
8	8	256,000	358,000	88	75,300	226,000	96	90,400	242,000
9	8	49,000	84,300	88	20,800	94,500	96	23,200	93,600
10	8	9,659	13,300	88	1,135	5,013	96	1,845	6,456
11	8	19,600	24,000	88	40,800	92,400	96	39,100	88,800
12	8	4,702	8,484	88	1,204	4,350	96	1,496	4,856
13	8	14,400	20,400	88	4,136	10,300	96	4,995	11,600
14	8	57,400	92,900	88	16,300	48,000	96	19,800	53,600

Key to industries: (1) Maize seed; (2) Other maize, unmilled; (3) Maize (corn) flour; (4) Groats and meal of maize (corn); (5) Bran, sharps and other residues, of maize; (6) Oilcake and other solid residues of oil from soybeans; (7) Oilcake and other solid residues of oil from colza seeds (rape or colza); (8) Soybeans; (9) Rape or colza seeds; (10) Cottonseeds; (11) Soybean oil, fractions; (12) Cottonseed oil and its fractions; (12) Maize (corn) oil, fractions; (14) Rape, colza, mustard oil

Source: Data collected by author from COMTRADE database

† GMO-free do not permit commercialization of GMOs but can have lab trials and may trade GMO-based industries.

Noticeably, there were far fewer GMO-commercializing countries importing products from GMO-based industries than GMO-free countries relative to exporting as industries. On average, GMO-commercializing countries constituted 11% of all importers of GMO-based industries. In all of the GMO-based industries, GMO-commercializing countries on average had higher imports from the ROW than GMO-free countries in 1998. Given that GMO-commercializing countries also accept trade of GMOs although at varying degrees based on the tolerance levels, higher imports of GMO-based industries from the ROW is expected. Besides, the disparity does not only show that GMO-commercializing countries' general openness to trade, but also intra-industry nature of their trade given that they also have higher average exports of the industries in question.

With regard to industry imports from the ROW among GMO-commercializing countries, foodstuffs such as maize flour; animal feed such as bran, sharps and other maize residues; and vegetable fats and oils such as cottonseed oil and its fractions constituted the lowest average imports from the ROW, while foodstuffs such as unmilled maize, oil seed and oleaginous fruit such as soybeans; and animal feedstuffs (like oilcake and other solid residues of oil from soybeans) constituted the highest average imports from the ROW among GMO-commercializing countries. Data from GMO-free countries show the same trade patterns. Country imports from the ROW by industry for the year 2006 are summarized in Table 1.9.

Table 1.9: Country imports from the ROW by industry, 2006 (thousands US$)

	GMO countries			GMO-Free countries†			All exporters		
Industry	N	Mean	Std.dev	N	Mean	Std. Dev.	N	Mean	Std. Dev.
1	20	33,200	51,400	76	10,000	28,900	96	14,900	35,800
2	20	168,000	284,000	75	72,100	175,000	95	92,400	205,000
3	20	3,449	5,806	76	801	1,968	96	1,352	3,312
4	20	2,934	5,264	76	1,320	2,685	96	1,656	3,416
5	20	1,106	2,379	76	679	1,979	96	768	2,063
6	20	204,000	289,000	76	95,900	158,000	96	119,000	196,000
7	20	21,200	46,200	76	4,947	16,100	96	8,326	26,000
8	20	537,000	1,660,000	76	76,500	206,000	96	172,000	788,000
9	20	72,300	149,000	76	22,500	91,500	96	32,900	107,000
10	20	5,322	15,400	76	1,627	6,467	96	2,397	9,079
11	20	114,000	223,000	76	32,800	52,300	96	49,600	115,000
12	20	1,178	2,279	76	631	1,432	96	745	1,646
13	20	4,509	5,840	76	4,863	14,600	96	4,790	13,300
14	20	92,700	251,000	76	16,700	56,000	96	32,500	126,000

Key to industries: (1) Maize seed; (2) Other maize, unmilled; (3) Maize (corn) flour; (4) Groats and meal of maize (corn); (5) Bran, sharps and other residues, of maize; (6) Oilcake and other solid residues of oil from soybeans; (7) Oilcake and other solid residues of oil from colza seeds (rape or colza); (8) Soybeans; (9) Rape or colza seeds; (10) Cottonseeds; (11) Soybean oil, fractions; (12) Cottonseed oil and its fractions; (12) Maize (corn) oil, fractions; (14) Rape, colza, mustard oil

Source: Data collected by author from COMTRADE database

The summary in Table 1.9 shows that relative to 1998, there were more countries that commercialized GMOs in 2006. Like 1998, GMO-commercializing countries on average had higher imports from the ROW than GMO-free countries in 2006.

In terms of industry imports from the ROW the patterns in 2006 are similar to that of 1998. For example, among GMO-commercializing countries, foodstuffs such as maize flour; animal feed, such as bran, sharps and other maize residues, and vegetable, fats and oils such as cottonseed oil and its fractions again registered the lowest average imports from the ROW, while unmilled maize, oil seed and oleaginous fruit such as soybeans; and animal feed including oilcake and other solid residues of oil from soybeans, constituted the highest average imports from the ROW among GMO-commercializing countries. Data from GMO-free countries show the same trade patterns.

Having looked at country exports to and imports from the ROW, now let's look at country bilateral trade by industries. Table 1.10 shows 1998 value of country exports industry averaged over categories of exporters – GMO-commercializing countries, GMO-free and all exporter countries. Because of the sample difference there was far less bilateral flows of all the GMO-based industries among GMO-commercializing countries than GMO-free countries. Inspection across these categories of countries reveals that, on average, GMO-commercializing countries had higher bilateral trade than GMO-free countries. Among the GMO-commercializing countries more bilateral trade was seen in foodstuffs such as unmilled maize; oil seed and oleaginous fruit such as soybeans; and animal feedstuffs (like oilcake and other solid residues of oil from soybeans). This pattern is not surprising because as we saw earlier, these very industries indeed constituted the highest average trade to or from the ROW. Among the GMO-free countries, high bilateral trade was registered in the same categories.

Table 1.10: Country bilateral trade (thousands US$) by industry, 1998

	GMO countries			GMO-Free countries†			All exporters		
Industry	N	Mean	Std.dev	N	Mean	Std. Dev.	N	Mean	Std. Dev.
1	760	560.30	4,520.32	8360	27.52	753.33	9120	71.92	1,497.54
2	760	7,718.55	64,300.00	8360	124.92	3,715.38	9120	757.72	19,000.00
3	760	41.09	376.70	8360	3.02	130.71	9120	6.19	166.08
4	760	94.85	955.12	8360	5.14	120.67	9120	12.61	299.82
5	760	25.00	240.17	8360	2.15	51.00	9120	4.05	85.00
6	760	3,892.24	20,100.00	8360	359.11	7,285.27	9120	653.54	9,120.90
7	760	274.19	6,313.27	8360	28.73	1,017.84	9120	49.19	2,066.81
8	760	6,724.14	51,600.00	8360	330.49	9,783.08	9120	863.29	17,700.00
9	760	2,539.57	27,200.00	8360	35.16	661.65	9120	243.86	7,905.02
10	760	127.54	1,569.37	8360	1.57	63.43	9120	12.07	458.14
11	760	2,933.04	18,000.00	8360	229.98	5,311.51	9120	455.23	7,306.97
12	760	100.79	1,070.33	8360	3.28	78.16	9120	11.41	318.87
13	760	389.90	3,221.65	8360	7.18	170.69	9120	39.07	949.62
14	760	916.47	11,000.00	8360	127.52	2,643.10	9120	193.27	4,066.25

Key to industries: (1) Maize seed; (2) Other maize, unmilled; (3) Maize (corn) flour; (4) Groats and meal of maize (corn); (5) Bran, sharps and other residues, of maize; (6) Oilcake and other solid residues of oil from soybeans; (7) Oilcake and other solid residues of oil from colza seeds (rape or colza); (8) Soybeans; (9) Rape or colza seeds; (10) Cottonseeds; (11) Soybean oil, fractions; (12) Cottonseed oil and its fractions; (12) Maize (corn) oil, fractions; (14) Rape, colza, mustard oil

Source: Data collected by author from COMTRADE database

† GMO-free do not permit commercialization of GMOs but can have lab trials and trade GMO-based

The fact that all exporters category of countries have higher average bilateral trade than the GMO-free countries reveals underlying issues with the bilateral trade data. There may be missing/zero bilateral trade of GMO-based industries among GMO-free countries compared to GMO-commercializing. Therefore, the use of all exporters' data biases results because zero trade would lower average trade flows hence underestimating actual trade.

For 2006, the analysis more or less remained the same as in 1998 in terms of which industries and categories of countries dominated the bilateral trade (Table 1.11). However, there is increase in the bilateral trade volume as revealed by increase in the mean.

Table 1.11: Country bilateral trade (thousands US$) by industry, 2006

	GMO countries			GMO-Free countries†			All exporters		
Industry	N	Mean	Std.dev	N	Mean	Std. Dev.	N	Mean	Std. Dev.
1	1900	354.59	3,499.04	7220	45.99	969.94	9120	110.28	1,819.37
2	1900	4,866.01	58,500.00	7220	104.32	1,829.68	9120	1,096.34	26,800.00
3	1900	41.87	605.60	7220	3.81	97.56	9120	11.74	290.08
4	1900	52.01	491.65	7220	6.36	111.81	9120	15.87	246.12
5	1900	31.01	411.62	7220	1.61	42.39	9120	7.73	191.96
6	1900	4,554.49	32,700.00	7220	210.17	5,313.21	9120	1,115.24	15,700.00
7	1900	301.86	5,297.53	7220	25.92	557.87	9120	83.41	2,470.45
8	1900	4,924.74	52,400.00	7220	74.66	3,209.79	9120	1,085.09	24,200.00
9	1900	1,268.27	18,400.00	7220	70.13	1,124.29	9120	319.74	8,489.22
10	1900	75.81	1,872.64	7220	7.97	430.10	9120	22.10	936.74
11	1900	2,347.41	25,000.00	7220	114.66	2,253.69	9120	579.82	11,600.00
12	1900	18.14	262.39	7220	1.96	55.76	9120	5.33	129.78
13	1900	168.32	2,282.06	7220	16.80	297.68	9120	48.37	1,076.31
14	1900	944.68	12,600.00	7220	160.97	3,505.42	9120	324.24	6,543.59

Key to industries: (1) Maize seed; (2) Other maize, unmilled; (3) Maize (corn) flour; (4) Groats and meal of maize (corn); (5) Bran, sharps and other residues, of maize; (6) Oilcake and other solid residues of oil from soybeans; (7) Oilcake and other solid residues of oil from colza seeds (rape or colza); (8) Soybeans; (9) Rape or colza seeds; (10) Cottonseeds; (11) Soybean oil, fractions; (12) Cottonseed oil and its fractions; (12) Maize (corn) oil, fractions; (14) Rape, colza, mustard oil

Source: Data collected by author from COMTRADE database
† GMO-free do not permit commercialization of GMOs but can have lab trials and trade GMO-based

Consistent with the pattern in 1998, Table 1.11 shows that among the GMO-commercializing more bilateral trade was again seen in unmilled maize; oil seed and oleaginous fruit such as soybeans; and animal feedstuffs like oilcake and other solid residues of oil from soybeans. But what is interesting is that the increase was so significant in 2006 relative to 1998.The same pattern is true for GMO-free countries.

Now turning attention to growth rates, Table 1.12 shows growth rates in exports by industry between 1998 and 2006. I computed growth as continuous rather than discrete even though I use two time periods (1998 and 2006). The continuous growth rate unlike discrete considers the annual rate as constantly changing. In this instance, the actual increase in trade over the course of any year between 1998 and 2006 depends on all the average growth rates during the year. Thus, the growth rates shown are instantaneous rates of growth of exports.[10] All the GMO-based industries experienced significant positive growth, with variations across industries. Maize oil fractions and animal feedstuffs, such as oilcake and other solid residues of oil from soybeans registered the highest average export growth rates between 1998 and 2006. Even though maize oil fractions registered the highest average export growth rate, the higher standard deviation corresponding to this growth implies that the industry's average exports to the ROW in both periods were spread out over large range of values, an indication that some countries were dominating trade in the industry. This might in part be explained by difference in non-traditional and institutional endowments. But it remains an empirical question at this point.

[10] $T_{2006} = T_{1996}e^{g.t}$ where T is export, e is exponential, g is growth rate and t is time.

Table 1.12: Growth rates of exports to and imports from the ROW (1998-2006) by industry

	Exports			Imports		
Industry	N†	Mean	Std.dev	N†	Mean	Std. Dev.
1	53	0.85	2.52	80	0.64	1.91
2	58	0.80	2.89	82	0.35	1.72
3	53	0.44	2.37	72	0.68	1.92
4	46	0.63	2.15	73	0.12	1.64
5	29	0.50	2.09	57	0.13	3.43
6	41	0.42	3.04	74	0.56	1.85
7	26	1.05	1.58	30	0.93	1.67
8	54	0.68	2.70	78	0.61	1.89
9	39	0.64	2.26	57	1.37	2.14
10	23	0.32	2.45	30	-0.15	2.87
11	53	-0.29	2.61	84	0.36	2.36
12	30	-1.26	2.81	57	-0.44	3.02
13	49	0.38	2.89	81	0.10	1.87
14	43	0.71	2.81	74	-0.34	3.44

Key to industries: (1) Maize seed; (2) Other maize, unmilled; (3) Maize (corn) flour; (4) Groats and meal of maize (corn); (5) Bran, sharps and other residues, of maize; (6) Oilcake and other solid residues of oil from soybeans; (7) Oilcake and other solid residues of oil from colza seeds (rape or colza); (8) Soybeans; (9) Rape or colza seeds; (10) Cottonseeds; (11) Soybean oil, fractions; (12) Cottonseed oil and its fractions; (12) Maize (corn) oil, fractions; (14) Rape, colza, mustard oil

Source: Data collected by author from COMTRADE database

† Only selected countries with positive trade are considered in this Table.

With regard to animal feed such as oilcake and other residues of oil from soybeans, the industry constituted one of the highest average exports to the ROW among GMO-commercializing, GMO-free and all exporter countries in both 1998 and 2006. There are several reasons responsible for such growth. First, the increased applications of new technologies like agricultural biotechnology and increased trade liberalization (among other factors) are cited as responsible for the increased growth of this industry. Some research shows that globally strong growth of animal production and a tendency towards decreasing reliance on grazing and increasing importance of fodder crops and feed concentrates, cause a major increase in the production and demand for feedstuffs (Bouwman & Booij, 1998). Yet other research shows that such increase may be simply due to policy shifts in both exporting and importing countries. For example, rise in soybean exports in Brazil is attributed to opening of new markets and easement of policies towards GMOs (James, 2007). To this end, James writes that in 2006 China eliminated annual authorization of Brazil soybean exports and instead approved importation up to five years. This is likely to stimulate strong export market for oil seeds for feed.

Elsewhere, Sharma (2007) reports that such growth is related to market access according to the Food Agricultural Organization (FAO) of the United Nations. For example, rapid growth in Brazil's agricultural exports such as soybean products was attributed to remarkable and consistent crop yields. In addition, the period in which this remarkable growth took place also coincides with the period marking tremendous growth in agricultural biotechnology across countries. Other industries that registered relatively higher growth between 1998 and 2006 include oilcake and other oils from soybean, maize oil fractions, rape, colza and mustard oil. All the remaining industries registered modest growth between 1998 and 2006.

With regard to GMO-based industries' import growth rates between 1998 and 2006, Table 1.13 shows variation across industries. Animal/vegetable fats and oils such as rape, colza and mustard oil, oil seed (e.g. cottonseed), and foodstuffs such as groats and meal of maize registered the highest average import growth between 1998 and 2006. All other industries registered positive import growth rates.

Table 1.13: Growth rate of bilateral trade (1998 to 2006) by industry, 2006

	GMO countries			GMO-Free countries†			All exporters		
Industry	N	Mean	Std.dev	N	Mean	Std. Dev.	N	Mean	Std. Dev.
1	1900	-0.46	-0.26	7220	0.51	0.25	9120	0.43	0.19
2	1900	-0.46	-0.09	7220	-0.18	-0.71	9120	0.37	0.34
3	1900	0.02	0.47	7220	0.23	-0.29	9120	0.64	0.56
4	1900	-0.60	-0.66	7220	0.21	-0.08	9120	0.23	-0.20
5	1900	0.22	0.54	7220	-0.29	-0.18	9120	0.65	0.81
6	1900	0.16	0.49	7220	-0.54	-0.32	9120	0.53	0.54
7	1900	0.10	-0.18	7220	-0.10	-0.60	9120	0.53	0.18
8	1900	-0.31	0.02	7220	-1.49	-1.11	9120	0.23	0.31
9	1900	-0.69	-0.39	7220	0.69	0.53	9120	0.27	0.07
10	1900	-0.52	0.18	7220	1.62	1.91	9120	0.61	0.72
11	1900	-0.22	0.33	7220	-0.70	-0.86	9120	0.24	0.46
12	1900	-1.72	-1.41	7220	-0.51	-0.34	9120	-0.76	-0.90
13	1900	-0.84	-0.34	7220	0.85	0.56	9120	0.21	0.13
14	1900	0.03	0.14	7220	0.23	0.28	9120	0.52	0.48

Key to industries: (1) Maize seed; (2) Other maize, unmilled; (3) Maize (corn) flour; (4) Groats and meal of maize (corn); (5) Bran, sharps and other residues, of maize; (6) Oilcake and other solid residues of oil from soybeans; (7) Oilcake and other solid residues of oil from colza seeds (rape or colza); (8) Soybeans; (9) Rape or colza seeds; (10) Cottonseeds; (11) Soybean oil, fractions; (12) Cottonseed oil and its fractions; (12) Maize (corn) oil, fractions; (14) Rape, colza, mustard oil

Source: Data collected by author from COMTRADE database
† GMO-free do not permit commercialization of GMOs but can have lab trials and trade GMO-based

With regard to the bilateral trade growth rates we see a different pattern (see Table 1.13). On average, all exporters registered positive bilateral growth rate for all industries except cottonseed oil and its fractions. But in disaggregating these exporters into GMO-commercializing and GMO-free the pattern quickly changes. For example, GMO-free countries register positive bilateral growth rates in foodstuffs of cereals and cereal preparations type such as maize flour and maize seed among other maize products, as well as rape or colza seeds, cottonseeds, and maize (corn) oil, fractions. On the other hand, for GMO-commercializing countries, positive bilateral growth rates are registered in animal feedstuffs such as bran, sharps and other residues of maize, oilcake and other solid residues of oil from soybeans, oilcake and other solid residues of oil from colza. Also, positive growth has been registered in rape, colza, and mustard oil.

1.3 Countries' trade orientation in GMO-based industries

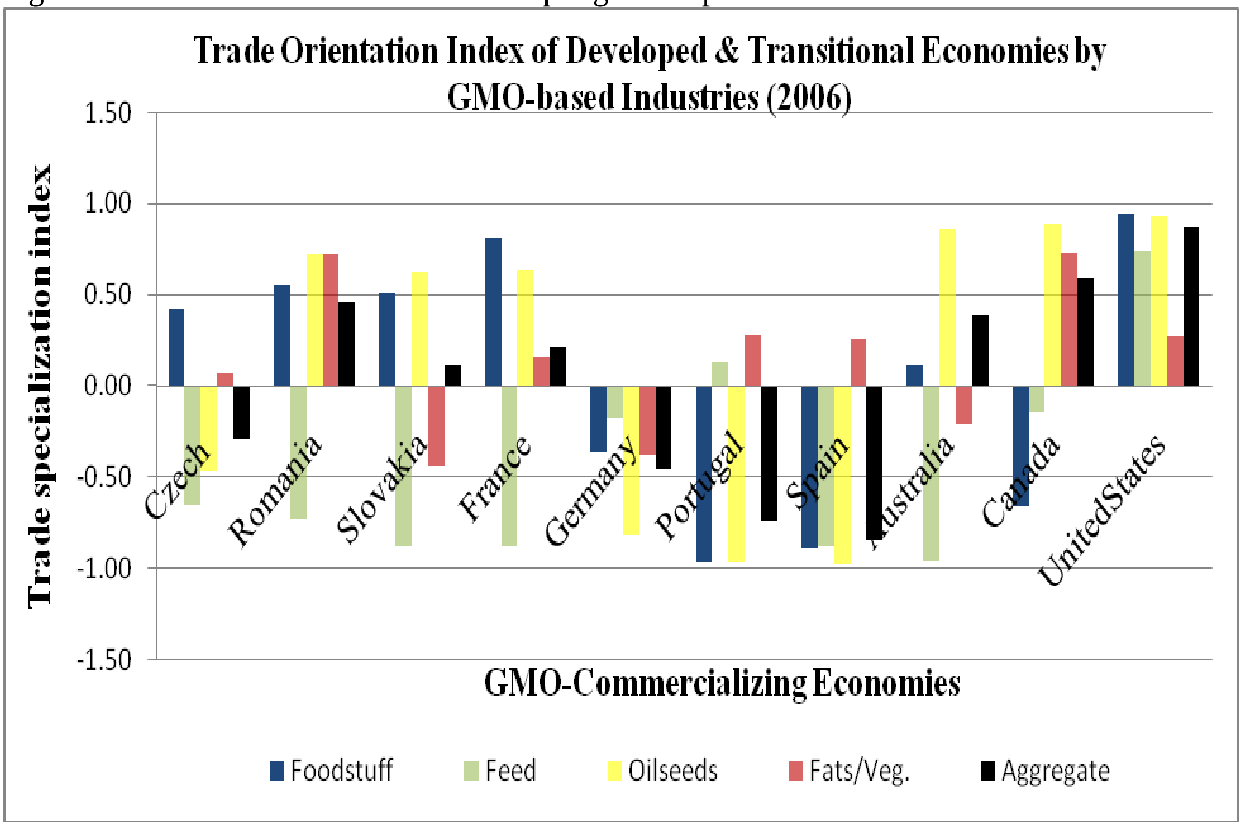
Tables 1.11, 1.12 and 1.13 discussed exports to the ROW, imports from the ROW and their respective growth rates between 1998 and 2006. These discussions were done in isolation. In other words, I looked at exports by industry and country without simultaneously looking at import, and conversely. In what follows I combine discussions of exports and imports using a single index – trade orientation. Given the sensitivity of GMO-based industry, especially in the wake of increased adoption and commercialization of agricultural biotechnology it is important to establish the degree of pattern of trade orientation of each country (i.e. whether a country has export or import orientation). One way to determine such trade orientation is to simply normalize net exports (exports minus imports) by expressing as a trade volume (exports plus imports) in each industry.[11] The ratio ranges from (+1) to (-1), with (+1) indicating complete export orientation and (-1) implying complete import orientation.

Figure 1.1 summarizes trade orientation of some selected GMO-commercializing developed and transitional countries. The figures show the trade orientation index which I constructed from ratio of trade balance (exports minus imports) and trade volume

[11] An advantage of this trade index in the context of the present study is that it may give a glimpse of what to expect when analyzing effect of GMO commercialization on the flow of trade in GMO-based industries to or from ROW.

(exports plus imports). Notice that I aggregate the GMO-based industries discussed earlier based on the classification defined in Section 1.1 (Table 1.1). Four broad subaggregates sectors/industries are shown. The categories include foodstuffs, animal feed, oil seed/fruit, and animal/vegetable fats/oil.

Figure 1.1: Trade orientation of GMO adopting developed and transitional economies



Source: Data collected by author from COMTRADE database

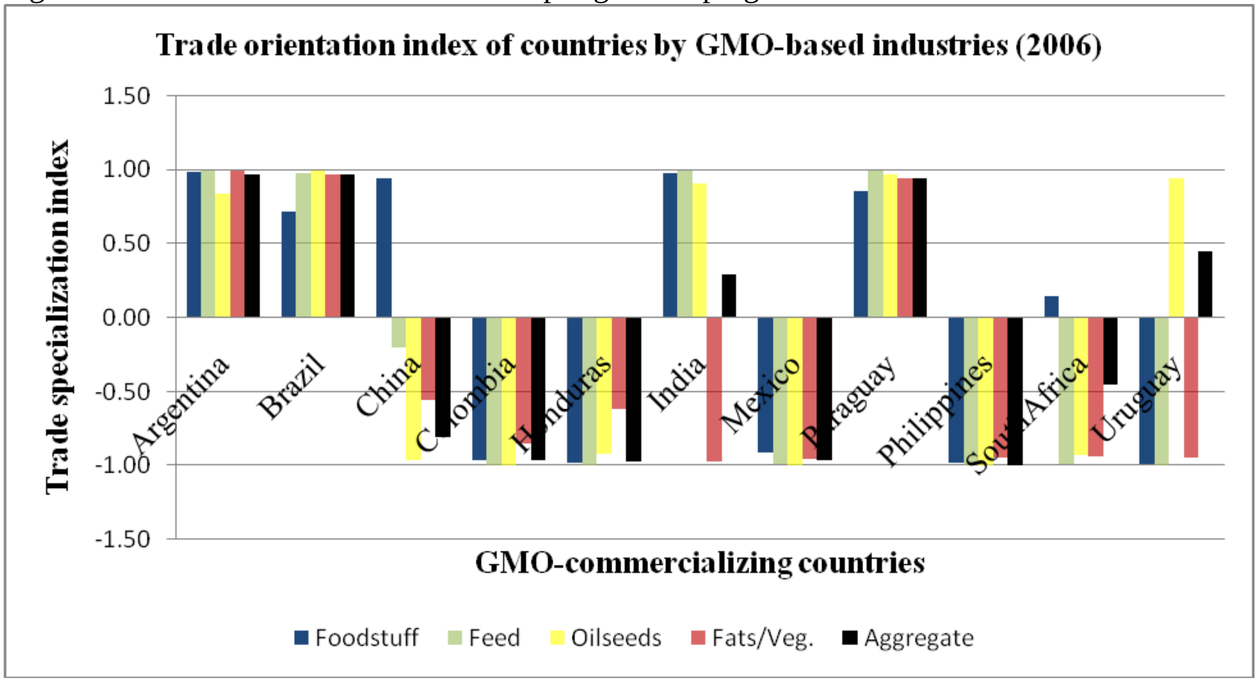
It is worth noting that Figure 1.1 does not reveal a clear picture of regional trade orientation of the subaggregates shown. Neither does it reveal a clear picture of trade orientation of these subaggregates within a country with exception of Germany and the United States. Germany has import orientation in all the categories while the United

States has export orientation in the same categories.[12] All the other countries have either export or import orientation in at least one of the categories. This mixed picture reveals interesting insights on GMO-commercializing countries' characteristics. Canada has import-orientation in food and feedstuffs but near complete export-orientation in oil seed/fruit and animal/vegetable fats/oil, which overall give the country export-orientation at the aggregate level. France has import-orientation in animal feedstuffs but export-orientation in all other sub-aggregates. The contrasting picture of France and Germany in terms of trade orientation of GMO-based industries is unexpected given similarities in the kind of GMOs they allow and regulatory frameworks.

Similarly, figure 1.2 presents trade-orientation of selected GMO-commercializing developing countries. Unlike in the developed panel, there is a clearer picture of within-country trade orientation of the subaggregates, but less definitive regional trade orientation with the exceptions of China, India, South Africa, and Uruguay.

[12] Germany and France were the first few countries in Western Europe to commercialize GMOs in 1998 following the EU executive directive. Germany started commercialization in earnest in the year 2000 when it allowed Bt 176 corn. Later in 2003 Germany introduced MON 180 corn. For example, these countries allowed a particular brand of corn called MON 180 developed by Monsanto. France basically allowed only MON 180. However, recently in 2009 and 2010, there were renewed debates in both governments to ban this brand, despite declaration by the European Food Safety Authority (EFSA) as safe. Given the timing of the present study, this debate is of no consequence, however.

Figure 1.2: Trade orientation of GMO adopting developing economies



Source: Data collected by author from COMTRADE database

India has near perfect export-orientation in foodstuffs, animal feed and oil seed/fruit but a near perfect import-orientation in animal/vegetable fats/oil; South Africa has export-orientation in foodstuffs but import orientation in the rest of the categories; Uruguay has a near perfect export-orientation in oil seed/fruit but import-orientation in the rest of the categories. The rest of the other countries in figure 1.2 have either export or import orientation in all the categories including aggregate trade.

1.4 Patterns of land use for GMOs-based industries

Experts are divided over benefits and costs of GMOs. The discussions around this topic still remain fluid a decade after commercialization of GMOs. For example, there is still a debate whether dramatic advances such as biotechnology adoption remedies problems of regional production and demands for food. There is also the debate whether the technology itself changes land use affecting productivity. Farmers around the globe have continued to plant more biotech crops between 1996 and 2006, the debates notwithstanding. Next, I look at patterns of land use. In particular, I examine biotech land relative to total agricultural land in a country.

Table 1.14: GMO land and agricultural land (000 ha) (1998 & 2006), by country†

Country	**GMO land (1998)**	**Ag. Land (1998)**	**GMO land (2006)**	**Ag. Land (2006)‡**
Argentina	4300	128405	18000	128405
Australia	100	463786	200	463786
Brazil*	0	260110	11500	260110
Canada	2800	67834	6100	67834
China	50	537866	3500	537866
Colombia	0	45543	100	45543
Czech	0	4284	100	4284
France	50	29927	100	29927
Germany	0	17373	100	17373
Honduras	0	3395	100	3395
India	0	180758	3800	180758
Mexico*	100	107400	100	107400
Paraguay	0	22896	2000	22896
Philippines	0	12000	200	12000
Portugal	0	3770	100	3770
Romania	0	14747	100	14747
Slovakia	0	2443	100	2443
S. Africa	100	99678	1400	99678
Spain	50	29958	100	29958
Uruguay	0	14912	400	14912
USA	20500	414588	54600	414588
Totals	28100	2461673	102700	2461673
Average	1338.1	117223	4890.48	117223

Source: From World Bank, FAO and ISAAA.
† Table reflects GMO-commercializing countries and ‡ Agricultural land 2006 is provisional.

Table 1.14 shows GMO land by country for 1998 and 2006. Nine countries grew transgenic crops in 1998 with a number of others testing in laboratories and conducting field trials. The total biotech land was 27.8 million hectares in 1998. The transgenic crops planted commercially in 1998 were led by industrial countries such as the United States, Canada, and Australia. Developing countries of Argentina, China, Mexico, and South Africa were also commercializing transgenic crops at the time. In addition, Spain and France planted limited small introductory areas despite the EU moratorium on GMOs and widespread consumer resistance.

The year 2006 marked the beginning of the second decade of commercialization of biotech crops. The global area of biotech crops continued to increase with the total reaching 102.7 million hectares (James, 2007). There were 21 countries that commercialized transgenic crops, with the United States leading the way. However, many countries had embraced the technology and by 2004, there were 63 countries that either commercialized, approved for adoption, field tested or simply researched in a laboratory/greenhouse in 57 biotech crops around the world (Runge and Ryan, 2004). In addition, the ISAAA report documents a new record in 2006 as the number of farmers adopting or growing biotech crops exceeded 10 million. Overall, the accumulated hectarage from 1996 to 2006 was more than half a billion hectares standing at 577 million hectares (1.4 billion acres). The report noted that the adoption was unprecedented given that it was a 60-fold increase between 1996 and 2006, making the technology one of the fastest and highest unprecedented adopted crop technology in recent history.

Although the United States remained the leading GMO commercializing country in terms of transgenic crops planted, other industrial countries such as Australia and Canada were overtaken by such countries as Argentina and Brazil. Other developing countries planted transgenic crops, including Argentina, Brazil, China, Mexico, South

Africa, Paraguay, Uruguay, Honduras, India, Philippines and Colombia. In addition to Spain and France which planted limited small introductory areas in 1998, other EU members including Germany, Portugal, Romania and Slovakia planted transgenic crops in 2006.

What is interesting to note is that for the past decade, the proportion of the global area of biotech crops grown by developing countries has increased consistently every year and mimics that of the industrial countries and world trend. What is also encouraging, at least for the proponents of agricultural biotechnology, is that the five leading developing countries (India, China, Argentina, Brazil and South Africa) represent all three continents of the South - Asia, Latin America, and Africa where global poverty and malnutrition is prevalent. The regional representation and trend is not only an important indication of how far and wide the technology is being adopted, but also may point to implications for global international trade. In all the adoptions, maize, soybean and cotton have been the industries or sectors where substantial research was directed. However, because cotton is not as widely adopted by countries or widely used as intermediate in the manufacture of other products, the modest amounts of trade in cotton reflected in the trade patterns discussed earlier is not surprising.

Table 1.15 shows GMO land as a share of total agricultural land. In order to make analysis more meaningful, only countries that commercialized transgenic crops are represented. GMO land as a share of total agricultural land is generally small for both 1998 and 2006. Consistently, across the countries there has been an increase in biotech land and hence its share of total agricultural land. This is due to the tremendous adoption of agricultural biotechnology across these countries. Argentina has the highest GMO land per agricultural land (0.14), closely followed by the United States with a share of 0.13. Between 1998 and 2006 it is important to note that some countries like Brazil significantly changed their patterns of land use with the share of GMO land rising sharply. Several reasons could be responsible for this increase. First it is important to note that this coincided with a period when Brazil's agricultural exports reached US$50 billion in 2006 owing to strong domestic and export markets for grain and oil seeds for feed and adoption of innovative technologies like biotechnology (James, 2007).

Table 1.15: GMO land (%) share of total agricultural land (1998 & 2006), by country

Country	**GMO/AgLand 1998**	**GMO/AgLand 2006**
Argentina	3.35	14.02
Australia	0.02	0.04
Brazil*	<0.01	7.67
Canada	4.13	8.99
China	<0.01	0.65
Colombia	<0.01	0.22
Czech	<0.01	2.33
France	0.33	0.33
Germany	<0.01	0.58
Honduras	<0.01	2.95
India	<0.01	2.10
Mexico	0.32	0.32
Paraguay	<0.01	8.74
Philippine	<0.01	1.67
Portugal	<0.01	2.65
Romania	<0.01	0.68
Slovakia	<0.01	4.09
S. Africa	0.10	1.40
Spain	0.33	0.33
Uruguay	<0.01	2.68
USA	4.94	13.17

Source: Compiled from World Bank, FAO, and ISAAA

1.5 Policies that affect trade in GMOs-based industries

1.5.1 National policies

According to Zarrilli (2005), factors influencing countries' positions on and development of GMOs include policy awareness, level of risk involved and willingness to undertake, and capacity to conduct risk assessment in the sector and implement adequate legislation. Zarrilli also points out that perception of benefits from biotechnology, dependence on agricultural exports, reliance on food aid, and investment in the sector may influence countries. However, Hobbs et al. (2007) argue that national policies towards GMOs appear to diverge on three key fronts, all of which have international trade implications. These include regulation of product versus process, risk assessment, and labeling. Under respective national policies and from various sources, I discuss and summarize various policies in Tables 1.16 -1.20 at the end of this chapter. The tables detail and summarize select countries regarding the following: (1) the regulatory system and agencies responsible for oversight of GMOs and related products (2) GMO products approved, and (3) labeling and tolerance requirements.

1.5.2 United States policies

The United States follows the regulatory approach based on *product* rather than *process*. A product-based approach is applied where the focus is on the safety of the *product* rather than the *process* of production. The position of countries such as the United States, which subscribe to a product regulatory approach, is that GMOs are subject to the same health and safety approval as non-GMOs. This is the principle of *'substantial equivalence'* in determining whether a product should be approved for production and commercialization. According to Isaac (2002), *substantial equivalence* is "a 'gateway' regulatory principle used to determine novelty, which is the key aspect in determining the regulatory path that a product must follow …. and that it is products and the application of the technology that should be regulatory focus, not the use of the technology or the process *per se*."

In other words, the concept that maintains a novel food such as GMOs are 'like' non-GMOs provided it exhibits same characteristics and composition as non-GMOs and that regardless of the production process, the risk from two 'like' products are substantially equivalent. For countries that follow this principle such as those of North America, it makes regulation less costly because the same regulatory framework of conventional food is applied. The United States persistently opposes *labeling* because it is a basically another form of technical barriers to trade.

1.5.3 European policies

During the 1990s, the European Union (EU) put in place an approval system for GMOs. Its aim was to ensure protection of health and environment, placing emphasis on the *'process'* by which the GMOs are produced. The EU has promulgated regulations governing GMOs in which manufacturers and importers must prove that release and commercialization of GMOs do not pose risks either to human health or the environment. In addition, the EU has defended the '*precautionary principle,'* which calls for *risk assessment* in situations of uncertainties to regulate GMOs. Here the responsibility is on regulatory agencies to prove that GMOs are harmless before they can be released to the market. This contrasts with the '*scientific principle*' applied by the United States and Canada. It is difficult to prove absolute safety, and the EU has been criticized by exporting countries for disregarding science as the basis for product approval. Further, the EU has a mandatory *labeling regulation* for any product that contains 0.9 (1%) of GMO ingredients. The concern regarding consumer health and safety is reinforced by the fact that genetically modified ingredients tend to become part of the general food supply rather than being discrete food items consumers can either choose or refuse (Nottingham, 1998).

The resistance to GM trade has been, in part, attributed to these concerns. However, increased adoption of agricultural biotechnology, demand for food and nutrition, and pressure to conform to international rules have exerted tremendous pressure on countries that spearheaded the resistance of GMO crops, notably the EU and Japan. Consequently, relinquishing of part of the polar positions held by such countries is being witnessed. In 2003, for example, the Commission of the European Communities recommended to the Member States (non-binding) guidelines for the development of national strategies and best practices to ensure the coexistence of GM crops with conventional and organic farming. This coexistence guideline seeks to establish that no form of agriculture -be it conventional, organic, or GMOs - should be excluded in the EU (Tothova & Oehmke, 2004).

Due to the reality that it is becoming increasingly difficult to source GMO-free soybean, the EU Executive in 2008 proposed to further revise the present tolerance threshold level of 0.9% for genetically modified material in food and animal feed. The current threshold considers tolerance above 0.9% as GMOs and they must be labeled as such. Although this proposal is likely to ease trade tensions, it was necessitated by the fact that the EU livestock producers heavily rely on imported soybean products including beans and meal for their protein and other high - quality feed from genetically modified growing and exporting countries such the United States, Brazil and Argentina. This argument appears to bolster the view that many genetically modified products have successfully passed the deregulation process and are being integrated into domestic and international agricultural markets (Sedjo, 2006) even though disputes remain as to whether and under what conditions countries can refuse to import GMOs.

1.5.4 Policies of other developed countries

Other developed countries including Japan, Canada, and Australia have a variety of policies to regulate GMOs. They often introduce intermediary regulations between the United States and the EU. In terms of *labeling*, Japan, for example, has a mandatory labeling regulation for foodstuff containing GMO ingredients of 5% threshold. Australia and New Zealand are in the process of developing labeling regulations while Canada essentially remains in the league of the United States in opposing mandatory labeling and considers it as a technical barrier to trade.

1.5.5 Policies of developing countries

Many developing countries still lack, or are in the process of developing, comprehensive regulatory systems to deal with the challenges of agricultural biotechnology or GMOs. As a result, the development of regulatory framework for

GMOs is both costly and lengthy. Countries in South America have had mixed reaction to GMOs. As one of the six founders of biotech crops, Argentina, for example, remains the second largest grower of biotech crops (18 million ha) in 2006 (James, 2007), in part because farmers have aggressively adopted GMO technology.

On the other hand, Brazil has had numerous court decisions banning commercial planting of GMO crops in the mid1990s up until 2003. To date, many areas in Brazil are considered GMO-free. These decisions are informed, in part, by perceived advantage in international trade in non-GMO markets such as Europe and Japan. But in the latter years, Brazil has become the world's second-largest exporter of soybeans (second to the United States) and experts in the GMO issue feel that Brazil's future course will have a major impact on the biotech industry worldwide. Following presidential decrees in 2003 and the enactment of biosafety laws, several crops, including soybean, are now commercialized. By 2006, Brazil was the third overall grower of biotech crops (11.5 million ha).

In Asia, India and China have major influence in the industry as they shape up to be the largest future GMO battlefronts. China in particular has the second largest rate of GMO research after the United States. Both countries spend colossal money in research and development in order to be technologically relevant and alleviate poverty in the long run. But bowing to consumers and NGOs, India and China now require mandatory labeling for GMOs. In India, for example, cotton is projected to cover 9.4 million hectares by 2007. Nearly two-thirds (66%) of the hectares are estimated to be covered by Bt cotton. This was up from 40% coverage in 2006. Like the United Sates, Argentina, and Canada, China is a member of the group of six that pioneered biotech crops. Nationally, China is increasingly adopting biotech crops, including Bt cotton.

National policies for regulating GMOs in most African countries are not in place yet. However for few countries, biosafety developments are underway. Countries in North Africa such as Tunisia and Egypt have biosafety guidelines in place. Others in Sub-Sahara Africa such as Kenya, Uganda and Zambia have sketchy legislations, while others like South Africa and Zimbabwe have enacted GMO legislations. South Africa in particular has a fairly superior national biotechnology policy in place because it leads in adopting and commercializing GMOs. Coalition government ministries, including Agriculture, Science & Technology, Environmental Affairs, Health, Labor, Trade & Industry, and Water Affairs & Forestry constitute GMO Executive Council that regulates GMOs. The Council also advises the Minister of Agriculture on all aspects concerning the development, production, use, application and release of GMO products, as well as assess the potential socio-economic impact of the GMO products and communicate and interact with the public on issues regarding GMOs. In addition, there is a Scientific Advisory Committee whose duty is to conduct risk assessment and management as well as appoints the Scientific Review Panel. Finally, the GMO Registrar in the Department of Agriculture is given special duties in biosafety administration by monitoring all GMO facilities and activities as well as conducting routine inspections and overseeing the Appeal Board.

1.6 International GMO-related policies

International GMO-related policies are worth mentioning because in the spheres of trade they help us answer the question of what happens when GMOs or GMO-sensitive foods are traded internationally. Currently, no specific international regulatory systems are in place. However, several international organizations are involved in developing protocols for GMOs. There are various international harmonization efforts to regulate GMOs and related trade. Some of these include the Codex Alimentarius Commission (CAC), the Cartagena Biosafety Protocol and various WTO agreements. Practically, these efforts are far from being harmonized.

1.6.1 Codex Alimentarius

The CAC is a collection of internationally recognized standards, codes of practice, guidelines, and other recommendations relating to food, food production and food safety. The Codex is developed and maintained by CAC, a body that was established in 1963 by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). The aim of CAC is to safeguard the health of consumers and ensure fair practices in the international food trade, and covers all foods (processed, semi-processed and raw) but focuses primarily on marketed food. More than 180 countries are now members of the Codex within the framework of the joint food standards program.

1.6.2 Cartagena protocol on Biosafety

This protocol was established in January 2000 in Montreal. It was basically reinforcement of the ‘precautionary principle’ in handling GMOs. The protocol states that, “Lack of scientific certainty due to insufficient relevant scientific information and knowledge should not in any way hinder or prevent that party from taking a decision, as appropriate, with regard to the import of the living modified organism.” It is formulated in accordance with the precautionary approach contained in Principle 15 of the Rio Declaration on Environment and Development to, “ensure an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on transboundary movements.”

As it stands today, many countries do not have the capacities to handle and use the technology safely. Accordingly, it is safe for such countries to support the protocol and ascribe to the precautionary principle.

1.6.3 WTO Agreements that have direct implication

The Uruguay Round GATT negotiations, which saw the birth of the World Trade Organization (WTO), made important changes to the multilateral trading system to facilitate reduction of non-tariff barriers to trade. Four agreements have important implications for international trade in GMOs. Below I review each of these agreements briefly.

First, there is agreement on Sanitary and Phytosanitary (SPS) measures, which was established to counter countries’ misuse of domestic regulations of protecting living organisms' health and safety to protect domestic producer interests by curtailing imports. The agreement required WTO members go through some mechanism to determine whether national regulations of food were appropriate or merely a disguised form of protectionism. In the same vein, it allowed countries to institute more stringent standards as long as they were based on sufficient scientific evidence. The SPS Agreement was born out of shared common concerns about market-access barriers facing food trade (Isaac, 2002). In addition, these share concerns were in fact a product of a convergence of economic interests, such as food-exporting countries and multinational food processing and distribution companies. Therefore, SPS literally came into being to bring about understanding in the area of food safety and introduce measures and rules for when and how members can deny market access to certain exporters due to risk posed by imports.

Second, in order to foster free trade, the agreement on Technical Barriers to Trade (TBT) attempts to limit the trade impacts of standards and other technical regulations which are likely to become trade barriers. The agreement covers trade barriers arising from 'technical regulations' (mandatory requirements) and 'standards' (voluntary regimes) regarding all products including GMOs. In addition, the agreement covers issues of conformity assessment procedures. Among the issues it covers are labeling requirements relating to *product* characteristics or their related *process* of production.

Third, there is the Trade-Related Intellectual Property Rights (TRIPs) which as mentioned in Section 1.1 ensures minimum levels of protection that individual country has to offer to member countries. One line of argument about strengthening intellectual property rights protection is that it may enhance biotechnology industry investments and profitability. In this regard, TRIPs may be seen as enhancing adoption and production of

GMOs. However, as mentioned, the agreement grants permission for patents on living organisms, including inventions of genetically engineered ones, an issue that rattles many countries and other interested agencies and NGOs. Several revisions have been proposed, but due to lack of consensus the revision is still going on. Some of the revisions proposed include amending TRIPS to require patent applications to disclose the source of origin of the biological resources and associated traditional knowledge, in addition to providing evidence of prior informed consent and benefit sharing.

Finally, there is the General Agreement on Tariffs and Trade (GATT 1994). GATT 1994, as in the original GATT 1948, has the principal of nondiscrimination. Provisions of this principal include the national treatment provision (Article I) that advocates for the same treatment of domestic and foreign products. Another provision is the most-favored-nation principle (Article III) that advocates for non-discrimination between domestic and imported goods. These provisions are believed to have implication on all traded goods including GMOs and their derivatives. This means that a country that imports GMOs is not allowed to apply foreign products measures more onerous than those applied to ‘like domestic products.’ The 2006 ruling by the WTO in favor of three GMO-commercializing countries (the United States, Canada and Argentina) considered a six-year ban on GMOs by the EU as violation of international trade. The provisions of the principal of non-discrimination informed the ruling in this case.

It is not hard to see why harmonization efforts of international policies are far from achieved. The WTO is the overall trade-regulating body. Although the WTO, at least from its actions, refers to the Codex as reference to all food related issues, it does not necessarily consider the Biosafety protocol. It is not surprising, therefore, that GMO-exporting countries, such as the United States, Canada, and Argentina who are incidentally not members of the Biosafety Protocol override the protocol's provisions via the WTO.

1.7 Conclusion

In summary, Chapter 1 laid out the general overview of this dissertation. The chapter also descriptively discussed role of R&D stock and biotech land, as well as institutional and policy factors which characterize trade in GMO-based industries. The chapter also alluded to the application of factor-content and gravity models of international trade and data used in the subsequent chapters. The chapter further explained what constitutes GMOs and the current issues surrounding it, the patterns of trade in GMO-based industries, and patterns of land use for GMO-based industries. Across industries, the trade descriptive statistics show that GMO-commercializing countries on average had higher exports to and imports from the ROW than GMO-free countries in 1998 and 2006.

In terms of land use, the data shows that consistently across the countries, there has been an increase in the share of GMO land in total agricultural land. Countries that have higher biotech land per agricultural land such as the United States, Argentina, and Brazil have higher exports.

Finally, the chapter discussed the policies that affect trade in GMO-based industries. In particular, the chapter compared national and international policies, treaties and arrangements that affect trade in GMO-based industries. The policies adopted by countries are as varied and many as there are countries. The chapter also discussed factors influencing countries' positions on and development of GMOs. These factors included policy awareness, level of risk, willingness to undertake and capacity to conduct risk assessment. Countries in North America and the EU have taken opposite positions on GMOs, with the former block supporting GMOs. Although initially rejecting GMOS, the EU in the later years eased moratorium on GMOs by marginally increasing its tolerance level.

Table 1.16: GMO regulations of the European Union (EU)

Countries	Regulatory system & agency responsible	GM products approved	Labeling requirement
European Union	• **Pre-moratorium** – 14 GMOs for commercial release over two years (1996-1998) were approved. Since 1998 there has been a de facto moratorium on processing and approval of applications for commercial release and human consumption. • **Moratorium** – Officially notified by 5 EU members in 1999. Suspended any new authorizations for GMO production and marketing until labeling and traceability of GMOs and GMO-derived products was introduced. • **Directive 2001/18**. Deliberate release on to the environment of GMOs was approved and enforced 17 Oct. 2002. Harmonized procedures and criteria for case-by-case evaluation of potential risks. • **Regulation 1829/2003 on GM food and feed** – authorization procedure for market placement of GMOs (food and feed) whether there is DNA or protein of GM origin in final product. Simplified approval procedure. The European Food Safety Authority (EFSA) carries out scientific risk assessment. • **Regulation 1830/2003 on traceability and labeling of GMOs**. Enforced in November 7, 2003and applies of April 18 2004. Strengthened mandatory traceability and labeling.	• 18 GMOs and 16 GM food products were approved even though no authorizations were granted for 1998 – April 2004 period. But in May, July and October 2004 three authorizations were granted. • Currently several applications for placing on the market and applications for GM food products are pending.	• Mandatory labeling for all GMOs & GM products, including food and feeds produced from GMOs but no longer containing GM material, unless presence of GM is adventitious and less 0.9%.

Table 1.17: GMO regulations of the United States

United States	• Has variety of existing laws governing GMOs. • 1986 Coordinated framework for regulation of biotechnology. • USA applies existing laws based on equivalence principle to regulate GMOs e.g. Plant Protection Act (PPA), the Federal Food, Drug and Cosmetic Act (FFDCA), FDA, Animal and Plant Health Inspection Service (APHIS), EPA etc. • 1992 Statement of policy for food derived from new plant varieties – encouraged developers to cooperate (non-mandatory) to allow FDA obtain necessary information to conduct risk assessment before commercialization of GMOs. • FDA 2001 –Draft pre-market notice concerning Bioengineered foods. • FDA 2001 – Draft guidance for industry labeling – To establish whether food have been bioengineered or not. • Further de-regulation 2007. APHIS has proposed changes to regulations on introduction of organisms and products altered or produced through genetic engineering.	105 GM crop plants for food and feed have been approved.	Labeling not required. But proposals on voluntary and mandatory labeling are not off limit.

Table 1.18: Domestic GMO regulations of other developed countries

Canada	Canadian Food Inspection Agency (CFIA) - regulates field trials & conducts risk assessment. Health Canada – regulates biotechnology-derived products. Mandatory pre-market notification to the Novel Food Office that regulates full scientific safety assessment of the product, based on substantial equivalence.	By 2003 more than 60 crops were already approved.	Standard for voluntary labeling of foods derived from biotechnology.
Australia & New Zealand	Australia Gene Technology Act 2000 Effected in June 2001 Prohibited GMOs research, production, marketing unless scientific risk assessment was conducted by a regulatory expert. New Zealand Hazardous Substance & New Organisms Act 1996 Moratorium governed approval of GMOs October 29 2003 – Moratorium lifted and allowed 'conditional release' to complement full approvals or rejection in the moratorium. Environmental Risk Management Authority controls GMOs on a case-by-case basis. Australia New Zealand Food Standards Code – regulates marketing of GMOs 1999 Standard 1.5.2(amended in 2000) – mandatory pre-market safety assessment & labeling. Food Standards Australia New Zealand (FSANZ) does the enforcement.	By April 2003 numerous field trials are in progress Various crops have been approved including soybean, canola and cotton among others.	Labeling is mandatory for all GMOs and ingredients (DNA or protein in final product. Derivatives no longer containing GMOs are not required to be labeled.

Table 1.19: Domestic GMO regulations of developing countries – Selected South America Countries

Argentina	• Resolutions No. 656 (1992), Resolution No. 837 (1993), Resolution No. 57 (2003 of Secretariat of Agriculture, Livestock, Fisheries and Food (SAGPyA) provides science-based regulations of GMOs.	• Mainly maize, soybean and cotton	• Pretty much sides with United States
Brazil	• Brazilian Biosafety Law No. 8974, 1995 – Controlled the use of genetic engineering techniques and environmental release of GMOs and to authorize a new regulatory institution, the National Biosafety Commission, comprising of specialists, government officials and private sector representatives, regulates the experimentation, registration, use, transportation, storage, commercialization, liberation and waste removal of GM materials and classifies GMOs according to risk and assesses levels of biosecurity. • **Presidential decrees in 2003**. Approved production and commercialization of GMOs including soybeans. • Draft Law PL 2401/2003 – amended former legislations on GMOs. **National Biosafety Council -** Comprising 12 ministers, advises on the formulation and implementation of governmental policy and draws up guidelines for other federal organizations. • **Biosafety law in March 2005** – Provided first time legal framework for GMO approval and commercialization.	• Soybeans is widely grown	• Mandatory labeling for GMO-derived or GMO-containing and food ingredients for human and animal consumption above 1% threshold since March 2004.

Table 1.20: Domestic GMO regulations of developing countries – Selected Asia and African Countries

India	Rules for GMOs (manufacture, trade, storage) – Ministry of Environment and Forest since 1989. Review Committee on genetic manipulation (RCGM), Department of Biotechnology – monitors biosafety.	Approves varieties including cotton	Mandatory labeling
China	Framework Regulation on GMOs – Ministry of Agriculture 2001- regulates GMOs and conducts biosafety assessment. Also, regulates GMO imports and labeling.	Approves variety including cotton	Mandatory labeling for soybeans, corn seeds, rape seeds, cottonseeds and tomato seeds
South Africa	GMO Act 1997 (implemented in 1999) GMO Executive Council - Coalition of government departments, Agriculture, Science & Technology, Environmental Affairs, Health, Labor, Trade & Industry, Water Affairs & Forestry. Coalition approves imports and releases of GMOs & advises the Minister of Agriculture on all aspects of GMOs as well as assessing the potential Socio-Economic impact of the GM Product and communicating and interacting with the public on GMOs. Scientific Advisory Committee - conducts risk assessment & appoints Scientific Review Panel. GMO Registrar - Department of Agriculture is given special duties in Biosafety Administration by Monitoring all GMO facilities and activities as well as conducting routine inspections and overseeing appeal board.	Several crops, food and feeds have been approved for commercialization including soybeans and cotton.	Mandatory labeling required as long as foods are substantially different and contain allergens from a list of specific products. "Not genetically modified" is labeled only if produced with an identity preservation system.

Source: Various literatures

CHAPTER 2: COMPARATIVE ADVANTAGE OF NON-TRADITIONAL FACTORS

2.0 Introduction

This chapter analyzes the relationship between countries' non-traditional endowments (R&D stock and biotech land) and trade in GMO-sensitive industries. The underlying theoretical framework for this chapter is the factor-content model of Heckscher-Ohlin-Vanek (HOV). In this theory, trade is driven by countries' differences in relative factor endowments. In this framework, countries export goods that make intensive use of their relatively abundant factors.[13]

The factor-content theory is a departure from the traditional trade in the sense that the focus is on the factor-content of the goods that are traded. The theory extends the traditional trade theory by assuming that factors move across borders embodied in the products. The present study follows the HOV literature which assumes that factors are immobile with products embodying the factors.[14] I place emphasis on non-traditional endowments of R&D stock and biotech land because the trade literature has not accorded due attention to the role played by these endowments, especially in industries that are sensitive to GMOs.

I consider the question of whether 'non-traditional' factors (R&D stock and biotech land) confer comparative advantage to countries that export GMO-sensitive

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[13] A central assumption of the traditional theory of trade as discussed is that factors of production are mobile within country and immobile across countries due to international worker and capital movement restrictions.

[14] With non-traditional factors the assumption that factors are mobile across borders implicitly embodied in the products fits the nature of the non-traditional factors.

industries to the rest of the world. I examine this question using two estimation methods – the first is non-parametric and the other parametric. In the next section I present a conceptual framework for assessing the above question using these two estimation methods.

2.1 Conceptual Framework

As mentioned, the framework for analyzing factor-content theory is the Hechscher-Ohlin-Vanek (HOV). The model is an extension of the H-O and predicts that a country's factor-content of trade equals its own factor endowment minus its world-expenditure share of the world factor endowment. The advantage of this framework is that one can implicitly infer the inverse of the matrix of factor intensities by using net trade and factor endowment.

Following Leamer (1984), suppose there are $l = 1, \ldots\ldots, L$ goods produced under perfect competition and constant return to scale (CRS). Suppose further that there are $i = 1, \ldots\ldots, N$ endowments (factors) and technologies of all goods and quality of all factors be the same for all countries. Assume $L \geq N$. Assume all individuals have identical and homothetic preferences and they face the same price vector. Assume free trade among countries so that there is price equalization.

In addition to these regularities, I assume that the N endowments include traditional endowments plus R&D stock and biotech land. I assume that countries have identical CRS production functions.

Let the factor input requirements be expressed by the matrix as:

$A = A_j$ For all countries $j \in J$. *(2.1)*

Columns of this matrix represent input coefficients for a given good or industrywhile rows represent the input coefficients for a given factor across all goods or industries. Let country *j'*s industry output be given by Q_j and primary input vector by V_j. Assuming full employment of resources under the assumption of zero profit, implies that factor demands and supplies equate in each country.

$$V_j = AQ_j \quad (2.2)$$

Assuming matrix *A* is invertible, equation (2.2) can rewritten as:[15,16]

$$Q_j = A^{-1}V_j \quad (2.3)$$

According to the literature, A^{-1} is a vector of Rybczynski coefficients obtained from the factor requirements of equation (2.1). The coefficients, A^{-1} are derived from the factor input requirements and which link endowments, outputs, and trade at constant commodity and factor prices. These coefficients are according to HOV constant across countries.

Let D_j be country *j'*s vector of industry final goods demands (assumed to be identical and homothetic). Let Q_w be world industry output vector and s_j be country *j'*s share of world spending/consumption. With free trade, the assumption is that each country *j* consumes goods in the same proportion given identical preferences. Assuming

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[15] The inverse is possible provided the relative input intensities are unequal.

[16] Analogously, the assumption is that world factor demands and supplies equate. Thus, $Q_w = A^{-1}V_w$. Where Q_w is world industry output vector and V_w is total world factor supplies.

balanced trade takes place and that preferences across countries are homothetic where the value of consumption equals the value of production we will have:

$$PQ_j = P\,D_j = s_j PQ_w \tag{2.4}$$

where s_j is the consumption share which is further given as follows:

$$s_j = PQ_j/PQ_w \tag{2.5}$$

Equation (2.5) implies that country *j* is consuming its income share in world income. Now let the net trade vector be expressed as follows:

$$T_j = X_j - M_j = Q_j - D_j \tag{2.6}$$

where X_j is the export by country *j*, M_j is the import by country *j*. $T_j > 0$ implies country *j* is the net exporter and $T_j < 0$ implies country *j* is the net importer. This means that the net exports of country *j* is the difference between production and final consumption. The net trade also is the difference between exports and imports. Since relative prices of industries or goods are given in world markets and hence are similar across countries, equation (2.4) can be written as:

$$D_j = s_j Q_w \tag{2.7}$$

Equation (2.7) assumes that country *j* consumes commodities in the same proportion. In other words, there is a demand similarity in the sense that individuals consume as if each were maximizing an identical homothetic utility function.[17] Identical homothetic assumption ensures consumers with different incomes but facing the same prices will demand goods in the same proportion. Using consumption share, let country *j'*s imports be defined in terms of the world imports and relative import propensity as.

$$M_j = s_j \Omega M_w \tag{2.8}$$

where M_w is industry imports of the world and Ω is country *j's* import propensity relative to the world in each industry. Here I consider a scenario where Ω is normalized to unity because countries are assumed to have equal import propensities. Adding M_j both sides of equation (2.6) and substituting (2.3), (2.7), and (2.8) we have:

$$X_j = A^{-1}V_j - Q_j / Q_w(Q_w - M_w) \tag{2.9}$$

Then scaling equation (2.9) by Q_j we have the HOV trade equation.

$$X_j / Q_j = \psi + A^{-1}(V_j / Q_j) \tag{2.10}$$

where $\psi = -1 + M_w / Q_w < 0$ since $0 < M_w / Q_w < 1$. Next assuming that country *j's* import propensity relative to the world in each industry is not constant, that is, allowing countries to have varying import propensities we can maintain imports in the HOV equation. Thus, equation (2.9) can be rewritten as:[18]

[17] Equations (2.4), (2.6) and (2.7) together also help define the HOV theorem which is that a country will export services of abundant factors and import the services of scarce factors. A country by definition is abundant in a factor if its share of the world's supply exceeds its consumption.

[18] One can also write factors embodied in net exports as, $AT = A(X_j - M_j) = (V_j - s_j V_w)$. The embodied trade, can according to Leamer (1984), be positive in which case factor services (embodied in goods) are exported or negative implying that factor services (embodied in goods) are imported.

$$X_j - M_j = A^{-1}V_j - s_j Q_w \qquad \textit{(2.8')}$$

Recall that $s_j = Q_j/Q_w$ assuming price equalization. Thus,

$$X_j - M_j = A^{-1}V_j - Q_j \qquad \textit{(2.9')}$$

where $(X_j - M_j)$ is the net export of country j.

Rather than equation (2.10), I use trade orientation index shown in equation (2.10'). There are two advantages of this index. First, it incorporates the assumption of varying import propensity of a country relative to the world in each industry consistent with the HOV equation. In addition, it eliminates concerns relating to the non-trivial number of trade flows (observations) where the three-digit level of the Standard International Trade Classification (SITC) trade flows (exports or imports) were zeros. Thus, I use the approach suggested by Balassa (1986) and scale net trade by volume of trade of country j.[19]

$$\frac{X_j - M_j}{X_j + M_j} = A^{-1}(V_j/(X_j + M_j) - Q_j/(X_j + M_j)) \qquad \textit{(2.10')}$$

In addition to addressing the concerns of the non-trivial trade, the scaling normalizes the net trade so that the bias in trade arising from size of countries is minimized. As revealed by the closed interval [-1, 1], the measure of this index is symmetric around zero. Graphically, the index is shown for selected countries in Section 1.3 of Chapter 1.

[19] SITC is a form of classification used in international trade (exports and imports). Such classification compares across countries within a year or over several years. In 2006 the SITC classification was at revision three. In the same year this classification was revised. Although the current SITC classification is at revision four (Rev. 4), the use this version was not possible because of its provisional status. According to the UN Statistics Division (2008), the commodity groupings of SITC reflect five aspects, namely: (a) the materials used in production, (b) the processing stage, (c) market practices and uses of the products, (d) the importance of the commodities in terms of world trade, and (e) technological changes.

2.1.1 Applying factor-content theory

The fundamental theory grounding for the factor-content trade model is derived in equation (2.1) through equation (2.10) where the trade-revealed factor endowments is treated as a proxy for the factor-content trade. However, to widen the general applicability, I apply and modify this standard model by including non-traditional endowments such as R&D and biotech land.[20]

First I define country endowments in a unique way. Most studies define country endowments to include capital, labor, and land. More recent studies disaggregate these endowments by type. For example, studies have disaggregated labor by type of skill, or land by character. In this dissertation, I disaggregate capital by type to include the traditional component plus a knowledge capital component. I refer to this knowledge capital component as an R&D stock throughout this dissertation. Further, I disaggregate land by type to include agricultural land and biotech land. This disaggregation of endowments allows me to assess the role of *select types of endowments* as a source of comparative advantage or disadvantage in trade. The effects of specific types of endowments are washed out in broader studies that assume all types of capital or labor or land play a similar role in determining trade. Furthermore, the disaggregation of endowments by type can be informative to policy. For example, understanding the effects

[20] The HOV model unlike H-O model conveniently generalizes application of 2 X 2 world and N X N world (Leamer, 1984). Hence application of HOV model to multifactor, multigood scenario does yield clear predictions about which goods are exported and which are imported.

of GMO land or knowledge capital on trade may be more useful than understanding the effects of aggregate capital and aggregate land on trade.

Second, the present study is unique in its focus on GMO-intensive industries. Factor-content theory links country-level endowments to a country trade at the industry level. That is, a country's industry-level trade is predicted by a country's endowments (not factor inputs). In this dissertation, I define the industry as GMO-intensive industries. That is, I focus specifically on those industries where there is a positive probability that there is GMO content in the goods. I described these industries in Chapter 1 and listed in Table 1.1. I describe these industries as *"GMO-intensive"* because there is no way to know from the data the proportion of GMO content of the goods. In Section 2.2.2 and equations (2.14) and (2.15), I discuss how I apply the factor-content theory to an industry where the proportion of GMO content is unknown. I refer to this proportion as the *tolerance level*.

2.2 Alternative methods

In this section I present methods of testing HOV theory via calculation and regression procedures. Typically, calculation method involves non-parametric computation of trade revealed factor endowments (TRFE) and relative true factor endowment (RTFE), as well as the sign correspondence of their relationship. The regression method on the other hand is via parametric estimation where countries' endowments explain variations in the net trade.

2.2.1 Non-parametric or Calculation method

This method entails rank and sign confirmation of the HOV theorem. Establishing this confirmation however requires certain assumptions. First, as pointed out by Helpman & Krugman (1985), I assume unbalanced trade where a country's share of world income is its share of world spending. Consequently, countries export the services of factors of which they have higher share of the world endowment than their share of world expenditure. However, as pointed out by Torstensson (1995) such an assumption is cumbersome to maintain as it requires one to gather information about the absolute endowments of the factors in question. To circumvent this potential problem, a procedure that uses relative endowments and which assumes that trade imbalance affects exports and imports in the same manner is often utilized.[21] Such a procedure assumes that trade imbalance affects exports and imports in the same manner and the effect is proportional and cuts across all industries/sectors.

To understand this adjustment first one needs to look at the definition of the HOV theory. The factor-content theory states that factor services embodied in net exports are equal to the difference between the supply of factor services and the domestic use of the factor services. But the supply of factor services may be defined as factor-content of production and the use of factors as the factor-content of consumption.

Next, defining factor services in (net) exports, $\overline{T}_j$ as the difference between factor-content of production and factor-content of consumption, equation (2.10) can be rewritten as follows:

[21] Ibid

$$\overline{T}_{kj} = V_{kj} - ((Q_j - b_j)/Q_w)V_{kw} \qquad (2.11)$$

where $\overline{T}_{kj}$ is factor-embodied exports or country *j*'s factor services of exports for a particular factor *k*, V_{kj} is country *j*'s supply of factor *k* and V_{kw} is world supply of factor *k*, and b_j is trade balance.

The factor-content of consumption is by assumption equal to the share that a country uses from total available world factor supplies. This share is also assumed to be the same as the share of national income corrected for the trade balance in total world income.

In order to compute country *j*'s net trade in terms of trade revealed factor endowments (TRFE) from relative true factor endowments (RTFE), equation (2.11) can be rearranged. Then diving both sides of equation (2.11) by V_{kw} and Q_j / Q_w and subtracting both sides by b_j / Q_w yields:

$$\frac{\overline{T}_{kj} / V_{kw}}{Q_j / Q_w} - b_j / Q_j = \frac{V_{kj} / V_{kw}}{Q_j / Q_w} - 1 \qquad (2.12)$$

Factor-content trade often refers to measures of *trade revealed factor endowment* which is shown in the left hand side of equation (2.12). The first term of the right hand side of the same equation measures *true factor endowments*. Equation (2.10) is consistent with equation (2.12) except that the latter expresses the factor services embodied in net exports as equal to the difference between factor-content of production and the factor-content of consumption corrected for trade balance.

While considering all the 14 GMO-based industries and to make equation (2.12) adaptable to the endowments of interest described in Section 2.1.1, I define endowment $k \in (R\,\&\,D\,\text{stock}, \text{biotech land})$ to determine trade-revealed and true factor endowments of each country relative to the ROW. Therefore, the results must be interpreted in relative terms. These two definitions of factor abundance must correspond with each other, otherwise if the factor-content of trade are not in line with relative true factor endowment, then the HOV theorem must be rejected (Cörvers & Ted Reininga, 1998).

Next, while adapting that definition, I determine from trade-revealed factor endowment which of the non-traditional factors is more abundant. Focusing on the two non-traditional endowments, this determination involves establishing whether the following inequality holds from the right hand side of equation (2.12).

$$\overline{T}_{R\&D,j} / V_{R\&D,w} > \overline{T}_{Biotechland,j} / V_{Biotechland,w} \qquad (2.13)$$

If the inequality holds, then country *j* is relatively more abundant in R&D endowment than in biotech land. And such a country will export R&D factor services more than biotechnology land and conversely. Results of these calculations and the testing of the theorem are presented in Section 2.6.1.

Hypotheses

1(a) *Country j abundance of R&D stock (relative true R&D endowment being positive) implies that it has net exports of embodied R&D.*

1(b) Country j abundance of biotech land (relative true biotech land endowment being positive) implies that it has net exports of embodied biotechnology land factor.

2.2.2 Theory extension and estimation method

The second procedure for confirming or testing factor-content trade is the regression method. The justification for such estimation has been documented in the factor-content literature. First, Leamer (1984) acknowledges that the testing of the HOV theory is concerned with independent measuring of three concepts and how they conform to the HOV equation. These concepts are the matrix of factor intensities, vector of net exports, and vector of factor endowments. Trade studies have tended to use two of these measures and infer the third (Leamer, 1984) . Leontief (1953) for example used trade and factor intensities to infer factor abundance. However other cross-section regression studies implicitly infer the inverse of the matrix of the factor intensities by using trade and factor endowment (Baldwin, 1971; Leamer, 1974; Leamer, 1984).[22]. Such literature shows that even though T_j (net trade) and factor input requirement (A) discussed in Section 2.1 are observed, the $\overline{T}_{kj}$ (factor services embodied in net exports) can be captured by simply regressing the trade vector on the factor endowments (H. P. Bowen & Sveikauskas, 1992; Leamer & Bowen, 1981). The present study follows the approach of these studies. The rationale is that although GMO trade is not discernible, I can predict the trade vector from factor endowments by regressing the trade vector on the endowments. This way I can infer factor intensities.

In what follows I show a simple way to augment the factor-content equation and widen its applicability to non-traditional endowments. First, I assume that all the GMO-

[22] Yet other studies show that factor-content of trade can be captured using total direct and indirect factor intensities (A. V. Deardorff, 1982; Hamilton & Svensson, 1984)

based industries considered in the present study have some content derived from genetically modified crops. The products from such industries are used as intermediate in the production of other intermediate or final products. Accordingly, I assume that the value of the share of GMO-sensitive/derivative net trade is proportional to the tolerance level of the *adventitious presence* of GMOs in total trade flows from *j* to the ROW. In each industry, I assume the GMO content in production is proportional to the GMO content in the traded product as:

$$\overline{T}_j^{GMO} = \phi \overline{T}_j \qquad (2.14)$$

where $\overline{T}_j^{GMO}$ is the GMO content in the total trade of a particular GMO-based industry from j to the ROW, $\overline{T}_j$ is the value of trade in a particular GMO-based industry from j to the ROW, ϕ is the tolerance level of GMOs in trade flows and $0 < \phi < 1$ by assumption. Equation (2.14) basically implies that the GMO trade is a fraction of export services of the endowments depending on the level of tolerance.

Using equation (2.14) and defining exports as factor services trade, equation (2.9) can be modified as:

$$\overline{T}_j / Q_j = \frac{1}{\phi}\, \psi \text{ [illegible] } + A^{-1}(V_j / Q_j) \qquad (2.15)$$

where variables are as defined earlier. For countries that fully commercialize GMOs such as the United States, ϕ approaches unity and in the absence of labeling GMOs and non-GMOs are considered alike. On the other hand, for countries like those in the EU, ϕ approaches zero, in which case any GMO flows in trade is minimal or negligible. In this set up I assume that the GMO trade depends on the tolerance level set by a country. Given the sensitivity of the industries of interest, the assumption in equations (2.14) and (2.15) is that there is some tolerance level of GMO content.

Adding a disturbance term to equation (2.15) one can write this equation in general statistical form as follows:

$$\overline{T}_j = \tau + \eta V_j + \varepsilon_j \qquad (2.16)$$

where T_j and V_j are the trade value and the factor endowments respectively(scaled by Q_j) $\eta = B/\phi,\ \ B = A^{-1}$, and $\tau = \frac{\psi}{\phi} = \frac{1}{\phi}(1 + M_w / Q_w)$. Notice that the tolerance level (ϕ) appears as a scale term to the estimated coefficients. The lower this tolerance level is, the lower the trade in GMO-intensive industries.

2.3 Statistical specifications

2.3.1 Linear-logarithm specification

To derive the statistical equation I define equation (2.16) for country j and define endowments to include those discussed in Section 2.1.1 as follows:

$$\overline{T}_j = \alpha_0 + v_j \alpha_1 + \varepsilon_j, \qquad j = 1,2,\ldots\ldots\ldots,N$$

$\varepsilon_j = 1,2,\ldots\ldots\ldots\ldots N;$ and $\varepsilon_j \sim iid\ (0,\sigma^2)$ (2.17) where T_j is the value of trade, V_j is a $1 \times K$ vector of endowments, ε_j is a disturbance term and α_1 is a $K \times 1$ vector of parameter estimates.

The endowments include capital (physical capital and knowledge capital), labor, and land (biotech land and agricultural land). I have disaggregated the endowments as discussed in Section 2.1.1. The capital endowment includes a non-traditional component that I refer to as knowledge capital or R&D stock. The land endowment includes a non-traditional component that I refer to as biotech land. The parameter estimates are Rybczynski coefficients scaled by the tolerance level (ϕ).

Specification (2.17) predicts trade to the ROW from factor endowments. I place particular emphasis on the parameter estimates associated with the non-traditional endowments. Parameter estimates of biotech land (GMO) and knowledge capital (R&D) are expected to be positive and significant if they confer comparative advantage in trade, negative if they confer a comparative disadvantage. This interpretation of sign patterns also applies to the parameters of the traditional endowments.

Four econometric issues arise in the estimation of equation (2.17). The first is that the dependent variable (i.e., trade) takes a value of zero for some countries. Since the logarithm of zero is undefined, this variable cannot be measured in logarithm form. To address this issue of *zero observations*, I employ four econometric methodologies. One methodology I utilize is the estimation of a linear-logarithmic model where the trade value (dependent variable) is linear (level) but the endowments are logarithmic. The parameter estimates of this model are the absolute changes in trade values for percent change in the endowments.[23] In addition, I employ a common procedure where small values are added to the dependent variable (I use 1E-10 for my case) to estimate log-log model, in which case the coefficients are elasticities except for dummy variables. I used this procedure as a robustness check. Further, I address the problem of zero observation by converting trade value into trade orientation index which weights trade values by trade volume (see equation 2.18). This technique yields a set of index values that are not necessarily zero. It also has an added advantage in that the weighting (by trade volume) minimizes biases associated with country size. Finally, I employ censored regression such as the Tobit model to minimize inconsistent estimates. I discuss this procedure a little deeper shortly in Section 2.3.2.

The second econometric issue that arises in the estimation of equation (2.17) is *multicollinearity*. Multicollinearity can arise between the right-hand-side variables (i.e., endowments). For example, one might expect the knowledge endowment (R&D stock) to be correlated with the biotech land endowment (GMO land). That is, one could argue that countries with large endowments of GMO land also have large R&D stocks. To address this issue, I generate descriptive statistics on the relationship between endowments. I find that the descriptive statistics do not support this relationship. Instead, the data show that countries with large R&D stocks include countries with both small and large GMO land endowments. And, countries with large GMO land endowments include countries with both small and large R&D stocks.

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[23] Using differential calculus and the fact that a change in the logarithm of a number is a relative change, one can show that the absolute change in trade value is equal to coefficient times the relative change in endowments. Thus, $dT/dV = \alpha_1(1/V)$ or $\alpha_1 = dT/(dV/V) = \Delta T/(\Delta V/V)$. If the relative change in endowments $(\Delta V/V)$ is multiplied by 100, then $\Delta T/(\Delta V/V)$ yields the absolute change in trade value for a percentage change in an endowment. All parameter estimates are therefore divided by 100 (or multiplied by 0.01).

Third, the endowments are viewed as *exogenous* stocks of a country in the theory framework. One may question whether the GMO land and R&D stock are indeed exogenous stocks. I address this issue in two different ways. For the R&D endowment, I construct a stock measure rather than a flow. The R&D stock as opposed to R&D flow contains both contemporaneous R&D and past investments. This means that the influence of past R&D investment on trade in the GMO-sensitive industries is already taken into account, potentially minimizing any correlation between R&D stock and the error term. To assess the exogeneity of the biotech land endowment, I undertake some sensitivity analysis. I tested whether biotech land is endogenous in equation (2.17). Rewrite (2.17) as follows:

$$\overline{T}_j = \delta_0 + \delta_i \log V_j + \delta_5 GMO_j + \varepsilon_j$$

$$E(\varepsilon_j) = 0, \quad \text{Cov}(V_i, \varepsilon_j) = 0, \quad i = 1, 2, \ldots\ldots, 4 \qquad (2.17')$$

Where V_j includes R&D, capital stock, labor, and agricultural land. From the data, the correlation between trade in the GMO-based industries and biotech land is large. One cannot tell whether such correlation reflects the relationship between trade in GMO-based industries and biotech land. It is also true that the correlation between size of a country (GDP) and trade in the GMO-based industries on one hand, and biotech land and GDP on the other is large. In such scenario, one can speculate that both variables are influenced by a country size (GDP), hence inflated correlation. Accordingly, there is also a likelihood that biotech land and disturbance term in equation (2.17) are correlated, violating the basic assumption of independence. For this reason I speculate that biotech land (GMO) is potentially endogenous. The estimation of δ_i in (2.17) is inconsistent because $\text{Cov}(\text{GMO}, \varepsilon_j) \neq 0$.

Wooldridge (2003) shows that the method of instrumental variable (IV) remedies the problem of endogeneity. However, to use of IV with the endogeneous variable, one needs an observable variable (GDP in this case), which is not in (2.17) but satisfies two conditions:

i) $\text{Cov}(\text{GDP}, \varepsilon_j) = 0$.

ii) As pointed out, there must relationship between GDP and the endogenous variable (Biotech land)

However, in the empirical section I show that there is no significant difference between the IV (2SLS) and linear-log model coefficients, indicating that Linear-Log model is indeed consistent and that there is no endogeneity due to biotech land (Tables A.75, A.76, and A.77 in the Appendix).

Next I estimate a version of equation (2.17) where I replace the response variable (trade values) with trade orientation index. As pointed out in equation (2.10'), the rationale is that this specification not only circumvents concerns relating to the non-trivial number of trade flows (observations) but also weights net trade by trade volume thus minimizing biases associated with country size.

$$TOI_j = \gamma_0 + v_j \gamma_i + u_j \ , \qquad j = 1,2,\ldots\ldots\ldots,N$$

$$u_j = 1,2,\ldots\ldots\ldots\ldots N; \ \ and\ u_j \sim iid\ (0,\sigma^2) \qquad (2.18)$$

where TOI is trade orientation index $(X - M)/(X + M)$. V_j is as defined in equation (2.17). The index is a ratio that ranges from (+1) to (-1), with (+1) indicating complete export orientation and (-1) implying complete import orientation.

Finally, the last econometric issue is the question of *mobility*. That is, endowments are viewed as immobile across countries in the theory framework. Specifically, in the factor-content framework, endowments move across countries embodied in the goods that are traded. One may question this assumption of immobility for knowledge capital (R&D stock) in particular. That is, the R&D relevant to a given country's GMO related trade may not wholly take place in that country. Thus, there may be measurement error in the construction of the R&D stock variable at the country level. If present, this measure error would diminish the statistics significance of the R&D stock variable in the estimations. That is, the empirical results would be weakened rather than strengthened by the factor mobility. Indeed, the empirical findings do show a weaker than expected role of the R&D stock in conferring a comparative advantage in trade in GMO intensive goods (See the results sections for findings.)

2.3.2 Tobit estimation

Out of the 96 countries in the sample, 11% have no aggregate trade (exports) to the rest of the world. In the subaggregates and individual GMO-based industries, the percentage of zero trade is even greater. The positive trade values range from less than US$100 to US$ 16.6 billion. The zero trade values stem from countries not exporting some of the industries of interest (zero trade). The previous section outlined procedure for estimating trade to the ROW using OLS. It considered whole trade (positive trade and zero trade) together as a single set. The assumption was that OLS yields consistent parameter estimates. It has been shown that using the entire sample or subsample for which trade is strictly positive are both inconsistent (Wooldridge 2003).

When the range of data is large, or when the percentage of the zero values is sufficiently large, the data lends itself to some methodologies that employ censoring (Wooldridge, 2003). In such a scenario, the response variable becomes a good candidate for the Tobit model. In this regard, it is best to introduce a latent variable to estimate a structural Tobit equation of the form:[24]

$$T_j^* = \beta X + \varepsilon_j \tag{2.19}$$

where T^*_j is the unobserved trade or the latent variable, β is an $M \times 1$ column vector of parameters to be estimated, and ε_j is normally distributed error term with a mean zero and constant variance: $\varepsilon_j \sim i.i.d\ \mathrm{N}(0, \sigma^2)$.

The observed trade values T_j is defined by the following measurement equation.[25]

$$T_j = \begin{cases} = T_j^* & \text{if } T_j^* > 0 \\ = 0 & \text{if } T_j^* \le 0 \end{cases} \tag{2.20}$$

where T_j is the observed trade values of exporting countries and T_j* is a latent unobserved variable.[26]

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[24] But historically Tobin (1958) first developed censored regression where he observed that many household purchases of some goods were zero in some periods. He then proposed latent model shown in (2.19). From household consumption of durable goods, the model has been subsequently employed in many fields of economics and other social sciences, including international trade.

[25] Statistically, OLS on either the whole sample or the uncensored sample often provides biased and inconsistent coefficient estimates. In an uncensored sample the expectation of the error term given *T*, *X* is not zero because the *x*'s will be correlated with the disturbance term, leading to inconsistent estimates.

[26] Equation (2.20) is considered as behavioral arising from the actions of the economic agents in a country. Let $h(\varepsilon_j)$ be density function for ε_j and $h^*(T_j|T_j^*>0)$ be density function for countries with positive trade. Let also $Pr(\beta X+\varepsilon_j>0)$ be probability trade is positive and $Pr(\beta X+\varepsilon_j\leq 0)$ be probability that country j has zero trade. By construction the conditional probability of observing T_j given that positive trade is observed is written as:

$$h^*(T_j \mid T_j^* > 0) = \frac{h(T_j - \beta X)}{\Pr(\beta X + \varepsilon_j > 0)} \tag{2.21}$$

The likelihood function can be expressed as:

$$\Pr(\beta X + \varepsilon_j \leq 0) * \Pr(\beta X + \varepsilon_j > 0) * \frac{h(T_j - \beta X)}{\Pr(\beta X + \varepsilon_j > 0)} \tag{2.22}$$

Thus, the likelihood function collapses to:

$$\prod_{j=1}^{w} \Pr(\beta X + \varepsilon_j \leq 0) * h(T_j - \beta X) \tag{2.23}$$

$$\begin{aligned}
\Pr(\beta X + \varepsilon_j \leq 0) \\
&= \Pr(\varepsilon_j \leq -\beta X) \\
&= 1 - \Pr\left(\frac{\varepsilon_j}{\sigma} \leq \frac{\beta X}{\sigma}\right) \\
&= \Pr\left(\frac{\varepsilon_j}{\sigma} \leq \frac{\beta X}{\sigma}\right) = \Phi\left(\frac{\beta X}{\sigma}\right)
\end{aligned}$$

where σ is the standard error. With assumption of normal distribution of the error term, the general Tobit likelihood function can be expressed as:

$$L(\beta, \sigma \mid T, X) = \prod_{j=1}^{w} (1 - \Phi\left(\frac{\beta X}{\sigma}\right) * \frac{1}{\sigma} \phi\left(\frac{T_j - \beta X}{\sigma}\right) + \varepsilon_j \leq 0) * h(T_j - \beta X)$$

(2.24)

where $\Phi\left(\frac{\beta X}{\sigma}\right) = \int_{-\infty}^{\beta X/\sigma} \phi(t)dt$, $(\phi(t))$ is the density function of for an $N(0, 1)$.

Assuming that likelihood function is concave, L is maximized with respect to β and σ. This means that maximum likelihood parameter estimates can be obtained. Thus, the Log-likelihood function for the Tobit model is:

$$\ln(L(\beta, \sigma \mid T, X)) = \sum \ln\left[1 - \Phi\left(\frac{\beta X}{\sigma}\right)\right] + \left\{\ln\left[\phi\left(\frac{T_j - \beta X}{\sigma}\right)\right] - \ln(\sigma)\right\}$$

(2.25)

The common vector of parameters to be estimated typically represent the marginal effects also commonly referred to as Tobit coefficients is given by:

$$\frac{\partial E(T^* \mid X_j)}{\partial X_j} = \beta.$$

(2.26)

Hypotheses

From equation (2.17), (2.18) and (2.19), I test the following hypotheses.

2(a) R&D stock confers comparative advantage to country j in exporting to the ROW.

(b) Biotech land (GMO land) confers comparative advantage to country j in exporting to the ROW.

Table 2.21: Expected Signs of the variables used in Chapter 2

Variable	Abbreviation	Expected Sign (equation 2.17)	Expected Sign (equation 2.18)	Expected Sign (equation 2.19)
Biotech land	GMO	$\alpha1>0$	$\gamma1>0$	$\beta1>0$
R&D (stock)	R&D	$\alpha2>0$	$\gamma2>0$	$\beta2>0$
Capital (stock)	K	$\alpha3>0$	$\gamma3>0$	$\beta3>0$
Labor	L	$\alpha4>0$	$\gamma4>0$	$\beta4>0$
Agricultural Land	AgLand	$\alpha5>0$	$\gamma5>0$	$\beta5>0$

2.4 Some Reservations

The factor-content model is widely applied in the empirical analyses and considered one of the most influential theories in international economics. However, the core assumptions about this theory and hence its central standing has in the past two decades prompted flurries of empirical scrutiny. I will mention two of these criticisms that relate to the two estimation approaches I employ in this chapter.

One line of criticism suggests that the factor-content of trade is immaterial when factor prices are different because the sum of factors a country claims to have exported will differ from the amounts of factors the ROW claim to have imported, and hence the sum of trade volume will not add up to zero. In other words, factor services in exports might not be equal to the difference between factor-content of production and the share of a factor that a country uses from the total available world factor supplies.

Using data for two-time (1958 and 1972) period and for three high quality factors (professional, unskilled labor and capital) for the United States, Maskus (1985) carried out both sign and rank tests. Under the appropriate computations of the factor-content of trade and production, the results showed a mismatch of the United States' data and the prediction of the HOV model. In particular, the result showed that the sign test was only correct for one factor out of the three under consideration in 1958, but for all three in 1972, an indication that the theorem fared well in the latter years. However, the paper is quick to suggest that if signs were randomly determined then there will be two or fewer sign failures out of six tries 34.4 percent of the time.

Another shortcoming of the HOV theory has to do with the level of aggregation of both trade and factor endowments. For example, Leamer & Bowen (1981) have shown that the net trade of sectors is dependent on country-specific factor endowments rather than on sector-specific factor inputs. However, a number of studies have subsequently shown that explaining of net trade flows from country endowments also poorly fit the HOV (Bowen, Leamer, & Sveikauskas, 1987); (Bowen & Sveikauskas, 1992). This debate continues to generate more questions than answers. The present study is part of this debate. However, it sets to investigate whether country endowments of non-traditional endowments can be employed to explain sector-specific net trade.

2.5 Data and sources

I analyze GMO-based industries factor-content trade using the two procedures discussed in Section 2.2 and 2.3. In what follows I discuss the nature and the source of data used.

The *trade data* consists of products derived from the GMO-sensitive industries and are thought to contain *adventitious presence* of GMO material. I obtained the *trade data* from the United Nations COMTRADE database. Specifically, I used the 3-digit level of the Standard International Trade Classification (SITC). The choice of GMO-based industry is important because GMO-based industries as defined earlier either have significant share of their products used as intermediate from genetically modified crops or contain *adventitious presence* of GMOs. These industries include maize seed, other unmilled maize, maize flour, groats /meal of maize, animal feedstuffs (bran, sharp and other residues of maize), oilcake from soybeans, oilcake from colza seeds (rape or colza), soybeans, rape/colza seeds, cottonseeds, soybean oil fractions, cotton oil fractions, maize oil fractions, and rape/colza mustard oil.

I construct measures of endowments to match the conceptual definitions described in Section 2.1.1. First, I construct the measure of *knowledge endowments* as stock (rather than flow). Using perpetual inventory method (PIM) I computed cumulated R&D stock for 2006 from a flow of past R&D investments as follows:

$$K_t^s = R\&D_t^f + (1-\delta)K_{t-1}^s \qquad (2.22)$$

where K_t^s is cumulated R&D stock (knowledge capital) in year *t*, $R\&D_t^f$ is R&D investment in year *t*, δ is rate of depreciation (assuming obsolescence of knowledge capital) assumed to be 6%. I then calculated the benchmark value of 1996 R&D stock (initial stock) as:

$$K_0^s = \frac{R\&D_0^f}{g+\delta} \tag{2.23}$$

where K_0^s is initial R&D stock in 1996, $R\&D_0^f$ is R&D investment in 1996, and ***g*** is the average geometric growth rate of R&D expenditure over the period from 1996 to 2006. Obviously, there were few unreported R&D data for the years used to construct the R&D stock. As is common, I interpolated the unreported data by using available share of the nearest year.

Second, the data on *biotech land* is from the International Service for the Acquisition of Agri-biotech Applications (ISAAA). ISAAA annually releases data on the global status of commercialized biotech/GMO crops. This contains the stock of global area under GMO crops in million hectares. I use biotech land data to construct a binary measure (GMO). This variable captures whether a country commercializes GMOs or not. In other words, I assign value 1 if a country has a positive stock of biotech land and 0 if it does not. There are two advantages to using this binary measure. First, since only 25% of the countries in the sample have positive biotech land stock, the number of observations in the estimations will drastically reduce, potentially inviting problems relating to validity of the empirical results. Thus it preserves sample size. In addition to preserving the full sample, the coefficient of the biotech land as a binary explanatory variable represents the

GMO-based industries' trade differential between countries with positive biotech land stock and those without. This makes interpretation of results less cumbersome.

The *remaining data* provides measures of labor, capital, agricultural land, as well as country size indicators such as per capita income and population for various estimations. I obtained these data from the World Bank's World Development Indicators (WDI). Labor is measured as total employments; physical capital stock is derived from gross fixed capital formation values, and agricultural land is in hectares. Although some studies use disaggregated data it was not possible for the present study to break down the data further. In any case, the nature of these endowments conceptually maps the theory requirements. In particular, I computed the *capital stock* endowment from gross fixed capital formation investment using a perpetual inventory method. In particular, I measured capital stock in the following manner. I obtained a long-run (10 year) average growth of gross fixed capital formation in each country. This method involves the following assumptions and procedure. I assumed capital to depreciate at the rate of 6%. I generated initial capital stock using this depreciation rate and average growth of gross fixed capital formation from 1996 to 2006.[27]

[27] Notice that I used the same depreciation rate for both R&D stock (knowledge capital) and physical capital stock computation because using a higher depreciation rate for R&D (that is, assuming R&D technological obsolescence is more rapid than physical capital) did not markedly change the results. A limitation of perpetual inventory method in computing the R&D stock and physical capital stocks is the need to specify a depreciation rate. Sensitivity analysis is sometimes carried out to establish the theoretically plausible rate of depreciation. The rate of depreciation I assumed is within this theoretically plausible rate.

2.6 Results

2.6.1 Results of non-parametric approach

This section presents the empirical results using the assumptions and method discussed in Section 2.2. I calculated relative true non-traditional factor endowments (GMO land and R&D stock) and trade-revealed non-traditional factor endowments of countries according to HOV theorem. Specifically, I used equation (2.11) and procedure outlined in Section 2.2.1 to implement this estimation. As discussed earlier, the present study in part examines the predictions of the HOV theorem on countries' net trade. I present results of true relative factor endowment and trade-revealed factor endowments of the non-traditional factors for selected countries in Tables 2.22, 2.23, 2.25, and 2.26. Table 2.22 presents the results of the non-parametric estimation. The results verify whether countries with higher R&D endowments than the world average should have net exports of embodied R&D. Based on countries' relative true R&D endowment, four countries (Colombia, the United States, Germany, and France) should have net export of embodied R&D while the rest of the countries should have net import of embodied R&D. This can be seen from the expected sign of column G. However, the results show that four countries (Colombia, the United States, Germany, and India) indeed have net export of embodied R&D.

Table 2.22: Relative true factor abundance & Trade-revealed factor abundance of R&D

A	B	C	D	E (D-1)	F:	G	H
Reporter	R&D share	GDP share	(B/C)	RTFE	TRFE	Sign of E	Sign of F
Colombia	0.0116	0.0028	4.1429	3.1429	0.2412	+	+
United States	0.3656	0.2753	1.3280	0.3280	0.1673	+	+
Germany	0.0757	0.0606	1.2492	0.2492	0.0896	+	+
France	0.0548	0.0470	1.1660	0.1660	-0.4233	+	-
Slovakia	0.0012	0.0012	1.0000	0.0000	-0.2518	-	-
Romania	0.0024	0.0025	0.9600	-0.0400	-0.2959	-	-
Australia	0.0124	0.0151	0.8212	-0.1788	-0.4042	-	-
Canada	0.0213	0.0266	0.8008	-0.1992	-0.2366	-	-
India	0.0144	0.0192	0.7500	-0.2500	2.8333	-	+
Brazil	0.0142	0.0223	0.6368	-0.3632	-0.6212	-	-
China	0.0343	0.0556	0.6169	-0.3831	-0.7674	-	-
South Africa	0.0027	0.0053	0.5094	-0.4906	-0.5282	-	-
Argentina	0.0021	0.0045	0.4667	-0.5333	-0.1203	-	-
Spain	0.0104	0.0256	0.4063	-0.5938	-0.5688	-	-
Portugal	0.0016	0.0041	0.3902	-0.6098	-0.6441	-	-
Mexico	0.0044	0.0176	0.2500	-0.7500	-0.0294	-	-
Uruguay	0.0001	0.0004	0.2500	-0.7500	-0.7816	-	-
Philippines	0.0006	0.0025	0.2400	-0.7600	-0.7102	-	-

RTFE = Relative True Factor Endowment = $\dfrac{V_{R\&D,j}/V_{R\&D,w}}{GDP_j/GDP_w} - 1$

TRFE = Trade revealed factor endowment= $\dfrac{\bar{T}_{R\&D,j}/V_{R\&D,w}}{GDP_j/GDP_w} - b_j/GDP_j$

The interpretation of the results in Table 2.22 is such that positive trade-revealed factor supply means a country has a revealed abundance of R&D. In other words, the country has revealed comparative advantage in goods that make intensive use of R&D. Another way to verify the hypothesis that countries with higher R&D endowments than the world average should have net exports of embodied R&D is to rank countries according to their net exports of embodied R&D. This ranking should according to the HOV theorem correspond with the ranking of countries according to their relative true factor endowments. Although the ranking of countries according to their relative true

R&D endowments (column G) does not perfectly match with the ranking according to their net exports of embodied R&D (Table 2.23), a mean difference reported in Table 2.24 rejects the hypothesis that there is no relationship between trade revealed and true R&D endowment. In other words, the ranking of countries according to their true R&D endowment positively corresponds with trade-revealed R&D endowment. Therefore, countries that have revealed abundance of R&D stock also have revealed comparative advantage in goods that make intensive use of this factor.

Table 2.23: Rank: Relative true R&D abundance & Trade-revealed R&D abundance

A	B	C	D	E (D-1)	F:	G	H
Reporter	R&D share	GDP share	(B/C)	RTFE	TRFE	Rank of E	Rank of F
Colombia	0.0116	0.0028	4.1429	3.1429	0.2412	1	2
United States	0.3656	0.2753	1.3280	0.3280	0.1673	2	3
Germany	0.0757	0.0606	1.2492	0.2492	0.0896	3	4
France	0.0548	0.0470	1.1660	0.1660	-0.4233	4	11
Slovakia	0.0012	0.0012	1.0000	0.0000	-0.2518	5	8
Romania	0.0024	0.0025	0.9600	-0.0400	-0.2959	6	9
Australia	0.0124	0.0151	0.8212	-0.1788	-0.4042	7	10
Canada	0.0213	0.0266	0.8008	-0.1992	-0.2366	8	7
India	0.0144	0.0192	0.7500	-0.2500	2.8333	9	1
Brazil	0.0142	0.0223	0.6368	-0.3632	-0.6212	10	14
China	0.0343	0.0556	0.6169	-0.3831	-0.7674	11	17
South Africa	0.0027	0.0053	0.5094	-0.4906	-0.5282	12	12
Argentina	0.0021	0.0045	0.4667	-0.5333	-0.1203	13	6
Spain	0.0104	0.0256	0.4063	-0.5938	-0.5688	14	13
Portugal	0.0016	0.0041	0.3902	-0.6098	-0.6441	15	15
Mexico	0.0044	0.0176	0.2500	-0.7500	-0.0294	16	5
Uruguay	0.0001	0.0004	0.2500	-0.7500	-0.7816	17	18
Philippines	0.0006	0.0025	0.2400	-0.7600	-0.7102	18	16

RTFE = Relative True Factor Endowment = $\dfrac{V_{R\&D,j}/V_{R\&D,w}}{GDP_j/GDP_w} - 1$

TRFE = Trade Revealed Factor Endowment= $\dfrac{\overline{T}_{R\&D,j}/V_{R\&D,w}}{GDP_j/GDP_w} - b_j/GDP_j$

Table 2.24:t-Test: Paired relative true R&D endowment & trade revealed R&D endowment

	Sign		Rank	
	RTFE	*TRFE*	*RTFE*	*TRFE*
Mean	0.22	0.22	9.50	9.50
Variance	0.18	0.18	28.50	28.50
Observations	18	18	18	18
Pearson Correlation	0.68		0.62	
Hypothesized Mean Difference	0.00		0.00	
Df	17		17	
t Stat	0.00		0.00	
P(T<=t) one-tail	0.50		0.50	
t Critical one-tail	1.74		1.74	
P(T<=t) two-tail	1.00		1.00	
t Critical two-tail	2.11		2.11	

RTFE = Relative true factor endowment; TRFE = Trade revealed factor endowment

Likewise in Tables 2.25 and 2.26, I show the results of sign and rank order of relative true factor endowment of biotech land and trade revealed factor endowment for selected countries with positive stock of biotech land. Seven of the 18 countries have relative true biotech land abundance. Unlike R&D stock, the ranking of countries according to their relative true biotechnology land endowments (column G) does match with ranking according to their net exports of embodied biotechnology land (Table 2.26).

Table 2.25: Sign of true biotech land abundance &Trade-revealed biotech land abundance

A	B	C	D	E (D-1)	F:	G	H
Reporter	GMO share	GDP share	(B/C)	RTFE	TRFE	Sign of E	Sign of F
Argentina	0.1754	0.0045	38.9864	37.9864	22.0471	+	+
Uruguay	0.0039	0.0004	9.7466	8.7466	4.6830	+	+
Brazil	0.1121	0.0223	5.0263	4.0263	1.9543	+	+
South Africa	0.0136	0.0053	2.5746	1.5746	0.5061	+	+
Canada	0.0595	0.0266	2.2351	1.2351	0.3159	+	+
United States	0.5322	0.2753	1.9330	0.9330	0.1378	+	+
India	0.0370	0.0192	1.9290	0.9290	0.1377	+	+
Slovakia	0.0010	0.0012	0.8122	-0.1878	-0.5087	-	-
Philippines	0.0019	0.0025	0.7797	-0.2203	-0.5333	-	-
China	0.0341	0.0556	0.6135	-0.3865	-0.6388	-	-
Romania	0.0010	0.0025	0.3899	-0.6101	-0.7744	-	-
Colombia	0.0010	0.0028	0.3481	-0.6519	-0.7978	-	-
Portugal	0.0010	0.0041	0.2377	-0.7623	-0.8591	-	-
Australia	0.0019	0.0151	0.1291	-0.8709	-0.9241	-	-
Mexico	0.0010	0.0176	0.0554	-0.9446	-0.9674	-	-
Spain	0.0010	0.0256	0.0381	-0.9619	-0.9776	-	-
France	0.0010	0.0470	0.0207	-0.9793	-0.9878	-	-
Germany	0.0010	0.0606	0.0161	-0.9839	-0.9905	-	-

RTFE = Relative True Factor Endowment = $\frac{V_{GMO,j} / V_{GMO,w}}{GDP_j / GDP_w} - 1$

TRFE = Trade Revealed Factor Endowment = $\frac{\overline{T}_{GMO,j} / V_{GMO,w}}{GDP_j / GDP_w} - b_j / GDP_j$

Table 2.26: Rank of true factor abundance & Trade-revealed factor abundance of Biotech land

A	B	C	D	E (D-1)	F:	G	H
Reporter	GMO share	GDP share	(B/C)	RTFE	TRFE	Rank of E	Rank of F
Argentina	0.1754	0.0045	38.9864	37.9864	22.0471	1	1
Uruguay	0.0039	0.0004	9.7466	8.7466	4.6830	2	2
Brazil	0.1121	0.0223	5.0263	4.0263	1.9543	3	3
S. Africa	0.0136	0.0053	2.5746	1.5746	0.5061	4	4
Canada	0.0595	0.0266	2.2351	1.2351	0.3159	5	5
USA	0.5322	0.2753	1.9330	0.9330	0.1378	6	6
India	0.0370	0.0192	1.9290	0.9290	0.1377	7	7
Slovakia	0.0010	0.0012	0.8122	-0.1878	-0.5087	8	8
Philippines	0.0019	0.0025	0.7797	-0.2203	-0.5333	9	9
China	0.0341	0.0556	0.6135	-0.3865	-0.6388	10	10
Romania	0.0010	0.0025	0.3899	-0.6101	-0.7744	11	11
Colombia	0.0010	0.0028	0.3481	-0.6519	-0.7978	12	12
Portugal	0.0010	0.0041	0.2377	-0.7623	-0.8591	13	13
Australia	0.0019	0.0151	0.1291	-0.8709	-0.9241	14	14
Mexico	0.0010	0.0176	0.0554	-0.9446	-0.9674	15	15
Spain	0.0010	0.0256	0.0381	-0.9619	-0.9776	16	16
France	0.0010	0.0470	0.0207	-0.9793	-0.9878	17	17
Germany	0.0010	0.0606	0.0161	-0.9839	-0.9905	18	18

RTFE = Relative True Factor Endowment = $\dfrac{V_{GMO,j} / V_{GMO,w}}{GDP_j / GDP_w} - 1$

TRFE = Trade Revealed Factor Endowment = $\dfrac{\bar{T}_{GMO,j} / V_{GMO,w}}{GDP_j / GDP_w} - b_j / GDP_j$

As indicated by the perfect match of column G and H in Table 2.26 I reject the hypothesis that there is no relationship between trade-revealed and true biotech land endowment. As both the sign and rank order reveal, relative true biotechnology land endowment positively corresponds with trade-revealed biotechnology land endowment. This means that being endowed with this factor reveals comparative advantage in goods that make intensive use of the factor in question.

I further explore which of the two non-traditional endowments is relatively abundant based on the trade-revealed factor endowment according equation (2.12) in Section 2.2.1. Table 2.27 shows that 11 of the 18 countries with positive stock of biotech land are abundant in R&D while the rest are more abundant in biotech land. For the countries with relative abundance in R&D, the ratio of R&D factor in these countries relative to the world is greater than the ratio of biotech land in these countries relative to the world.

Table 2.27: Relative Abundance of R&D and Biotech land

A	B	C	D
Reporter	TRFE_R&D	TRFE-biotech land	Abundant
Colombia	0.2412	-0.7978	R&D
United States	0.1673	0.1378	R&D
Germany	0.0896	-0.9905	R&D
France	-0.4233	-0.9878	R&D
Slovakia	-0.2518	-0.5087	R&D
Romania	-0.2959	-0.7744	R&D
Australia	-0.4042	-0.9241	R&D
Canada	-0.2366	0.3159	Biotechnology land
India	2.8333	0.1377	R&D
Brazil	-0.6212	1.9543	Biotechnology land
China	-0.7674	-0.6388	Biotechnology land
South Africa	-0.5282	0.5061	Biotechnology land
Argentina	-0.1203	22.0471	Biotechnology land
Spain	-0.5688	-0.9776	R&D
Portugal	-0.6441	-0.8591	R&D
Mexico	-0.0294	-0.9674	R&D
Uruguay	-0.7816	4.6830	Biotechnology land
Philippines	-0.7102	-0.5333	Biotechnology land

Source: Computation from R&D, GMO land and trade data

The important thing to mention from this result is the pattern that emerges. Countries in Western Europe and transitional economies of Eastern Europe are relatively

R&D abundant than biotech land. This result is intuitive given that these countries have lower share of biotech land to total agricultural land as discussed in Chapter 1 (see Table 1.15). The countries in Latin America, Canada, and others that embraced agricultural biotechnology turn out to have relative abundance in biotech land than R&D even though some of these countries have significant R&D stock in absolute terms.

The goal of this nonparametric approach was to identify patterns that emerge across countries. There are, of course, anomalies or outlier countries. For example, one would wonder why Colombia is ranked above developed countries such the United States, Germany, and France in terms of trade revealed relative R&D abundance. These anomalies are not, however, totally unexpected, especially when one looks at the underlying assumptions and equations used to produce the nonparametric results. [28]

2.6.2 Results of Approach 2 – Parametric estimation

This section reports the empirical findings of the second approach for estimating factor-content trade. In particular, the relationship between factor-content trade and the non-traditional factors is given emphasis. Estimation of equations (2.16), (2.17), and (2.18) are reported in Table 2.28 through Table 2.44. Depending on the nature of the data and for reasons expounded in Section 2.2 and 2.3, I consider two models namely OLS and Tobit. I consider different specifications corresponding to equations (2.16), (2.17), and (2.18) in each of these models. And for each of these specifications, I present the

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[28] Recall in equations (2.12) that both the trade revealed factor endowment and relative true factor endowment are weighted by ratio of country industry output to world industry output. For countries like the United States, this ratio is expected to be bigger. Thus, in relative terms, the United States might be ranked below countries like Colombia, which certainly are less endowed in non-traditional factors in absolute terms.

results of aggregate, subaggregates and individual industries. Aggregate and subaggregates are presented in Tables 2.28, 2.33, 2.34, 2.39, 2.40 respectively while the individual industry estimates are presented in Table 2.29, 2.30, 2.31, 2.32, and 2.35 through 2.44.

2.6.3 Linear – Log results of Aggregate and Subaggregate trade estimations

Table 2.28 reports estimates of equation (2.17). The signs of the coefficients reveal whether or not the factors confer comparative advantage or disadvantage in the all industries.[29] As pointed out earlier the estimates are Rybczynski coefficients. Using the linear-logarithmic specification (Table 2.28), the aggregate trade data shows only GMO land has positive and significant coefficients. In light of the working hypothesis this implies that the biotech land confers comparative advantage. The linear-log model reveals that at the aggregate, a country with positive GMO land exports $ 1.2 billion more to the ROW compared to countries with no biotech land. In terms of subaggregates, a country with positive stock of biotech land exports $344 million more of foodstufffs, $384 million more in the animal feed, $ 610 million more in the oil seed, and $120 million more in the fat/vegetable oils than a country no biotech land stock. The results for the subaggregates are somewhat comparable to and consistent with the aggregate results. In particular, all the subaggregates yield comparable results. Foodstuffs, Oil seed, and

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[29] Note: In all estimations I have corrected for heteroskedasticity. Following Stock and Watson (2003) I have assumed heteroskedasticity in the models as a rule of thumb. The standard errors reported are White's heteroscedasticity consistent standard errors. It is only the standard errors rather than the coefficients themselves which are biased (and inconsistent). The approach is like Wald test but alternatively estimates of the standard errors. White suggests replacing $\sigma_i^2 = \sigma^2$ with $\sigma_i^2 = e_i^2$, the appropriate OLS residual. This is implemented in STATA Version 10 using the 'robust' option. Weighted least square here is not feasible since I do not have knowledge of conditional variance on which the weights are based.

fats/oils have expected sign with biotech land consistently conferring comparative advantage.

With regard to trade from country *j* to the ROW, the coefficient on R&D stock is positive as expected. However, it is not significant at aggregate, and in foodstuffs, feedstuffs and oilseeds subaggregates. This implies that R&D stock neither confers comparative advantage nor comparative disadvantage and in the interpretation of the factor-content theory this implies that the endowment does not make a country export or import services embodied R&D trade of GMO-based industries. Considering these parameter estimates as Rybczynski coefficients one can conclude that the R&D endowment is not necessarily linked to country *j*'s output and hence trade to the ROW.[30] These weak results may be explained by the cross-country mobility of R&D as described in Section 2.3.1. However, for fats/vegetable oils subaggregate industries, the R&D endowment has the expected sign and is statistically significant hence conferring comparative. In this subaggregate industry, a 1% increase in the R&D stock leads to a 0.24% increase in predicted trade (Table 2.28). With regard to traditional endowments, the results are mixed. These factors all have the expected sign save for labor. Once the non-traditional endowments are controlled for, the traditional endowments are not statistically significant. This result may be an indication of how countries utilize non-traditional endowments to leverage exports to the ROW.

In terms of overall fit, the endowments jointly explain 24% of the variation in the predicted trade on GMO-sensitive industries. In terms of subaggregates, they explain

[30] Recall that Rybczynski coefficients are typically the coefficients of the factor input requirements which link endowments, outputs, and trade at constant commodity and factor prices. These coefficients are according to HOV constant across countries.

about 16% in foodstuffs manufactures, 18% in animal feed, 22% in oil seed, and 28% in fats/vegetable oils.

Recall that I employed specification (2.17) to perform a robustness check by replacing the dependent variable based on trade orientation index. The estimation results are comparable to the otherwise analogous specification (2.16) both in terms of sign and significance.[31]

2.6.4 Tobit results of Aggregate and Subaggregate trade data

Non-traditional factors

Table 2.39 shows the Tobit model predicting aggregate GMO-based industries from exporter country factor endowments. The Tobit estimation from these factors including GMO land and R&D stock is statistically significant in aggregates as well as subaggregates.

Not all the factors in the model were statistically significant. In aggregate, the results show that a country with positive GMO land exports $ 805 million more to the ROW compared to a country with no biotech land. In addition, a country with positive GMO land stock exports $ 229 million more of food stuff subaggregate to the ROW compared to a country with no biotech land while a country with positive GMO land stock exports $ 259.8 million more of animal feed to the ROW. Similarly, a country with positive GMO land respectively exports $ 359 million and $ 89.03 million more in oil

[31] Of course, since the dependent variable in specification (2.16) is export values and dependent variable in specification (2.17) is a measure of trade orientation index with close interval (-1, 1) symmetric around zero, the magnitudes of the estimates cannot be directly compared.

seed and fat/vegetable oils. Although the R&D variable had the expected sign, the coefficients are not statistically significant, an indication that the stock of R&D does not confer comparative advantage. Like in the aggregate trade, once the non-traditional endowments are controlled for, the traditional factors do not confer comparative advantage. The parameter estimate on agricultural land is the only positive and significant estimate in the case of oil seed subaggregates.

2.6.5 Comparison of OLS and Tobit results

Since 10 out of 96 countries (or about 11% of the sample) have zero export to the ROW, the Tobit and OLS results are similar. As expected the Tobit estimates are somewhat bigger in magnitude even though the corresponding sign and statistical significance largely remain the same (compare Tables 2.28 through Table 2.39).[32] It is worth mentioning that capital stock is consistently significant, an indication that it confers comparative advantage in the case of Tobit estimation. For the non-traditional endowments in particular, they are statistically significant in the aggregate and subaggregate trade (Table 2.39 and Table 2.40). Overall, the R^2 indicates that the two methods fit the data similarly. However, R^2 for the Tobit model are slightly lower than

[32] The magnitudes of the Tobit parameter estimates cannot be directly compared with OLS estimates. To compare the estimates directly, the Tobit estimates in equation (2.26) is multiplied by an adjustment factor evaluated at the estimates and the mean values of the explanatory variables. The adjustment factor is typically less than one. Thus, $\frac{\partial E(T^* \mid X_j, T^* > 0)}{\partial X_j} = \beta_j \left\{ \underbrace{1 - \lambda(\beta X / \sigma)[\beta X / \sigma + \lambda(\beta X / \sigma)]}_{\text{The adjustment factor}} \right\}$.

where $\lambda(c) = \phi(c) / \Phi(c) \rightarrow$ inverse Mills ratio and c is a constant.

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that for the linear-log model. Thus, the Tobit model does not necessarily provide a better fit.

Table 2.28: Linear-log Aggregate and Subaggregates Trade Estimates

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Aggregate	Foodstuff	Animal feed	Oilseed	Fat/veg oil
Constant	-5,722	-1,987	-1,403*	-2,539*	-616.4**
	(3,503)	(1,480)	(760.3)	(1,497)	(238.5)
$GMO06_j$	1,228**	344.1*	384.2*	610.6**	120.1*
	(590.2)	(192.5)	(215.2)	(286.8)	(64.40)
Log ($R\&D_j$)	191.6	63.88	-6.247	62.93	23.56**
	(119.3)	(57.22)	(40.90)	(55.05)	(9.805)
Log($Capital_j$)	50.03	27.65	49.60	44.99	9.598
	(99.99)	(35.03)	(66.79)	(48.87)	(12.68)
Log($Labor_j$)	-27.63	-30.50	-15.87	-51.67	-4.843
	(142.4)	(49.90)	(68.63)	(77.38)	(16.93)
Log($AgLand_j$)	150.0	58.48	37.54	92.18	8.411
	(124.9)	(50.60)	(40.36)	(55.89)	(9.431)
Observations	86	87	87	87	87
R-squared	0.241	0.167	0.182	0.224	0.286

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1;
Dependent variables in million $ and not in logarithms.

Table 2.29: Linear-Log individual industry trade estimates

	Food			
	(1)	(2)	(3)	(4)
VARIABLES	x441	x449	x4711	x4721
GMO_j	20.97	317.2*	3.081**	2.851
	(14.13)	(183.8)	(1.512)	(2.696)
Log ($R\&D_j$)	3.761	58.43	0.511*	1.176*
	(2.414)	(55.28)	(0.303)	(0.622)
Log($Capital_j$)	1.749	25.57	-0.0950	0.431
	(1.942)	(33.01)	(0.318)	(0.627)
Log($Labor_j$)	-3.131	-27.32	0.195	-0.237
	(2.783)	(46.94)	(0.406)	(0.624)
Log($AgLand_j$)	1.802	55.90	0.205	0.569
	(1.428)	(48.94)	(0.235)	(0.523)
Constant	-73.69**	-1,870	-10.65	-32.20*
	(34.26)	(1,436)	(6.748)	(17.83)
Observations	87	87	87	87
R-squared	0.181	0.156	0.241	0.220

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
(x441) Maize seed; (x449) Other maize, unmilled; (x4711) Maize (corn) flour;
(4721) Groats and meal of maize (corn);

Table 2.30: Linear-Log individual industry trade estimates

	Feed		
	(5)	(6)	(7)
VARIABLES	x8124	x8131	x8136
GMO_j	1.752*	360.3*	22.09
	(0.994)	(214.7)	(13.63)
Log ($R\&D_j$)	0.354*	-10.43	3.828**
	(0.185)	(40.93)	(1.698)
Log($Capital_j$)	-0.106	51.01	-1.307
	(0.249)	(66.56)	(2.926)
Log($Labor_j$)	0.408	-19.17	2.886
	(0.486)	(67.60)	(4.203)
Log($AgLand_j$)	0.0273	38.92	-1.411
	(0.159)	(40.32)	(1.895)
Constant	-9.246**	-1,345*	-49.08
	(4.146)	(759.0)	(40.66)
Observations	87	87	87
R-squared	0.268	0.164	0.179

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
(x8124) Bran, sharps and other residues, of maize;
(x8131) Oilcake and other solid residues of oil from soybeans;
(x8136) Oilcake and other solid residues of oil from colza seeds (rape or colza

Table 2.31: Table 31: Linear-Log individual industry trade estimates

	Oil seed		
	(8)	(9)	(10)
VARIABLES	x2222	x22261	x2223
GMO_j	503.6*	104.6	2.460
	(280.2)	(71.39)	(3.024)
Log (R&D $_j$)	43.23	19.07	0.627
	(54.48)	(11.52)	(0.825)
Log(Capital $_j$)	46.18	-2.406	1.217
	(45.45)	(8.167)	(0.792)
Log(Labor $_j$)	-27.22	-22.59	-1.850*
	(72.79)	(16.57)	(1.039)
Log(AgLand $_j$)	79.17	11.43	1.576*
	(54.62)	(8.230)	(0.850)
Constant	-2,476	-30.85	-32.38
	(1,492)	(114.7)	(21.53)
Observations	87	87	87
R-squared	0.179	0.134	0.123

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
(x2222) Soybeans; (x2226) Rape or colza seeds; (x2223) Cottonseeds;
(x4211) Soybean oil, fractions;

Table 2.32: Linear-Log individual industry trade estimates

	Fat/Veg oils			
	(11)	(12)	(13)	(14)
VARIABLES	x4211	x4212	x4216	x4217
GMO_j	61.78	0.766	7.584	49.99
	(48.64)	(0.689)	(6.916)	(38.29)
Log ($R\&D_j$)	5.759	0.0826	2.473	15.25**
	(5.109)	(0.160)	(1.941)	(6.255)
Log($Capital_j$)	5.396	0.183	0.855	3.162
	(6.467)	(0.135)	(1.493)	(6.130)
Log($Labor_j$)	3.536	0.00244	0.360	-8.741
	(9.987)	(0.184)	(2.352)	(9.176)
Log($AgLand_j$)	4.133	0.185	1.602	2.491
	(5.271)	(0.173)	(1.802)	(4.889)
Constant	-324.2**	-8.249*	-83.44*	-200.6**
	(162.9)	(4.258)	(49.63)	(98.94)
Observations	87	87	87	87
R-squared	0.126	0.154	0.147	0.219

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
(x4211) Soybean oil, fractions; (x4212) Cottonseed oil and its fractions;
(x4216) Maize (corn) oil, fractions;
(x4217) Rape, colza, mustard oil

Table 2.33: Explaining Trade Orientation - Aggregate and Subaggregates

VARIABLES	(1) Aggregate	(2) Foodstuff	(3) Animal feed
Constant	0.480	-1.082	-0.920
	(0.785)	(1.169)	(0.926)
$GMO06_j$	0.579***	0.514**	0.372*
	(0.185)	(0.217)	(0.204)
Log ($R\&D_j$)	0.0839*	0.0822	0.00847
	(0.0479)	(0.0637)	(0.0636)
Log($Capital_j$)	-0.0805	-0.0903	-0.0384
	(0.0684)	(0.0913)	(0.0857)
Log($Labor_j$)	-0.0712	0.0576	0.0371
	(0.0731)	(0.0715)	(0.0873)
Log($AgLand_j$)	0.0585	0.0451	0.0376
	(0.0455)	(0.0369)	(0.0466)
Observations	84	84	84
R-squared	0.263	0.266	0.129

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1:
In each specification, dependent variable is trade orientation index *(X-M)/(X+M).*
The measure of this index is symmetric around zero with close interval [-1, 1]
i.e. the index is a ratio that ranges from (+1) to (-1), with (+1) indicating complete export orientation and (-1) implying complete import orientation.

Table 2.34: Explaining Trade Orientation - Subaggregates

	(4)	(5)
VARIABLES	Oilseed	Fat/veg oil
Constant	1.348	-1.656
	(1.004)	(1.023)
$GMO06_j$	0.582**	0.339*
	(0.224)	(0.200)
Log ($R\&D_j$)	0.0409	0.0375
	(0.0570)	(0.0592)
Log($Capital_j$)	-0.0864	0.0592
	(0.0812)	(0.0839)
Log($Labor_j$)	-0.123	-0.106
	(0.101)	(0.0760)
Log($AgLand_j$)	0.125**	0.0470
	(0.0535)	(0.0417)
Observations	84	84
R-squared	0.223	0.152

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1:
In each specification, dependent variable is trade orientation index *(X-M)/(X+M)*.
The measure of this index is symmetric around zero with close interval [-1, 1]
i.e. the index is a ratio that ranges from (+1) to (-1), with (+1) indicating
complete export orientation and (-1) implying complete import orientation.

Table 2.35: Explaining Trade Orientation-Disaggregate industries

	Food			
	(1)	(2)	(3)	(4)
VARIABLES	441	449	4711	4721
GMO_j	0.387**	0.578***	0.183	0.118
	(0.181)	(0.195)	(0.191)	(0.187)
Log (R&D $_j$)	0.0350	0.108*	0.127**	0.053
	(0.055)	(0.059)	(0.058)	(0.056)
Log(Capital $_j$)	-0.016	-0.201**	-0.159**	0.019
	(0.075)	(0.081)	(0.079)	(0.077)
Log(Labor $_j$)	0.080	0.144*	0.176**	0.0340
	(0.079)	(0.085)	(0.083)	(0.081)
Log(AgLand $_j$)	-0.046	0.033	0.003	0.072
	(0.046)	(0.049)	(0.048)	(0.047)
Constant	-1.361	0.245	-1.159	-3.331***
	(1.084)	(1.167)	(1.143)	(1.118)
Observations	87	87	87	87
R-squared	0.122	0.257	0.198	0.220

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(441) Maize seed; (449) Other maize, unmilled; (4711) Maize (corn) flour;
(4721) Groats and meal of maize (corn);

Table 2.36: Explaining Trade Orientation-Disaggregate industries

	Feed		
	(5)	(6)	(7)
VARIABLES	8124	8131	8136
GMO_j	0.233	0.302*	0.449**
	(0.190)	(0.177)	(0.179)
Log ($R\&D_j$)	-0.006	-0.009	0.070
	(0.057)	(0.053)	(0.054)
Log($Capital_j$)	-0.039	-0.048	-0.210***
	(0.079)	(0.073)	(0.074)
Log($Labor_j$)	0.00151	0.0859	0.0164
	(0.083)	(0.077)	(0.078)
Log($AgLand_j$)	0.088*	0.021	0.022
	(0.048)	(0.044)	(0.045)
Constant	-0.460	-0.904	3.614***
	(1.134)	(1.056)	(1.068)
Observations	87	87	87
R-squared	0.121	0.107	0.196

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(8124) Bran, sharps and other residues, of maize;
(8131) Oilcake and other solid residues of oil from soybeans; (8136) Oilcake and other solid residues of oil from colza seeds (rape or colza

Table 2.37: Explaining Trade Orientation-Disaggregate industries

	Oil seed		
	(8)	(9)	(10)
VARIABLES	2222	22261	2223
GMO_j	0.581***	0.348*	-0.0519
	(0.174)	(0.201)	(0.201)
Log ($R\&D_j$)	0.022	-0.004	-0.134**
	(0.053)	(0.061)	(0.061)
Log($Capital_j$)	-0.109	-0.0130	0.0850
	(0.072)	(0.083)	(0.083)
Log($Labor_j$)	0.0467	-0.144*	0.112
	(0.076)	(0.087)	(0.087)
Log($AgLand_j$)	0.038	0.100**	0.024
	(0.044)	(0.050)	(0.051)
Constant	0.580	0.870	-2.262*
	(1.042)	(1.201)	(1.203)
Observations	87	87	87
R-squared	0.199	0.111	0.114

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(2222) Soybeans; (2226) Rape or colza seeds; (2223) Cottonseeds

Table 2.38: Explaining Trade Orientation-Disaggregate industries

	Fat/Veg oils			
	(11)	(12)	(13)	(14)
VARIABLES	4211	4212	4216	4217
GMO_j	0.296	0.273	0.247	0.318
	(0.192)	(0.177)	(0.170)	(0.200)
$Log (R\&D_j)$	-0.0128	-0.131**	0.013	0.043
	(0.058)	(0.053)	(0.051)	(0.060)
$Log(Capital_j)$	0.0828	0.102	0.0388	-0.068
	(0.079)	(0.073)	(0.070)	(0.083)
$Log(Labor_j)$	-0.073	0.101	0.130*	0.102
	(0.087)	(0.077)	(0.074)	(0.087)
$Log(AgLand_j)$	0.038	0.015	-0.023	0.012
	(0.048)	(0.044)	(0.043)	(0.050)
Constant	-1.929*	-2.805***	-3.513***	-1.047
	(1.150)	(1.055)	(1.016)	(1.197)
Observations	87	87	87	87
R-squared	0.084	0.174	0.241	0.113

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(4211) Soybean oil, fractions; (4212) Cottonseed oil and its fractions;
(4216) Maize (corn) oil, fractions;
(4217) Rape, colza, mustard oil

Table 2.39: Tobit(MLE): Aggregate and Subaggregates Trade Estimates

VARIABLE	(1) Aggregate	(2) Foodstuff	(3) Animal feed
Constant	-8,131**	-3,444**	-2,681**
	(3,464)	(1,488)	(1,100)
GMO_j	805.3**	229.0*	259.8**
	(410.4)	(150.4)	(119.9)
Log (R&D $_j$)	89.90	30.03	-3.601
	(99.32)	(37.69)	(27.18)
Log(Capital $_j$)	88.76	40.41	52.56
	(138.0)	(52.25)	(37.99)
Log(Labor $_j$)	-31.66	-16.30	-20.87
	(145.5)	(55.22)	(40.37)
Log(AgLand $_j$)	110.3	33.63	23.33
	(84.86)	(32.52)	(23.42)
Observations	86	87	87
R-squared	0.24	0.16	0.17
Log-likelihood value	-711.98	-598.96	-525.47

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 2.40: Tobit(MLE): Subaggregates Trade Estimates

VARIABLE	(4) Oil seed	(5) Fats/Veg oils
Constant	-4,806***	-1,019***
	(1,772)	(344.7)
GMO_j	389.0**	89.03**
	(191.9)	(41.44)
Log ($R\&D_j$)	19.76	11.62
	(45.23)	(10.27)
Log($Capital_j$)	84.43	18.87
	(63.92)	(14.44)
Log($Labor_j$)	-65.77	-7.643
	(67.19)	(15.42)
Log($AgLand_j$)	74.63*	5.503
	(39.12)	(8.864)
Observations	87	87
R-squared	0.22	0.28
Log-likelihood value	-610.26	-503.97

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 2.41: Tobit(MLE): Individual industries trade estimates

VARIABLES	(1) 0441	(2) 0449	(3) 04711	(4) 04721
GMO_j	29.55**	358.5	3.457**	3.527
	(12.69)	(242.4)	(1.506)	(3.446)
Log ($R\&D_j$)	2.975	58.23	0.505	1.671
	(3.857)	(73.19)	(0.452)	(1.073)
Log($Capital_j$)	6.198	84.71	0.356	2.129
	(5.425)	(102.0)	(0.632)	(1.503)
Log($Labor_j$)	-3.348	-7.109	0.107	-2.036
	(5.710)	(108.4)	(0.676)	(1.573)
Log($AgLand_j$)	1.352	54.03	0.194	1.176
	(3.354)	(63.40)	(0.396)	(0.888)
Constant	-181.0**	-3,890**	-22.05**	-69.00***
	(79.67)	(1,510)	(9.294)	(22.34)
Observations	87	87	87	87
R2	0.17	0.15	0.22	0.19
Ll	-1208	-1500	-1107	-1000

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(441) Maize seed; (449) Other maize, unmilled; (4711) Maize (corn) flour;
(4721) Groats and meal of maize (corn);

Table 2.42: Tobit(MLE): Individual industries trade estimates

VARIABLES	(5) 08124	(6) 08131	(7) 08136
GMO_j	2.396*	489.9**	44.10***
	(1.305)	(198.3)	(15.18)
Log ($R\&D_j$)	0.265	-29.11	13.56**
	(0.381)	(60.63)	(5.882)
Log($Capital_j$)	0.658	170.3*	-0.356
	(0.550)	(87.09)	(7.408)
Log($Labor_j$)	0.292	-119.1	-5.920
	(0.579)	(93.01)	(7.175)
Log($AgLand_j$)	0.0142	64.98	-2.172
	(0.334)	(51.27)	(3.968)
Constant	-28.17***	-3,202**	-116.0
	(8.199)	(1,231)	(107.3)
Observations	87	87	87
R2	0.23	0.14	0.14
Ll	-732	-1251	-837

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(8124) Bran, sharps and other residues, of maize;

(8131) Oilcake and other solid residues of oil from soybeans;

(8136) Oilcake and other solid residues of oil from colza seeds (rape or colza

Table 2.43: Tobit(MLE): Individual industries trade estimates

VARIABLES	(8) 2222	(9) 22261	(10) 2223
GMO_j	624.4**	136.6*	5.231
	(297.4)	(72.12)	(7.167)
Log ($R\&D_j$)	37.59	32.69	-2.339
	(90.34)	(22.53)	(2.043)
Log($Capital_j$)	162.5	31.62	6.730**
	(128.0)	(32.02)	(2.988)
Log($Labor_j$)	-83.91	-78.73**	-1.278
	(135.2)	(34.13)	(3.256)
Log($AgLand_j$)	111.0	41.20*	3.514
	(78.95)	(21.92)	(2.263)
Constant	-5,246***	-788.3*	-180.8***
	(1,889)	(467.2)	(49.35)
Observations	87	87	87
R2	0.17	0.11	0.1
Ll	-1470	-988	-620

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(2222) Soybeans; (2226) Rape or colza seeds; (2223) Cottonseeds;

Table 2.44: Tobit(MLE): Individual industries trade estimates

VARIABLES	(11) 4211	(12) 4212	(13) 4216	(14) 4217
GMO_j	81.87*	0.725	5.086	64.34*
	(48.82)	(1.084)	(10.51)	(36.20)
Log ($R\&D_j$)	3.458	-0.281	2.971	14.47
	(14.66)	(0.317)	(3.242)	(11.33)
Log($Capital_j$)	28.54	1.081**	6.336	31.70*
	(21.35)	(0.463)	(4.562)	(16.54)
Log($Labor_j$)	-7.391	0.0841	-0.939	-25.23
	(22.86)	(0.477)	(4.786)	(17.30)
Log($AgLand_j$)	2.274	0.305	2.317	6.727
	(12.87)	(0.272)	(2.727)	(9.745)
Constant	-743.2**	-30.66***	-235.2***	-787.1***
	(306.0)	(7.332)	(67.24)	(239.9)
Observations	87	87	87	87
R2	0.11	0.13	0.13	0.19
Ll	-1291	-754	-1137	-1113

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(4211) Soybean oil, fractions; (4212) Cottonseed oil and its fractions;
(4216) Maize (corn) oil, fractions;
(4217) Rape, colza, mustard oil

2.6.6 Disaggregate industry estimation

Non-traditional factors

I now turn to disaggregate data of the individual GMO-based industries as expounded in Table 1.1 of Chapter 1. In this section, I present the estimation results of these industries. The idea here is to show whether, like the aggregate data, the disaggregate data supports the results. The linear-log model results shown (Table 2.29 through Table 2.32) indicate that while GMO land confers comparative advantage in 4 of the 14 industries, R&D does not confer comparative advantage in any of these industries. The industries for which GMO land confers comparative include cereals and cereal preparations such as unmilled maize, maize flour; animal feedstuffs such as bran, sharps and other residues of maize, as well as soybeans.

In the Tobit specification (Table 2.41 through Table 2.44), GMO land not only has the expected estimate sign in all the 14 GMO-based industries but also confers comparative advantage in more than half of the 14 GMO-based industries. For example, GMO land confers comparative advantage in 8 of the 14 industries and comparative advantage in 2 of the 4 individual industries in the foodstuffs and all of the animal feed, 2 of the 3 oil seed fractions subaggregates, and 1 of the 4 individual industries in the fats/oil subaggregates.

The estimate on the R&D stock is not statistically significant in all the 14 industries, an indication that the endowment does not confer comparative advantage in trade. This result is not surprising given that in Section 2.5, I found that many countries in the sample with modest R&D stock do not have embodied R&D trade. Further, as discussed earlier, the R&D stock (knowledge capital) does not fit the traditional immobility assumption. Knowledge capital spillovers may take place. Thus, the importance of knowledge capital is not showing up in the statistical results.

With regard to the traditional factors, capital stock consistently has positive and significant estimates in all of the 14 industries. However, labor largely has negative but statistically insignificant estimates in almost all of the industries. Agricultural land has positive expected estimate sign in most industries, implying that this endowment does confer comparative advantage. In general the results of the individual industries are consistent with those of the aggregates and subaggregates. Although GMO land and traditional endowments such as physical capital stock and agricultural land do moderately explain trade in GMO-intensive industries, much of the trade prediction is unexplained. It is beyond the scope of the present study for the unexplained trade variations. A further study that disaggregates factors such as labor into subaggregates may account for this unexplained trade. But as discussed in Section 3.6 the data in the present study is limited, and further disaggregation may not possible at this point.

2.7 Conclusion

In general, the results of the parametric estimation (regression) are comparable to the results of the non-parametric estimations in terms of the relationship between non-traditional endowments and embodied GMO-sensitive trade. In particular, the GMO land factor has both positive and significant coefficients, an indication that this endowment confers comparative advantage in predicting countries exports to the ROW. This result conforms to the HOV theorem about the correspondence between true factor abundance and trade-revealed factor endowment. In other words, these comparable results are consistent with the HOV theorem which indicates that a country with a relative abundance of a particular factor should have net exports of the services of that factor. Clearly, for those industries in which the non-traditional endowments positively and significantly predict GMO-intensive trade, there is support for the comparative advantage hypothesis where countries leverage export to the ROW. However, the fact that comparative advantage is not empirically supported in the case of R&D stock, particularly across aggregate and subaggregates deserves some explanation here. As such, countries do not have R&D embodied GMO-based net export. The most probable reason for this unexpected result is that the R&D stock (knowledge capital) does not fit the traditional immobility assumption of endowment across countries. The presence of R&D mobility across countries would serve to weaken the statistical results.

Further, the results reveal that the Tobit coefficient estimates have the same sign as the corresponding linear-log estimate, in part because overall 10 out of 96 countries have zero exports, to the ROW. As expected the Tobit estimates are somewhat bigger in magnitude even though their corresponding signs and statistical significances largely remain the same. Overall, the two methods fit the trade data similarly.

Finally, the evidence presented in this chapter generally sets out a framework for considering whether the non-traditional endowments (R&D stock and biotech land) confer comparative advantage to countries that export GMO-sensitive industries to the ROW. Where these endowments consistently confer comparative advantage (as in the case of biotech land), we have seen that countries leverage exports of GMO-sensitive industries to the ROW. Thus, the evidence in this chapter has both theoretical and policy implications. From a theoretical standpoint we have seen that the use of biotech land for example, maps with and conceptually explains trade in GMO-sensitive industries, conforming to the requirements of the HOV trade theory. And from a policy perspective, shift towards commercializing GMOs and increasing biotech land stock can enhance GMO-sensitive trade.

CHAPTER 3: ANALYSIS OF THE EFFECTS OF POLICIES ON TRADE IN GMOs

3.0 Introduction

In this chapter I examine the impact of the non-traditional endowments on *bilateral trade* of GMO-based industries. In addition, I analyze the effects of institutional endowments (IPRs and regulatory differences) on bilateral trade in GMO-based industries. In this chapter I also explore the interactive role of the non-traditional factors and differences in institutional endowments, including protections offered by relevant regulatory regimes and intellectual property right systems. For example, I examine the extent to which the impact of R&D stock on bilateral trade varies with the strength of intellectual property protection. The present chapter utilizes an integrated nested Gravity model. The non-traditional endowments are embedded in a gravity model to assess their impact on the bilateral trade flows.

The motivation for this chapter is that trade in GMO-based industries has been plagued by controversies associated with regulatory and policy differences across countries. For countries where GMO land has been increasing, there has been an increase in agricultural land productivity because of improved yield. Such change in productivity affects not only output and growth but also trade. Globally, there is a growing concern that this might create a more reliance on genetically modified product exports and to some degree dependence on imports of organic agricultural products. I assume that although at the production level GMOs and non-GMOs are segregated, they are used to produce mixed intermediate products that are traded internationally. The chapter is also motivated by the fact that international institutional endowments are believed to affect a country's exports even when that country's trade is not protected under its laws.

3.1 Commercialization of GMOs and trade

The current trends in agricultural biotechnology are an important indication of future adoption and acceptance of biotech crops worldwide. In particular, experts believe that GMO policy restrictions have had a negative impact on international trade in GMOs or related products and industries in the first decade (1996 to 2006). Yet trade in GMO-sensitive industries did not slow down during the same period. One reason why this trade continues to grow has been the modification of principal crops such as maize, soybean, cotton, and canola. The use of such crops cuts across sectors and industries and for some like soybeans and maize their *adventitious presence* in foodstuffs, animal feed and other products is becoming ubiquitous. That is, a number of marketed agricultural and industrial products rely on genetically modified crops or their derivatives as intermediate products. The reliance on GMOs is widespread, certainly in countries where GMOs are readily accepted.

In the United States for example, it is estimated that a 60-80% of the foods on the market have some GMO component, with maize and soybean-based ingredients accounting for the greatest share (Cornell University, 2002). This is consistent with the discussion in Chapter 1 that genetically modified ingredients tend to become part of the general food supply. It is the widespread uses of GMOs that add to the fears of traditional importers of products because many products derived from genetically modified crops are traded internationally and the regions where these products originate are likely to influence world trade. Ultimately, however, the effects of widespread uses and commercialization on international trade depend on whether or not this trade is left to take place without policy restrictions. Nielson and Anderson (2001b) state that, "determining whether or not a genetic modification affects the final product will probably have to be done on a case by case basis, but to the extent that a labeling program is covered by the TBT agreement, the WTO requires that it does not pose unnecessary barrier to international trade."

The number of countries adopting and commercializing GMOs is fast increasing around the world. However, losing GMO-free status is perceived by countries as having negative repercussions on their export opportunities for all agricultural products. This is due to the perception that consumers, especially in countries where resistance is high, may react negatively towards products that are susceptible to GMO contamination. From common sense, this implies that trade diversion might take place because of a shift in practices to replace inputs with others which do not bear the risk of being genetically modified.

Unlike industrial countries where case by case screening of GMOs for biological safety risks is a national policy, the regulatory caution toward GMOs in developing countries has largely been due to weak bureaucratic and technical capacity and fear of loss of export sales (Pearlberg et al. 2007). The fear of loss of export sales has in part forced countries with food and commodity export aspirations to feel safest to remain GMO-free.

Adding to these fears are actions of interest groups. For example, the International Pulse Trade & Industry Confederation in 2003 gave a statement that had ripple effects in the markets of pulse crops including, pea, bean, lentil, chickpea and all edible seeds of the hundreds of species in the legume family.[33] It asserted that commercial release of any recombinant DNA varieties may not be appropriate until it is satisfied that global markets have accepted trade in these varieties in their marketplace. However, it supported continuance of research into the use of modern biotechnology in pulses varieties for the benefit of consumers and producers. Despite the continued adoption and commercialization of biotech crops in many developed and developing countries, the multilateral trade debate about biotechnology in agriculture is acrimonious.

3.2 Regulatory differences of GMOs and trade

Globally, the widespread resentment of GMOs diffusion by consumers, governments, nongovernmental organizations, and environmentalists revolve around health safety, environmental risks, and issues of morality of agricultural biotechnology. Countries around the world have taken opposing and sometimes polar positions. Regulation policies substantially differ among countries and pit one trading partner against another. For example, the European Union (EU) and the United States have had polar positions on matters of GMO trade. These trading partners disagree over the regulation and trade of genetically modified products and derivatives. The EU, for example, has remained particularly opposed to GMOs throughout the 1990s and reacted by ratcheting up regulatory preferences. Many countries led by the EU support the *precautionary principle* in regulating GMOs and have erected policy barriers ranging from a total moratorium ban to technical barriers not only in adoption but also trade. The *precautionary principle* is based on the premise that the potential danger of GMOs can be reduced or prohibited

[33] http://www.cicilsiptic.org

before they are scientifically proven to cause catastrophic harm. For the decade that ended in 2005, EU's opposition to GMOs and uneasiness intensified in the aftermath of food safety crises that plagued the region such as mad cow disease, presence of dioxin in Belgian farm animal feed, discovery of salmonella in Britain eggs and hoof-and-mouth disease. For these and other reasons, the EU maintains there is more that is unknown about GM food and that without full information about its potential risks to human lives and the environment, free trade cannot be justified.

On the contrary, North America has long embraced GMOs. In fact, the bulk of agricultural biotechnology originated from the United States and Canada, the home of most of the corporations spearheading this technology around the world. North America's logic on GMOs is similar to the scientific consensus. Here the emphasis is given to the regulation of product rather than the process. The principle called *substantial equivalence* emphasizes that GMOs should receive the same regulatory treatment as other agricultural products. The position of the United States is that regulations of genetically modified foodstuff contravene the spirit of free trade and most favored nation (MFN). In addition, the United States, operating on a premise of scientific rationality (Isaac, 2002), maintains that current transgenic crops are 'substantially equivalent' to their non-transgenic counterparts and thus fall under the GATT definition of like products – products with the same end use and identical tariff classification. The 'substantial equivalence' in this interpretation means that no specific actions-either government or private are necessary to determine acceptable tolerance level of GM foods in the system. Moreover, this position implies that genetic modification is a production process (rather than production characteristic), and thus any ‘discrimination’ against GM foods is a trade barrier per WTO rules.

Unprecedented adoptions of agricultural biotechnology and subsequent opposing positions make the technology one of the most contentious issues before the WTO dispute settlement (Tothova and Oehmke, 2004). As a result, differences in regulating GMOs and related products raise the question – what is the implication on trade? In some parts of the world, agricultural biotechnology-related exports have been plagued by numerous interruptions. The United States’ corn exports to Europe were effectively outlawed because of European restrictions on GMO corn. Yet in other parts the impact is inconclusive given that regulations merely redirect trade but not slow or stop it altogether.

The EU bore losses arising from GMO trade restrictions. For example, many livestock farming businesses have lost significant input supplies essential for animal feed as a result of the EU and Member State zero tolerance policies of low-level presence of GMO material in imported agricultural commodities. This moratorium also put at disadvantage manufacturers of protein-rich feedstuffs and farm operators who are unable to obtain adequate supplies from domestic producers, and supplies of non-GM materials are steadily declining. It seems the moratorium has a trade diversion effect between the EU and GMO-commercializing countries not only in GMOs but related industries as well.

Elsewhere similar opposing policies and trade wars have been witnessed. In Asia, South Korea and China both instituted measures to deal with GMOs when China's non-GMO corn exported to South Korea was found contaminated with genetically modified corn pollen. China as an exporter had its own measures because the burden of proof fell squarely on its shoulders. China was obliged to do so in order to continue exporting and perhaps retain her market share.

The WTO considers the EU restrictions on genetically modified crops are incompatible with international trading rules. In this regard, Isaac (2002) concludes that "…. the debate about GMOs essentially boils down to contrasting two different regulatory approaches, each backed by different international treaties. The Cartagena Protocol on Biosafety (to which USA is not a signatory) endorses the *precautionary principle*, while the WTO agreements give their approval to scientific evidence – and indirectly endorse substantial equivalence."

To add to the inconclusive nature of the impact of GMOs on trade, it appears that bans merely redirect trade but not slow or stop it altogether. While overall trade in some of these genetically modified crops (e.g. soybean) have fallen in certain regions such as the EU, in other regions the value of trade has not slowed down. For example, the value of the United States genetically modified soybean export has doubled, rising from $ 3.5 billion in 1990 to $ 8 billion in 2003 (Smyth, Kerr, and Davey, 2004).

Global trade in some of the genetically modified crops continues to rise with the international market managing to adjust to the commercialization of genetically modified maize varieties (Smyth et al. 2004). They argue that maize seed export values have recovered to the same levels witnessed during the early 1990s. By the same token the paper argues "… the commercialization of genetically modified maize did have some market impacts and that the international market has adjusted as is evident in the rise of the United States' corn export". With the foregoing arguments it is not clear how regulations and policies directed at GMO industries changes the pattern of world production and trade.

The adoption and commercialization of GMOs is argued to confer comparative advantage. At the same time, the adoption of GMOs creates a friction that impacts trade. For example, in a theoretical framework, Anderson *et al* (2006) show that increased use of GMOs confers comparative advantage in the source country and that the use of biotechnology would result in support by farmers for GMO standards that are lenient like those seen in North America. Further, they back this argument empirically in a study that employed GTAP computable generable equilibrium model of global economy that concludes "given agricultural biotechnology adoption in America, farmers in the EU are better off denying themselves access to the technology in return for a ban on imports from GMO-adopting countries. These theoretical and empirical conclusions have implications for trade not only in GMOs but also GMO-sensitive industries.

In general, regulatory caution toward GMOs and the slowing down of the official approval process across countries are not necessarily driven by scientifically demonstrated biosafety or food safety risks. Rather, fear of lost export sales among other factors has chiefly been responsible for the slowdown (Pearlberg et al. 2007). For example, in early 2003, Zambia rejected importation of genetically modified corn from the United States on grounds of health concerns. Although Zambia did not have the capacity to evaluate the safety of GMOs, the ban was motivated by the need to safeguard concessions and the ready export market for fresh vegetables under the African Caribbean Pacific-EU (ACP-EU) Economic partnership. Zambia’s action was to a large extent driven by the underhand of the EU regulation on GMOs. Under similar circumstances, Thailand in 2003 resisted genetically seeds for fear that the EU agricultural exports would be adversely affected.

3.3 IPRs and Trade

The GMO-sensitive industries considered here are derivatives of the genetically modified crops. Intellectual property rights (IPRs) are likely to be an element in the debate on genetically modified foods and feeds, with an impact on the rights of farmers, production processes, and trade. At the same time IPRs, especially patenting obligations concerning trade-related have been discussed in the light of their consequences on the further availability of a diversity of crops. This implicitly implies that IPRs have bearing on modified crops and their derivatives, especially the GMO-sensitive industries. The intermediate use of agricultural biotechnology in traded products generates conflicts not only between IPRs and the access to genetic resources but also the sharing of the gains from trade. The WTO reviews such conflicts and sets minimum standards with a view to protecting technological innovation, to allow fair competition, balance rights and obligations, and transfer technology. Thus, whether such considerations affect the debate on genetically modified foods and feeds and by extension their derivatives, especially those whose share of genetic content is unknown is one of the empirical questions this chapter seeks to determine.

The importance of IPRs in the present chapter is underscored by two reasons. First, in the context of agricultural biotechnology, differences in resource endowments are themselves reflected in institutional endowments, including IPRs. Even though the GMO-sensitive industries considered in the present study might not have embodied selfreplicating technologies, the fear of *adventitious presence* of genetic materials in such industries may compel strengthening of IPRs (patent protection) in the destination country relative to the source country. Even though intellectual protection may be jurisdictional, strengthening of IPRs by importing country relative to the source country may in this sense have implications on trade.

Besides, the non-traditional factors, especially R&D as knowledge capital does not fit the traditional immobility of endowment of a particular country. Violation of the immobility assumption relating to knowledge capital is important in the context of GMO-sensitive trade because of its interaction with national differences in IPRs. Stamm (1993) argued that under weak intellectual property protection investments in R&D activities reduces trade. Goldsmith et al (2006) through a case study that used deductive method, provide empirical evidence in support of this proposition. They found that between 2001 and 2006, the Corn Division in Pioneer Company received 33.6 times more R&D spending than soybean. Part of the story of the relevance of IPRs in the context of the present study is reinforced by the fact that the use of corn and soybean is ubiquitous, especially in products of industries that are traded internationally. Thus, international institutions are believed to affect a country's exports even when that country's trade is not protected under its laws.

With regard to IPRs one cannot tell a *priori* the direction of this effect given that studies in international trade literature reveal that national differences in IPRs have indeterminate effect on trade because strong IPRs simultaneously increase trade via market expansion effect and decrease trade via market power effect. In the empirical implementation, I use a relative measure of strength of IPRs of importing country relative to exporting country. Thus, there are two possibilities. First, strengthening of IPRs in the destination country relative to the source country could reduce exports of genetically modified-sensitive products. In that case, there is a market power effect where strengthening intellectual property protection grants monopoly power to economic agents of importing country relative to exporting country. The other possibility is that strengthening of patent protection in the destination country relative to the source country could increase exports of genetically modified-sensitive products. In that case, there is a market expansion effect where strengthening IPRs reduce threat or fear of imitation.

3.4 Theoretical model framework

This section covers the theoretical basis for generalized gravity equation estimations. Bergstrand (1989) generalized gravity equation model provides the underlying theoretical framework for the present study. The model is consistent with the Heckscher-Ohlin (H-O) trade model. In this model, Bergstrand develops a general equilibrium model of world trade with two differentiated product industries and two factors to show how the gravity equation relates to other trade models such as the Heckscher-Ohlin model of inter-industry trade and the Helpman-Krugman-Markusen models of intra-industry trade.

An interesting feature of Bergstrand's work is the explicit theoretical derivation in which factors of production are nested within the gravity framework. In other words, Bergstrand's work includes endowment variables in a manner consistent with the H-O model, other trade models that account for tastes, size and similarities of countries, as well as the *New trade theory* which incorporates aspects of imperfect competition and product differentiation.[34]

In the present section I apply Bergstrand's integrated theory to GMO-sensitive industries. The purpose is to explore whether the non-traditional and policy endowments fit within a general equilibrium gravity model of trade.

This theoretical model is relevant to the present study because GMO-based products are differentiated given GMO-sensitive varieties of a firm are not identical to products from other firms in the same industry. I mentioned earlier that the relevance of patent protection to GMO trade stems from the fact that GMO-based products fall under categories (e.g. foodstuff) in which patents are granted for novel or industrial applicability. My assumption about the form of the GMO-based products is that they are derived from genetically modified crops and are used as intermediates to produce final differentiated marketed products. Hence, these products embody GMO technology. To the extent that they do, they will be affected by a country's intellectual property right systems. Therefore, the monopolistic framework may also be relevant in one other way. With the assumption of embodied technology, patents in GMO-based industries confer monopoly to the variety of the products. Yet patent law requirements with respect to coverage (jurisdiction), membership in international patent agreements, duration of protection, provision for loss of protection, and enforcement mechanisms establish limits on the extent of the monopoly power.

Bergstrand's model assumes that a representative consumer maximizes a nested Cobb-Douglas – CES-Stone-Geary utility function of the type:

---

[34] (A. V. Deardorff, 1995) using Ricardian and H-O also explicitly shows that gravity model in similar fashion.

$$
\begin{aligned}
&\mathrm{Max}\,U_{kl} = \left[\left(\sum_{j=1}^{N}\sum_{h=1}^{H_{Aj}} X_{Ahjkl}^{\theta^A}\right)^{1/\theta^A}\right]^{\delta}\left[\left(\sum_{j=1}^{N}\sum_{h=1}^{H_{Bj}} X_{Bhjkl}^{\theta^B}\right)^{1/\theta^B} - \underline{X}_B\right]^{1-\delta} \\
&s.t. \\
&Y_{kl} = \sum_{a=A,B}\sum_{j=1}^{N}\sum_{h=1}^{H_{aj}} \left(P_{ajk}T_{ajk}/E_{jk}\right)X_{ahjkl} \\
&-\infty < \theta^A,\ \theta^B < 1,\ 0 < \delta < 1
\end{aligned}
\tag{3.1}
$$

where $\theta^A = \dfrac{\sigma - 1}{\sigma}$ and $\sigma > 1$ is the elasticity of substitution between varieties; δ is a distribution parameter. X_{Ahjkl} (X_{Bhjkl}) is the amount of output of industry *A (B)* of firm *h* in country *j* demanded by consumer-worker *l* in country *k*. $\underline{X}_B$ is the minimum consumption requirement of good *B* by consumer; Y_{kl} is the consumer *l* income in the destination country k and equals expenditure; T_{ajk} is one plus the exogenous tariff rate on industry *A*, *B* exports from *j* to *k*; E_{jk} is the exogenous exchange rate between the two countries defined as *j's* currency per unit of *k's* currency; P_{ajk} is the freight on board (f.o.b) price of firm *h's* output of industry A, B exported from country *j* to *k.*

The outputs by each firm in the industries demanded by consumers are differentiated and produced with Chamberlinian-monopolistic-competition type market structure. The nested utility is particularly attractive for several reasons. First, the prices of all differentiated goods influence the demand for each good. These price differences are due not just to such factors as transport costs but also reflect differences in production standards and processes. Another attractive feature of the nested utility is related to prices of the differentiated products. Here, the model provides greater flexibility occasioned by parameter, σ (elasticity of substitution). This is particularly relevant for bilateral trade flows where greater degrees of substitution between products is important, especially when buyers of a product have to respond to price changes related but differentiated products. In addition, the underlying assumption that the goods are differentiated by the countries of origin partly enables representative consumers to maximize objective function (3.1), yielding the usual aggregate inverse market demand for the output of industry *A* produced by firm *h* in the source country.[35] The aggregation of demand is also possible because of the underlying assumption of homothetic preferences and identical consumers so that consumers with different incomes but facing the same prices will demand goods in the same proportions. Finally, income is not multiplicatively but additively included in the utility function. The idea here is to allow the prices of optimal consumption between two goods at different incomes vary so that utility function (3.1) is maximized subject to consumer income Y_{kl}.

On the supply, side assuming that for each firm *h* in industry A (B) produces differentiated product in monopolistic market competition using endowments according a linear technology, the representative firm maximizes profit according to the following.

$$\pi_{ahj} = \left\{ \sum_j P_{aj} X_{ahj} - (W_j \alpha_{La} + R_j \alpha_{Ka}) - W_j \beta_{La} \left[\sum_j (C_{aj} X_{ahj})^{\phi^a} \right]^{1/\phi^a} \right.$$
$$\left. - R_j \beta_{Ka} \left[\sum_j (C_{aj} X_{ahj})^{\phi^a} \right]^{1/\phi^a} \right\}$$

h = 1, ……., H_{aj}; a = A, B; j = 1, ….., N *(3.2)*

where W_j, R_j, are factor returns. C_{aj} is the c.i.f/f.o.b. factor (>1) to ship output in industry *a* from country j to k.

[35] The assumption of differentiation of goods according to country of origin is originally due to Armington (1969).

Equation (3.2) is maximized subject to linear technologies of production for industry *A* yielding marginal cost of exporting from *j* to *k* , which can be considered as supply or marginal cost of exporting[36,37]. In equilibrium the inverse demand derived from objective of the representative consumer and the supply derived from the firm's objective together yield the following *generalized gravity equation.*

$$PX_{Ajk} = \delta^{(\gamma^A+1)/(\gamma^A+\sigma^A)} (Y_j^{v})^{(\sigma^A-1)/(\gamma^A+\sigma^A)} (\beta_{v_2A}\beta_{v_1B} - \beta_{v_2B}\beta_{v_1A})^{-1}$$
$$[\beta_{v_1B} - \beta_{v_2B}\beta_{v_1B}(v_{1j}^{*} / v_{2j}^{*})^{-1}]^{(\sigma^A-1)/(\gamma^A+\sigma^A)}$$
$$(Y_j)^{(\gamma^A+1)/(\gamma^A+\sigma^A)} (- y_k^{-1})^{(\gamma^A+1)/(\gamma^A+\sigma^A)} C_{Ajk}^{-(\sigma^A-1)(\gamma^A+1)/(\gamma^A+\sigma^A)} T_{Ajk}^{-\sigma^A(\gamma^A+1)/(\gamma^A+\sigma^A)} E_{Ajk}^{\sigma^A(\gamma^A+1)/(\gamma^A+\sigma^A)}$$
$$\left\{\left[\sum_j (P_{Ajk} / C_{Aj})^{1+\gamma^A}\right]^{1/(1+\gamma^A)}\right\}^{-\gamma^A(\sigma^A-1)(\gamma^A+\sigma^A)} \left\{\left[\sum_j (P_{Ajk}T_{Ajk}) / E_{jk}\right]^{1-\sigma^A}\right\}^{-(\gamma^A+1)/(\gamma^A+\sigma^A)}$$

(3.3)

where PX_{Ajk} is the value of trade flows from county *j* to *k* in industry A and as pointed out Y_j^{v} is country *j*'s national output in terms of units of factor *v*

$(Y_j^{v_2} = v_{2j}^{*} = \sum_h^A \beta_{v_1A} X_{Ahj} + \sum_h^B \beta_{v_2B} X_{Bhj})$.

Notice that P is a price index in each country defined over the prices of individual varieties of differentiated goods produced in county *j* and exported to country *k*, P_{Ajk} as defined earlier. This equation has for some time provided theoretical underpinnings of the gravity trade models and is used in estimating bilateral flows. It shows the value of

---

[36] I leave the choice of two factors (traditional factors) intact henceforth principally for two reasons – first, because of convenience of derivation and second because the capital intensities can be proxied by size of a country. The latter argument is not uncommon because conceptually national output of exporting country j can be derived in terms of units of capital. In the gravity equation capital-labor ratios can be measured GDP per economically active population so that in a two-factor model, a country with higher GDP per economically active population also has higher capital-labor ratios.

[37] See Appendix for more exposition of this.

exports of country *j* to country *k*. I employ this model to specify a baseline gravity equation in the next section.

While the left hand side (LHS) of (3.3) often measures the value of trade flows, it is what is included in the right hand side (RHS) of the equation that makes the difference in terms of prediction of trade. For the present study, as mentioned earlier, the RHS incorporates the true relative endowments of the non-traditional and institutional policy endowments.

3.5 Empirical Model

3.5.1 Baseline specification

Following Bergstrand (1989), I specify a baseline gravity model of the type shown by equation (3.4):

$$T_{hjk} = \beta_{0h} (Y_j / N_j)^{\beta_{1h}} (N_j)^{\beta_{2h}} (Y_k / N_k)^{\beta_{3h}} (N_k)^{\beta_{4h}} (D_{jk})^{\beta_{5h}} (A_{hjk})^{\beta_{6h}} \varepsilon_{hjk} \qquad (3.4)$$

where T_{hjk} is the value of bilateral exports of a commodity in GMO-based industry *h* from country *j* to *k*; (Y_j/N_j) and (Y_k/N_k) are the respective per capita GDP of countries j and k; N_j, N_k are the population sizes of countries j and k; D_{jk} is the geographic distance (kilometers) between the biggest commercial port/hub of trading partners; A_{hjk} denotes trade distortionary factors that create or divert trade; ε_{hjk} is log-normally distributed disturbance term.

Taking the natural logarithm of equation (3.4) and using regional preferential trade arrangements and differences in IPRs as proxies for institutional endowments, one can write a baseline equation as follows:

$$\log T_{hjk} = \beta_{0h} + \beta_{1h}\log(Y_j / N_j) + \beta_{2h}\log(N_j) + \beta_{3h}\log(Y_k / N_k) + \beta_{4h}\log(N_k) + \beta_{5h}\log(D_{jk})$$
$$+ \beta_{6h} Border_{jk} + \beta_{7h} RTA_{jk} + \beta_{8h} NAFTA_j EU_k + \beta_{9h} MERCOSUR_j EU_k$$
$$+ \beta_{10h} MERCOSUR_j NAFTA_k + \beta_{11h}\log IPR_{kj} + \varepsilon_{hjk} \qquad (3.5)$$

where $Border_{jk}$ measures whether *j* and *k* share a common border. $Border_{jk}$ is literally a border variable in that it can be regarded either as a distance variable or a trade arrangement variable. IPR_{kj} is a measure of intellectual property protection strength of k relative to j; $Border_{jk}$ is a dummy equal to 1 if *j* and *k* have common border; RTA_{jk} is an all sample dummy denoting mutual regional trade agreement (RTA) membership between *j* and *k* and takes value 1 if both are members, and 0 otherwise; $NAFTA_jEU_k$ is a dummy that takes value 1 if j is in NAFTA and k is in EU, 0 otherwise; $MERCOSUR_jEU_k$ is a dummy that takes value 1 if j is in NAFTA and k is in EU, 0 otherwise; $MERCOSUR_jNAFTA_k$ is a dummy that takes value 1 if j is in NAFTA and k is in EU, 0 otherwise; ε_{ijk} is log-normally distributed disturbance term. The regional preferential trade arrangement variables are controlled for in order to isolate variations in the bilateral trade resulting from trade distortion in form of trade diversion or trade creation.

IPR is a measure of IPR strength of the importing country relative to exporting country. The form of the GMO-sensitive trade considered in the present study does not grantee that the bilateral trade flows embody intellectual property. Nonetheless, they embody R&D. IPRs are therefore relevant because they affect the R&D that gives rise to intellectual property. Even so, there are no priori expectations on the direction of the impact of IPRs on the bilateral trade in GMO-sensitive industries (see Section 3.3). Thus, the direction of effect is left to empirical assessment.

Using equation (3.5), I examine the following hypothesis:

Hypothesis 3.1: *(a) Institutional endowment (differences in patent strength regime) of the destination country (k) relative to the source country (j) increase or decrease the bilateral trade flows of GMO-based industries.*

(b) Institutional endowment (differences in regulation) in the destination country and the source country (j) decrease the bilateral trade flows of GMO-based industries.

3.5.2 Adapted specification

Next I adapt a gravity model of the type proposed by Bergstrand (1989) by integrating non-traditional endowments as follows:

$$
\begin{aligned}
\log T_{hjk} = {} & \beta_{0h} + \beta_{1h} \log (Y_j / N_j) + \beta_{2h} \log (N_j) + \beta_{3h} \log (Y_k / N_k) + \beta_{4h} \log (N_k) + \beta_{5h} \log (D_{jk}) \\
& + \beta_{6h} Border_{jk} + \beta_{7h} RTA_{jk} + \beta_{8h} NAFTA_j EU_k + \beta_{9h} MERCOSUR_j EU_k \\
& + \beta_{10h} MERCOSUR_j NAFTA_k + + \beta_{11h} \log IPR_{kj} + \beta_{12h} \left(\frac{V_{GMOj} / \sum_{j=1}^{N} V_{GMOj}}{Y_j / \sum_{j=1}^{N} Y_j} \right) \\
& + \beta_{13h} \left(\frac{V_{R\&Dj} / \sum_{j=1}^{N} V_{R\&Dj}}{Y_j / \sum_{j=1}^{N} Y_j} \right) + \varepsilon_{hjk}
\end{aligned}
\tag{3.6}
$$

The last two terms in RHS of equation (3.6) measure relative true non-traditional endowments of GMO land and R&D stock respectively. All other variables are as defined in equations (3.4) and (3.5). Notice that this specification is factor-incorporating because traditional endowments are in per capita. Therefore the coefficients for countries per capita incomes are regarded as proxies for the relative factor abundance (capital and labor). It incorporates relative traditional factor-endowment differences.

Incorporating the non-traditional factors serves the purpose of examining their roles in the bilateral trade flows of GMO-based industries. In addition, they act as a link between the factor-content model presented in Chapter 2 in an integrated way that is consistent with the factor-incorporating world trade generalized gravity expounded in Section 3.2 and theory.[38] In addition, the model maintains the proxies for institutional endowments as in the preceding specification (3.5). Thus, using equation (3.6), I examine the following hypotheses:

Hypothesis 3.2(a): *Biotech land affects the bilateral trade (exports) in GMO-based products positively.*

Hypothesis 3.2(b): *Knowledge stock (or R&D stock) affects the bilateral trade in GMO based products positively.*

3.5.3 Extended specification

Thus far, I assumed that the impact of true relative non-traditional factors (biotech land and R&D) on the bilateral trade of GMO-sensitive industries is independent of relative strength of protection of IPRs. In other words, we have assumed that the causal relationship between non-traditional factors (R&D and biotech land) and trade in GMO-based industries exists irrespective of institutional endowments, especially patent strength

[38] The inclusion of the non-traditional factors as basis for trade and the integration of the same in a way that is consistent with the factor-incorporating world trade generalized gravity model (3.6) and theory has not been done before, at least to my knowledge.

systems. As an extension I relax this assumption and allow non-traditional factors to interact with relative strength of IPRs.

In this extension, I define IPRs as a proxy for institutional endowment that affects adoption of agricultural biotechnology and innovation indicated by R&D activities. That is, in equation (3.7) I account for the joint effect of IPRs and R&D stock of a country.

$$
\begin{aligned}
\log T_{hjk} = {} & \beta_{0h} + \beta_{1h} \log\left(Y_j / N_j\right) + \beta_{2h} \log\left(N_j\right) + \beta_{3h} \log\left(Y_k / N_k\right) + \beta_{4h} \log\left(N_k\right) \\
& + \beta_{5h} \log\left(D_{jk}\right) + \beta_{6h} Border_{jk} + \beta_{7h} RTA_{jk} + \beta_{8h} NAFTA_j EU_k \\
& + \beta_{9h} MERCOSUR_j EU_k + \beta_{10h} MERCOSUR_j NAFTA_k + \beta_{11h} \log IPR_{kj} \\
& + \beta_{12h} GMO_j + + \beta_{13h} GMO_k + \beta_{14h} \log(R\&D_j + \beta_{15h} \log(R\&D_k \\
& + \beta_{16h} GMO_j * \log IPR_{kj} + \beta_{17h} GMO_k * \log IPR_{kj} \\
& + \beta_{18h} \log(R\&D_j * IPR_{kj}) + \beta_{19h} \log(R\&D_k * IPR_{kj}) + \varepsilon_{hjk}
\end{aligned} \tag{3.7}
$$

where GMO_j equals 1 for countries that commercialize GMO trade and zero otherwise. The last two terms on RHS of equation (3.7) are the interaction of the strength of patent protection of destination country (k) relative to the source country *j* and the non-traditional endowments of biotech land and R&D. All other variables are as defined earlier.

Hypothesis 3.3(a): The impact of biotech land in the source (destination) country on the bilateral trade of GMO-sensitive products varies with relative strength of intellectual protection in the destination country.

Hypothesis 3.3(b): The impact of R&D in the source (destination) country on the bilateral trade of GMO-sensitive products varies with relative strength of intellectual protection in the destination country.

Expected signs of Parameter estimates

Table 3.34 summarizes the expected signs of the variables used in the estimation of equations (3.5), (3.6) and (3.7).

Table 3.45: Expected Signs of the variables

Variable	Abbreviation	Expected sign (3.5)	Expected sign (3.6)	Expected sign (3.7)
GDP per Capita in j	GDPPCj	α1>0	β1>0	γ1>0
Population in j	Popj	α2>0	β2>0	γ2>0
GDP per Capita in k	GDPPCk	α3>0	β3>0	γ3>0
Population in k	Popk	α4>0	β4>0	γ4>0
Distance between j & k	$Dist_{jk}$*	α5<0	β5<0	γ5<0
Common border between j & k	$Cont_{jk}$	α6>0	β6>0	γ6>0
RTA both j & k	RTA_{jk}	α7>0	β7>0	γ7>0
j in NAFTA & k in EU	NAFTAjEUk	α8<0	β8>0	γ8>0
j in MERCOSUR & k in EU	MERCOjEUk	α9<0	β9>0	γ9>0
j in MERCOSUR & k in NAFTA	$MERCO_jNAFTA_k$	α10>0	β10>0	γ10>0
Patent protection strength in k relative to j	P_{kj}	α11<>0	β11>0	γ11<>0
GMO j (Biotech land) in j	GMOj		β12>0	γ12>0
GMOk (Biotech land) in k	GMOk		β13>0	γ13>0
R&D stock in j	R&Dj		β14>0	γ14>0
R&D stock in k	R&Dk		β15>0	γ15>0
Interaction of P_{kj} & GMOj	GMOj $\times LP_{kj}$			γ16<>0
Interaction of P_{kj} & GMOk	GMOk $\times LP_{kj}$			γ17<>0
Interaction of P_{kj} & R&Dj	R&Dj $\times LP_{kj}$			γ18<>0
Interaction of P_{kj} & R&Dk	R&Dk $\times LP_{kj}$			γ19<>0

* D_{jk} is the geographic distance (kilometers) between the biggest commercial port/hub of trading partners.

3.5.4 Heckman selection model

Next as a robustness check, I estimated a Heckman selection bias model. This was necessitated by the fact that the bilateral trade flows are often characterized by zero or missing values. There are several economic reasons why this is the case. For example, at the aggregate level, Frankel (1997) argues that zero flows occur for trade between small or distant countries. Also, there could be a very clear theoretical reason why some countries do not export products of certain industries. Historically, countries have tended to export to other countries primarily for two reasons. First, economic agents notably individuals, households and firms have been able to produce more of certain goods and services than can be consumed at home prompting to sell the "excess" production. Second, economic agents have been able to sell goods or services to other countries at prices higher than the prices they can obtain domestically. Thus, if the censoring occurs at the zero trade flows, one could argue (consistent with the underlying theory of trade) that some countries may not export a particular good owing to their comparative disadvantage.

Although many trade studies disregard zero flows and only analyze positive trade, the implication in terms of results can be far reaching. Besides, this action often leads to biased results. Eichengreen and Irwin (1998) for example posit that disregarding zero flows leads to information loss with regard to patterns of trade. Zero trade flows may be the result of the economic agents self-selection and not necessarily random action. The Heckman selection model (Heckman, 1979) allows us to utilize information from the countries with zero trade flows to improve the estimates of the parameters in the model.

Model

Consider $j = 1, \ldots\ldots, J$ source countries exporting GMO-sensitive differentiated products from $h = 1, \ldots., H$ GMO-based industries to $k = 1, \ldots\ldots, K$ destination countries. Whether j exports to k depend on a number of reasons as discussed above. Given that we observe all trade (including zero flows) at country level, then

$$T_{jk}^{*} = x^{'}\beta + \varepsilon_{jk}$$
$$T_{jk} = \begin{cases} 0 \text{ if } T_{jk}^{*} \leq 0; \\ 1 \text{ if } T_{jk}^{*} > 0 \end{cases}$$

(3.8a)

T^{*}_{jk} denotes an underlying trade in GMO-sensitive products, which is not observed if there is no trade between j and k and ***x***' is vector of covariates for the outcome equation.

$$Z_{jk}^{*} = v^{'}\gamma + \eta_{jk}$$
$$Z_{jk} = \begin{cases} 0 \text{ if } Z_{jk}^{*} \leq 0; \\ 1 \text{ if } Z_{jk}^{*} > 0 \end{cases}$$

(3.8b)

Z^{*}_{jk} latent variable i.e. dependent variable of the selection equation which might be thought of as the propensity to export GMO-sensitive products and ***v***' is vector of covariates for the outcome equation. The following conditions hold.

$$\varepsilon_{jk} \sim N(0,\sigma)$$
$$\eta_{jk} \sim N(0,\sigma)$$
$$corr(\varepsilon_{jk},\eta_{jk}) = \rho$$

$\varepsilon_{jk}, \eta_{jk}$ are respective error terms and ρ is the correlation between them. ***X*** and ***V*** are vectors of regressors comprising of supply and market capacities of *j* and *k* respectively including the relative true factor endowment of both the non-traditional factors. Equation (3.8a) is the outcome equation (Heckman regression) and the second is the selection equation.[39] Equation (3.8a) is the gravity model of interest. I consider it here as the behavioral equation arising from the rational decisions of economic agents. Equation (3.8b) is the selection model which determines whether we observe zero or positive trade flows of GMO-sensitive industries.

The conditions under which equations (3.8a) and (3.8b) hold need further explanation. When $corr(\varepsilon_{jk}, \eta_{jk}) = \rho = 0$, the outcome gravity equation via log-linear OLS estimation provides unbiased estimates. However, when the correlation is different from zero log-linear OLS estimates are biased and estimates are inconsistent estimates. In the former case there is sample selection bias in which case the positive bilateral trade flows we often observe between any pair of countries are not representative of all trade (zero and positive trade flows).

Following Heckman (1979), the solution lies in the implementation of equation (3.8a) and (3.8b) in two stages. First, I implement equation (3.8b) as probit model where a dichotomous variable Z determines whether or not trade (T_{jk}) is observed, trade being observed only if *Z=1*. In this first stage probit model one can compute *inverse mills ratio*.[40] In the second stage, I model expected value trade (T_{jk}) conditional on its being

---

[39] The outcome equation is a continuous regression model predicting trade flows while the selection part predicts whether a positive trade flow is observed.

[40] Assuming x is a random variable and normally distributed with a mean μ and variance σ^2, then $E\{x \mid x > \alpha\} = \mu + \sigma \frac{\{\varphi((\alpha-\mu)/\sigma)\}}{\{1-\Phi((\alpha-\mu)/\sigma)\}}$, where φ is the standard normal density function

observed. Thus, in the second stage I run a log-linear OLS with some explanatory variables plus the inverted mills ratio computed from the first stage. I then utilized the inverse of the mills ratio so generated as a control variable within Log-linear OLS regression model to obtain unbiased estimates. These two stages essentially check for selection bias.

3.6 Method and data

The method for the present chapter involves estimating equations (3.5), (3.6) and (3.7) using cross-section data for a large sample of countries. In particular, I estimate these specifications using 9120 bilateral trade flows detailed by both the source (exporter) and destination (importer) of trade. In order to avoid loss of observations when I transform the zero trade values into logarithms, I replace the zero trade values with a small number (1E-10) in all the estimations. The results are shown in Tables 3.36 through 3.44.

Also, for reasons expounded in the preceding section, I estimate a Heckman selection model (3.8a and (3.8b) which correspond with each of the log-linear OLS specifications. The results are shown in Tables 3.39, 3.40, and 3.41. The data covers the year 2006 because it is the most recent year for which comparable data was available. However, for variables such as R&D and capital, the final measures I use are actually stocks rather than flows which imply that past investments have taken into consideration.

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while Φ is the standard cumulative distribution function. $Mi = \frac{\{\varphi((\alpha-\mu)/\sigma)\}}{\{1-\Phi((\alpha-\mu)/\sigma\}}$, is the inverse mill's ratio.

Save for the descriptive statistics in Chapter 1 where I use data for 1998 and 2006 to explore any presence of unobserved heterogeneity across exporting and importing countries in unmeasured determinants of the bilateral flows of GMO-based industries), the rest of the data covers the year 2006. The two point estimation was not however necessary in the empirical estimations because the descriptive statistics of Chapter 1 showed greater variability across countries than across time. Besides, the use of panel across time was not feasible given some relevant data are available for a limited number of years or missing altogether. Cross-section data is also the appropriate match for the underlying theoretical framework.

It is important to note that the true relative non-traditional endowments measures I use in the present chapter are the same measures I computed in Chapter 2. In other words, I nested these factors on the bilateral trade flows to assess their comparative advantage.

Unlike the exports to the rest of the world used in Chapter 2, the trade data for the GMO-sensitive industries in the present chapter is bilateral. I construct the bilateral trade measure from an aggregate measure of 14 GMO-based industries defined earlier in Chapter 1. I also construct sub-aggregates of these industries namely foodstuff, animal feed, oil seed/fruit and animal/vegetable fats/oil. I then estimate each of the empirical specifications using aggregate and sub-aggregate constructs via the two estimation procedure discussed. In addition, I repeat all estimations using individual GMO-based industries. The idea here is to check whether the different levels of aggregation produce comparable estimates consistent with the present study's maintained hypotheses and theory.

The choice of the GMO-based industries is important for two reasons. GMO-based industries are derived from genetically modified crops and contain *adventitious presence* of GMO or are potentially susceptible to genetic modification. These industries are not only sensitive to propensity to adopt agricultural biotechnology but also are characterized by patent protection and substantial R&D investments. These industries include maize seed, other unmilled maize, maize flour, groats /meal of maize, animal feedstuffs (bran, sharp and other residues of maize), oilcake from soybeans, oilcake from colza seeds (rape or colza), soybeans, rape/colza seeds, cottonseeds, soybean oil fractions, cotton oil fractions, maize oil fractions, and rape/colza mustard oil.

Data for the commodities in this sector/industry is obtained from United Nations COMTRADE data base. Specifically, I use the three-digit level of the Standard International Trade Classification (SITC).

I employed R&D data to construct stock measures of knowledge capital. I obtained the R&D data from UNESCO. The UNESCO Institute for Science has recently published 2007/2008 data on Science and Technology (S&T) Statistics on research and experimental development (R&D). The R&D has subaggregates, but I used the aggregate measure. In addition, I obtained data for agricultural biotechnology adoption from the International Service for the Acquisition of Agri-biotech Applications (ISAAA). ISAAA annually reports and documents global status of commercialized biotech crops. Such reports contain the global area of biotech crops and number of countries planting biotech crops.

Per capita GDP, GDP, and population variables are obtained from the World Bank's World Development Indicators (WDI).

The IPR index is based on the Ginarte & Park (1997) and Park (2008) index which incorporates five aspects of patent laws for all countries around the world - the extent of coverage, membership in international patent agreements, duration of protection, provision for loss of protection, and enforcement mechanisms. The index is scored from 0 to 5, with higher values indicating stronger patent protection. The index is an unweighted sum of the values of all the categories, which implies that the categories have equal weights. Although this assumption seems impractical given that some aspects of the index might be weighted more than others by innovators, a sensitivity test conducted showed that the ranking of countries by patent protection levels is not sensitive to the application of equal weighting of the categories. The index was initially constructed for 110 countries for every 5 years from 1960 to 1990. It was later updated.

With respect to coverage, patents are in general granted for novel, industrial applicable, and non-obvious. However, most countries have, over time, specified unpatentable inventions. In this category, the strength of protection has been measured by the patentability of pharmaceuticals, chemicals, food, plant and animal varieties, surgical products, microorganisms and utility models. The relevance of this index to the present study in part also stems from the fact that GMO-based products fall under one or the other of these industries.

3.7 Results

3.7.1 Relative Strength of IPRs

In this section I report the empirical findings of Chapter 3. To begin, recall hypothesis 3.1 regarding the relationship between the relative strength of destination country IPR and trade in GMO-based industries. Equation (3.5) is the baseline estimation to test the hypothesis that differences in patent strength regime and regulation of GMOs of the destination country relative to the source country affect bilateral trade flows of GMO-based industries. The parameter interpretations come from the trade theory that underlies equation (3.4). The parameters of interest are β_8, β_9, β_{10}, and β_{11}. Specifically, I expect the parameters β_8 and β_9 to be negative reflecting that regulatory difference in GM trade decrease the bilateral trade, and β_{10} to be positive reflecting that similarities in regulation of GM trade increase the bilateral trade.

In this regard I estimated equation (3.5) to test hypothesis 3.1. Tables 3.47 and 3.48 reports the results of specification (3.5) for aggregate and subaggregate industries (Foodstuff, feedstuff, seed oil and fat/veg. oil) while Tables 3.49 through Table 3.52 report the results for individual products/disaggregates. Recall that the variable of interest in specification 3.5 is LP_{kj} (strength of destination country's IPR relative to source country. Recall that I capture IPR_{kj} as a measure of intellectual property protection strength of k relative to j, that is, the ratio of destination country IPR to source country) which when natural logarithms are taken amounts to the difference between the levels.

The coefficient for this proxy variable in the aggregate and in each of the four subaggregates (foodstuff, feedstuff, seed oil and fat/veg. oil) is consistently negative and significantly different from zero (see Tables 3.47 and 3.48). These results imply that strengthening of IPRs in the destination relative to the source country reduces trade in across these GMO-based industries. While negative effect of IPRs is observed for the aggregate and subaggregate industries, the results are mixed for individual products. The relative strength of IPRs in importing countries has a negative and significant effect on trade in 7 out of 14 individual GMO-sensitive products (see Table 3.49 through 3.52). These products cut across the four industries. The impact of IPRs on the rest of the products is insignificant.

In summary, the findings on the relationship between the relative strength of the destination country's IPR and trade in GMO-based industries is not unexpected given the ambiguity in the literature occasioned by the countervailing effects of market expansion and market power. But in general the results at the aggregate and subaggregate level suggest that less of the bilateral trade, especially exports in GMO-based industries is destined for countries with relative strong IPRs. This result is consistent with the market power explanation of the effects of IPRs on trade.

This result contradicts Maskus and Penubarti (1995) findings. Using an augmented version of Helman-Krugman model of monopolistic competition, these authors find that the effect of IPRs on trade ispositive. In particular, they find that stronger patent regimes import more. Elsewhere, Smith (2001) investigated whether foreign patent rights (FPRs) play a more important role in protecting knowledge that is transferred outside the source country and firm relative to knowledge inside the source country. Smith finds that strong foreign IPRs have a net positive market expansion effect on US affiliate sales and that strengthening foreign IPRs increase affiliate sales across countries with strong imitation abilities. Thus, given the theoretical and empirical ambiguity of the effect of IPRs on bilateral trade, these results are not surprising.

3.7.2 Relative strength of the Non-traditional endowments

In this subsection, I report the empirical findings on the hypothesis regarding the relationship between non-traditional factors and bilateral trade in GMO-based industries. I estimated equation (3.6) to test hypothesis 3.2(a) and 3.2(b). The results of this specification are reported in Table 3.53 and 3.54 (for aggregate and subaggregate industries) and in Tables 3.55 through 3.58 (for individual disaggregate industries). In particular, the coefficient on GMO land is consistently positive and significant in the regressions at all levels of industry disaggregation. This means that GMO land has a positive and significant impact on bilateral exports. In other words, the results indicate GMO land in the source countries increase trade in these GMO-based industries.

With regard to R&D, the direction of the impact as well as the significance is mixed. The results indicate that exporting country's R&D stock reduces bilateral trade. The result is consistently negative and significant at the aggregate level and in foodstuffs and fat/vegetable oils. This result is also consistent in 9 of the 14 individual industries cutting across foodstuffs, animal feed, seed oils, and fats or vegetable oils.

The coefficient on the R&D variable of the destination country reveals similar comparable results with the R&D stock of the source country. While coefficient of R&D stock of the destination country is not significant at the aggregate level, it does reveal consistent negative and significant impact on trade foodstuffs, animal feed, seed oils, and fat or vegetable oils subaggregates, as well as in more than half of the 14 GMO-sensitive industries. This result is not unexpected. In theory R&D can boost production through technology spillover but dampens world prices, especially in small open economies. Consequently, one cannot predict a priori the outcome. In the event that the downward price effect washes out the boost in production there is likelihood that the dollar value of net trade might be dampened hence this result.

It is also possible that the R&D stock is not entirely immobile across countries. Indeed, if R&D were mobile across countries, this mobility would diminish the statistical significance of the parameter on the R&D variable.

Finally, the parameter estimate for IPRs (LP_{kj}) when I include non-traditional endowments is negative and statistically significant in aggregate bilateral trade. However, when I excluded non-traditional endowments as in equation (3.5), parameter estimates of IPR was negative and statistically significant in aggregate and subaggregates, an indication of reduction in bilateral trade. The reduction of bilateral trade was greater at least in the case of aggregate bilateral trade. This result implies that impact of IPR resulted even in less bilateral trade, but it is practically non-trivial and statistically significant, at least in the case of aggregate trade (compare Tables 3.47 and 3.48).

3.7.3 Interaction of the Non-traditional factors and relative strength of IPR

The preceding results showed that bilateral trade in GMO-based industries is sensitive to the strength of the IPR of the destination country relative to the source country. In fact, the results revealed that regardless of the level of aggregation, the stronger the patent protection in the destination country relative to the source country, the less bilateral trade flows of GMO-based sensitive products. However, as an extension, I consider whether the impact of relative strength patent protection varies with non-traditional endowments (biotech land and R&D stock).The idea is to allow relative strength of IPRs to interact with non-traditional factors so that the effect of patent protection on GMO-sensitive trade is different in countries that commercialize GMOs than in GMO-free countries, and more R&D intensive countries than in less R&D intensive countries.

As noted earlier, the expected signs of the impact of these interaction terms are a priori ambiguous. From the estimation of equation (3.7), it turns out that the impact of the interaction of source country GMO land and the relative strength of patent protection in the destination country on bilateral aggregate exports is statistically insignificant at the aggregate and subaggregate level (Tables 3.59 and 3.60). This implies that the impact of the relative strength of intellectual protection on the bilateral trade of GMO-sensitive products does not vary with the amount of GMO land possessed by the source country. In other words, the interaction of GMO-commercialization in the source country and relative strength of patent protection in the destination is irrelevant, at least in the case of aggregate and subaggregate products. But looking at individual product flows (Tables 3.61 through 3.64) only 5 of the 14 individual products have this interaction statistically significant. These products are in foodstuff and oilseed subaggregates and include unmilled maize, maize flour, soybean oil, and rape/colza oil.

In the case of GMO-commercialization in the destination country, although positive parameter estimates on the interaction term indicate that there might be export expansion of aggregate and most subaggregate trade between trading partners, there is a significant reduction of trade in some subaggregates, such as seed oils.

But looking at the disaggregate industries, the results indicate that exports in maize flour, oilcake from colza seeds, and rape, colza, mustard oil from GMO-commercializing country tend to flow more towards an importing country that has relative stronger patent protection. However, exports in unmilled maize and soybean oil fractions from GMO-commercializing country trend to flow less towards an importing country that has relative stronger patent protection than exports from GMO-free country.

By the same token, the results indicate that countries with relatively stronger patent protection tend to attract more maize flour trade, and that trade flows is much more dramatic if the destination country commercializes GMOs than if she remains GMO-free. However, less trade in rape or colza seeds and cottonseeds flows toward such a country.

Further, results from export data show that relative strength of patent protection in destination country decreases bilateral trade in GMO-sensitive industries, especially across *exporting countries* with relatively higher R&D stock. In other words, relative strength of patent protection in the destination country has net negative effect on bilateral trade, and the magnitude is smaller for exporting countries with higher R&D stock. This result is true for aggregate, animal feed, seed oil, and fats or vegetables.

Results from export data also show that the relative strength of patent protection in the destination country decreases bilateral trade in GMO-sensitive industries, especially across *importing countries* with relatively higher R&D stock. In other words, relative strength of patent protection in the destination country has net negative effect on bilateral trade, and the magnitude is smaller for importing countries with higher R&D stock. This result is true for aggregate trade and in foodstuffs, and fats or vegetables.

Overall, one can see that aggregate and subaggregate results do seem to suggest that R&D stock (knowledge capital) confers comparative disadvantage in trade of GMO-sensitive industries. On one hand, this result is somewhat surprising because our expectation is that GMO-sensitive industries are intensive in knowledge capital. On the other hand, the result is not unexpected because closer scrutiny of the data shows that many countries that are leaders of GMO trade are developing countries with modest R&D endowments. A possible explanation is that knowledge capital is unlike traditional endowments more mobile across countries. In other words, it does not fit the traditional immobility of endowments of a particular country. Accordingly, the importance of knowledge capital is not showing up in the statistical results. The breakdown of the immobility assumption relating to knowledge capital is important in the context of GMO-sensitive trade in other way. If knowledge capital is mobile in this context, then national differences in policy (such as IPRs) that affect the movement of knowledge capital become relevant. In fact some of the empirical results show that there is more GMO-sensitive trade when the IPRs of the importing country are strong relative to the IPRs of the exporting country.

3.7.4 RTAs and Regulatory Differences

Because of the complexities and overlapping nature of FTAs, I employed regional dummies as proxies for FTAs. I include two layers of Regional Trade Area (RTA) dummies. I consider the case where both *j* and *k* are in the same RTA (RTA_{jk}). This case is intended to capture trade creation. The second case is specific paired RTAs which I employed to gauge trade friction/diversion, especially when countries trade GMO-sensitive products. The results show that the estimate on RTA_{jk} is positive and significant indicating that trade is *created* when the exporter and importer countries are in the same FTA. However, trade is not necessarily *diverted* if the two countries are in different FTAs (e.g. if j is in NAFTA and k is in the EU). In the wake of GMO commercialization, there is greater scrutiny of trade flows, especially when GMO-sensitive industries are thought to have been "contaminated" with GMOs. Thus, one would expect trade diversion to have occurred, especially between NAFTA and the EU. The absence of trade diversion can in part be explained by reliance on transitional laws used to regulate GMOs or related products. Even though they appear to vigorously oppose GMOs or related products, many developing countries do not have mechanisms in place to fully regulate GMOs, especially for the forms in which these products cross borders. This result also says something about the policies of developed countries such as those in the EU, especially the efficacy of moratorium on GMO-sensitive industries. In addition, some of the absence of clarity in the current international trade regimes and agreements, including those governing agricultural biotechnology (the WTO, NAFTA, MERCOSUR) were negotiated before GMOs were released into the international market (Gaisford, 2002). Thus, the result showing that trade is not diverted at such result does not come as a surprise.

3.7.5 Other results

Although not the focus of the present study, the results of the other key variables are worth mentioning. In all the specifications, the magnitude and direction of the impact of most variables largely remain the same. For example, the results consistently show that estimates on GDP per capita and GDP (income) of both the source and destination countries are positive and highly significant consistent with theory predictions.

The positive impact of these variables is a reflection that a country's size and economic development are positively related to bilateral trade. This is consistent with theoretical expectations. For example, an increase in exporter's income is expected to raise domestic demand which in turn puts upward pressure on domestic prices but which subsequently aids world prices of the commodities of the industries in question. Rational expectations of domestic economic agents increases economic activities notably production. For example, more households will be willing to supply labor as a result of more firms hiring and raising wages due to expected rise in revenues and hence profits. The overall impact this heightened economic activity increases outward trade. In the case of an increase in the importing country's income, increases in demand for foreign goods and services and trade increases. These results in general confirm the theoretical expectation that the higher the incomes the more trade between them (Feenstra, Markusen, & Rose, 1998).

In trade theory, distance and related variables are often employed as proxies for transactional costs. As the distance between two countries increases, the transaction costs are generally higher. The estimate on the distance variable (D_{jk}), for example, is negative and significant, indicating that geographic distance between any pair trading county dampens bilateral trade. Again, as the distance between two countries increases, the transaction costs are generally higher which in turn increases prices. As a result, world demand falls and bilateral trade falls too.

3.7.6 Robustness check

To deal with uncertainty that may be present in the data and hence results, I employed sensitivity analysis. Often, two approaches are used to check robustness. One is with respect to alternative explanatory variables. For this purpose I used current R&D stock (contemporaneous R&D) or lagged form. However, I also utilized cumulated R&D stock which made the use of past R&D investments to check robustness redundant. This is because R&D stock would have taken into consideration past investments as well. In any case, using these alternative variables yielded comparable results. But because of the difficulty associated with identifying appropriate lag structure and optimal lag length, the use of R&D stock are the results that I report. The other approach to check robustness involves alternative methods for estimation. I considered estimations such as seeming unrelated regression (SUR) in Chapter 2 and the Heckman selection bias model in Chapter 3.

Given that I constructed the aggregate and subaggregate trades from the individual industry trade flows, specifications for the aggregate, subaggregate, and individual industries are indeed system of related equations. One might assume contemporaneous correlation of errors across individual industry equations. For this reason, I estimated a seeming unrelated regression (SUR) to see whether efficiency of parameter estimates improves. But given that the independent variables are the same across equations, the SUR estimation yielded exactly the same results as equation by equation estimation of linear-log model (compare results in Table 2.29 through 2.33 in Section 2.6.5 with Table A.65 through A.68 in the Appendix). Linear-log and SUR models yield exactly the same parameter estimates, both in terms of magnitudes and significance. The standard errors of the linear-log model are marginally smaller.

The Heckman selection bias model to robustness check was necessary because the estimated correlation between the outcome equation (Heckman regression) and the selection equation is statistically different from zero based on the likelihood ratio test across specifications for any level of aggregation (Tables A.69 through A.73 in the Appendix). These results clearly indicate that it is not appropriate to estimate bilateral trade flows using a linear-log model and that disregarding *missing* or *zero* trade flows are likely to lead to bias due to non-random sample selection. Again, for the non-traditional factors, the results are comparable with log -linear model. However, when small values are added to the dependent variable (1E-10) to estimate log-log model, the bias appears to disappear given that results of log-log model and the Heckman model are comparable. Robustness checks clearly reveal that the trade data at the various levels of aggregation appear to stand up to not only the alternative methods employed, but also to variables consistent with theory.

Table 3.46: Key to industries in Tables 3.37, 3.38, 3.40, 3.41, 3.43, 3.44

1	Maize seed
2	Other maize, unmilled
3	Maize corn flour
4	Groats and meal of maize corn
5	Bran, sharps and other residues, of maize
6	Oilcake and other solid residues of oil from soybeans
7	Oilcake and other solid residues of oil from colza seeds rape or colza.
8	Soybeans
9	Rape or colza seeds
10	Cottonseeds
11	Soybean oil, fractions
12	Cottonseed oil and its fractions
13	Maize corn oil, fractions 1
14	Rape, colza, mustard oil

Source: UNCOMTRADE

Table 3.47: Aggregate and subaggregates bilateral trade estimates (Specification 3.5)

VARIABLES	Aggregate	Foodstuffs	Animal feed
$Log(GDPPC_j)$	3.435***	2.022***	1.545***
	(0.221)	(0.193)	(0.156)
$Log(pop_j)$	3.790***	2.611***	1.887***
	(0.117)	(0.110)	(0.104)
$Log(GDPPC_k)$	3.815***	2.387***	1.276***
	(0.231)	(0.200)	(0.151)
$Log(pop_k)$	2.325***	1.529***	0.766***
	(0.122)	(0.107)	(0.0874)
$Log(Dist_{jk})$	-3.776***	-2.515***	-2.020***
	(0.301)	(0.263)	(0.229)
$Cont_{jk}$	9.134***	12.25***	9.275***
	(1.247)	(1.342)	(1.459)
$RTA\_{}_{jk}$	7.401***	7.145***	4.902***
	(0.789)	(0.761)	(0.704)
$NAFTA_j\_EU_k$	4.985***	4.936***	-0.572
	(1.718)	(1.813)	(1.522)
$Merco_j\_EU_k$	14.85***	10.50***	12.15***
	(1.592)	(1.539)	(1.761)
$Merco_j\_NAFTA_k$	19.27***	14.12***	1.302
	(3.642)	(5.182)	(3.436)
LP_{kj}	-5.483***	-2.984***	-1.302**
	(0.908)	(0.759)	(0.550)
Constant	-151.4***	-106.6***	-73.79***
	(5.273)	(4.788)	(4.122)
Observations	5113	5113	5113
R-squared	0.394	0.320	0.262

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.48: Subaggregate bilateral trade estimates (Specification 3.5)

VARIABLES	Seed oil	Fat/Veg. oil
$Log(GDPPC_j)$	2.151***	3.157***
	(0.177)	(0.183)
$Log(pop_j)$	2.070***	2.723***
	(0.106)	(0.108)
$Log(GDPPC_k)$	2.334***	1.841***
	(0.173)	(0.193)
$Log(pop_k)$	1.244***	1.213***
	(0.0983)	(0.107)
$Log(Dist_{jk})$	-1.823***	-3.006***
	(0.248)	(0.259)
$Cont_{jk}$	11.37***	9.979***
	(1.370)	(1.320)
RTA_{jk}	5.417***	5.615***
	(0.721)	(0.767)
$NAFTA_j\_EU_k$	6.896***	-1.465
	(2.081)	(1.721)
$Merco_j\_EU_k$	7.807***	6.173***
	(1.610)	(1.418)
$Merco_j\_NAFTA_k$	15.68***	3.018
	(5.677)	(4.357)
LP_{kj}	-1.893***	-2.315***
	(0.652)	(0.703)
Constant	-100.9***	-104.5***
	(4.580)	(4.667)
Observations	5113	5113
R-squared	0.281	0.321

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.49: Disaggregate bilateral trade estimates (Specification 3.5)

	Foodstuffs			
VARIABLES/Industries	1	2	3	4
$Log(GDPPC_j)$	1.129***	1.409***	1.262***	0.989***
	(0.151)	(0.162)	(0.133)	(0.119)
$Log(pop_j)$	1.303***	1.646***	1.167***	1.110***
	(0.0868)	(0.0997)	(0.0806)	(0.0809)
$Log(GDPPC_k)$	0.940***	1.441***	1.241***	0.907***
	(0.145)	(0.164)	(0.131)	(0.127)
$Log(pop_k)$	0.876***	0.798***	0.618***	0.471***
	(0.0843)	(0.0907)	(0.0738)	(0.0673)
$Log(Dist_{jk})$	-1.489***	-2.022***	-0.578***	-1.135***
	(0.209)	(0.229)	(0.172)	(0.169)
$Cont_{jk}$	12.27***	12.04***	8.618***	7.223***
	(1.468)	(1.417)	(1.299)	(1.281)
RTA_jk	5.340***	4.896***	3.997***	3.162***
	(0.678)	(0.704)	(0.563)	(0.530)
NAFTAj_EUk	3.898**	6.583***	0.259	-0.837
	(1.700)	(1.833)	(1.398)	(1.226)
Mercoj_EUk	4.172***	9.620***	3.449***	2.152***
	(1.187)	(1.571)	(1.097)	(0.832)
Mercoj_NAFTA	6.825	-3.350***	8.371	1.989
	(5.371)	(1.068)	(5.102)	(3.027)
LP_{kj}	-1.136**	-1.034*	-0.282	-1.556***
	(0.537)	(0.617)	(0.425)	(0.411)
Constant	-63.83***	-70.26***	-69.59***	-55.96***
	(3.717)	(4.111)	(3.525)	(3.171)
Observations	5113	5113	5113	5113
R-squared	0.245	0.263	0.188	0.192

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.50: Disaggregate bilateral trade estimates (Specification 3.5)

	Animal feed		
VARIABLES/Industries	5	6	7
$Log(GDPPC_j)$	0.558***	1.357***	0.316***
	(0.0807)	(0.147)	(0.0851)
$Log(pop_j)$	0.519***	1.598***	0.455***
	(0.0615)	(0.100)	(0.0582)
$Log(GDPPC_k)$	0.310***	1.084***	0.595***
	(0.0687)	(0.141)	(0.0826)
$Log(pop_k)$	0.206***	0.571***	0.325***
	(0.0447)	(0.0819)	(0.0532)
$Log(Dist_{jk})$	-0.447***	-1.539***	-1.126***
	(0.124)	(0.211)	(0.155)
$Cont_{jk}$	7.257***	8.304***	8.001***
	(1.204)	(1.440)	(1.350)
RTA_jk	0.548	3.939***	2.351***
	(0.348)	(0.650)	(0.481)
NAFTAj_EUk	0.925	-0.905	-1.601***
	(1.099)	(1.382)	(0.202)
Mercoj_EUk	0.490	12.05***	0.384
	(0.526)	(1.778)	(0.384)
Mercoj_NAFTA	-0.718**	2.020	-0.813***
	(0.337)	(3.481)	(0.305)
LP_{kj}	0.337	-1.608***	-0.343
	(0.261)	(0.497)	(0.279)
Constant	-38.87***	-66.80***	-34.25***
	(2.450)	(3.901)	(2.210)
Observations	5113	5113	5113
R-squared	0.133	0.223	0.203

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.51: Disaggregate bilateral trade estimates (Specification 3.5)

	Seed oil		
VARIABLES/Industries	8	9	10
$Log(GDPPC_j)$	1.599***	1.192***	0.256***
	(0.152)	(0.126)	(0.0740)
$Log(pop_j)$	1.720***	0.734***	0.289***
	(0.102)	(0.0694)	(0.0485)
$Log(GDPPC_k)$	1.528***	1.219***	0.303***
	(0.146)	(0.123)	(0.0675)
$Log(pop_k)$	0.839***	0.586***	0.206***
	(0.0841)	(0.0747)	(0.0421)
$Log(Dist_{jk})$	-1.107***	-1.627***	0.000494
	(0.208)	(0.210)	(0.0957)
$Cont_{jk}$	12.02***	7.847***	4.228***
	(1.406)	(1.365)	(0.998)
RTA_jk	3.427***	4.174***	0.644*
	(0.615)	(0.642)	(0.330)
NAFTAj_EUk	8.012***	-0.208	1.331
	(2.108)	(1.337)	(1.062)
Mercoj_EUk	8.245***	-0.216	-0.404***
	(1.621)	(0.456)	(0.0987)
Mercoj_NAFTA	13.19**	2.177	-0.714***
	(5.613)	(4.055)	(0.215)
LPkj	-0.750	-1.095***	-0.0289
	(0.531)	(0.424)	(0.209)
Constant	-83.09***	-51.90***	-36.16***
	(4.067)	(3.331)	(2.284)
Observations	5113	5113	5113
R-squared	0.243	0.214	0.060

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.52: Disaggregate bilateral trade estimates (Specification 3.5)

	Fat/Veg. oil			
VARIABLES/Industries	11	12	13	14
$Log(GDPPC_j)$	2.281***	0.644***	1.270***	1.984***
	(0.157)	(0.0902)	(0.126)	(0.147)
$Log(pop_j)$	1.884***	0.559***	1.092***	1.487***
	(0.0984)	(0.0631)	(0.0832)	(0.0886)
$Log(GDPPC_k)$	0.806***	0.354***	0.750***	1.775***
	(0.160)	(0.0857)	(0.127)	(0.146)
$Log(pop_k)$	0.644***	0.172***	0.372***	0.775***
	(0.0944)	(0.0471)	(0.0706)	(0.0849)
$Log(Dist_{jk})$	-2.196***	-0.326***	-1.196***	-1.850***
	(0.234)	(0.118)	(0.174)	(0.216)
$Cont_{jk}$	9.128***	5.404***	9.274***	7.301***
	(1.388)	(1.097)	(1.342)	(1.374)
RTA_jk	4.229***	0.491	3.252***	5.136***
	(0.715)	(0.369)	(0.589)	(0.690)
NAFTAj_EUk	-3.391***	-1.768***	-1.093	1.581
	(1.234)	(0.518)	(1.175)	(1.750)
Mercoj_EUk	7.209***	0.673	1.727**	-1.434***
	(1.471)	(0.661)	(0.865)	(0.368)
Mercoj_NAFTA	1.757	-0.852**	2.321	-3.096***
	(4.046)	(0.372)	(3.270)	(1.039)
LPkj	-0.886	0.252	-0.960**	-1.379***
	(0.562)	(0.279)	(0.469)	(0.499)
Constant	-72.14***	-41.09***	-54.52***	-77.41***
	(4.099)	(2.622)	(3.108)	(3.786)
Observations	5113	5113	5113	5113
R-squared	0.245	0.092	0.200	0.261

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.53: Aggregate and subaggregate bilateral trade estimates (Specification 3.6)

VARIABLES/Industries	Aggregate	Foodstuffs	Animal Feed
$Log(GDPPC_j)$	3.664***	2.251***	1.622***
	(0.228)	(0.201)	(0.162)
$Log(pop_j)$	3.442***	2.290***	1.701***
	(0.124)	(0.114)	(0.100)
$Log(GDPPC_k)$	3.687***	2.278***	1.233***
	(0.238)	(0.204)	(0.158)
$Log(pop_k)$	2.307***	1.505***	0.812***
	(0.131)	(0.115)	(0.0985)
$Log(Dist_{jk})$	-4.434***	-3.088***	-2.289***
	(0.313)	(0.277)	(0.240)
$Cont_{jk}$	8.642***	11.87***	9.274***
	(1.203)	(1.305)	(1.470)
RTA_jk	6.350***	6.289***	4.523***
	(0.800)	(0.762)	(0.714)
NAFTAj_EUk	2.036	2.191	-1.851
	(1.751)	(1.874)	(1.557)
Mercoj_EUk	10.94***	6.807***	10.37***
	(1.669)	(1.615)	(1.830)
Mercoj_NAFTA	14.80***	9.899*	-0.547
	(3.687)	(5.323)	(3.509)
LPkj	-3.601***	-1.259	0.108
	(0.974)	(0.808)	(0.587)
GMO_J	4.910***	4.655***	2.311***
	(0.492)	(0.447)	(0.368)
GMO_K	0.416	0.433	-0.242
	(0.434)	(0.394)	(0.318)
LnR&Dj	-0.494***	-0.535***	-0.0339
	(0.169)	(0.142)	(0.0997)
LnR&Dk	-0.274	-0.259*	-0.287**
	(0.177)	(0.150)	(0.128)
Constant	-148.6***	-105.4***	-72.79***
	(6.516)	(5.806)	(4.891)
Observations	4971	4971	4971
R-squared	0.415	0.345	0.275

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.54: Subaggregate bilateral trade estimates (Specification 3.6)

VARIABLES/Industries	Seed oil	Fat/Veg. oil
$Log(GDPPC_j)$	2.206***	3.386***
	(0.186)	(0.190)
$Log(pop_j)$	1.843***	2.559***
	(0.106)	(0.111)
$Log(GDPPC_k)$	2.274***	1.857***
	(0.178)	(0.204)
$Log(pop_k)$	1.274***	1.280***
	(0.109)	(0.115)
$Log(Dist_{jk})$	-2.231***	-3.399***
	(0.263)	(0.273)
$Cont_{jk}$	11.16***	9.938***
	(1.371)	(1.301)
RTA_jk	4.765***	5.036***
	(0.736)	(0.781)
NAFTAj_EUk	5.325**	-3.143*
	(2.099)	(1.763)
Mercoj_EUk	5.740***	3.967***
	(1.662)	(1.496)
Mercoj_NAFTA	13.34**	0.641
	(5.696)	(4.404)
LPkj	-0.525	-1.117
	(0.706)	(0.769)
GMO_J	2.707***	2.761***
	(0.414)	(0.444)
GMO_K	0.0241	-0.222
	(0.368)	(0.372)
LnR&Dj	0.0156	-0.431***
	(0.123)	(0.125)
LnR&Dk	-0.256*	-0.356**
	(0.136)	(0.152)
Constant	-96.69***	-109.4***
	(5.386)	(5.666)
Observations	4971	4971
R-squared	0.294	0.334

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.55: Disaggregate bilateral trade estimates (Specification 3.6)

	Foodstuffs			
VARIABLES/Industries	1	2	3	4
Log($GDPPC_j$)	1.266***	1.673***	1.281***	1.037***
	(0.157)	(0.172)	(0.147)	(0.124)
Log(pop_j)	1.050***	1.510***	1.047***	1.068***
	(0.0861)	(0.102)	(0.0848)	(0.0810)
Log($GDPPC_k$)	0.879***	1.468***	1.275***	0.906***
	(0.150)	(0.169)	(0.137)	(0.134)
Log(pop_k)	0.805***	0.839***	0.630***	0.469***
	(0.0905)	(0.0997)	(0.0789)	(0.0754)
Log($Dist_{jk}$)	-1.976***	-2.462***	-0.792***	-1.248***
	(0.229)	(0.246)	(0.185)	(0.180)
$Cont_{jk}$	11.88***	11.90***	8.566***	7.346***
	(1.447)	(1.415)	(1.315)	(1.302)
RTA_jk	4.616***	4.280***	3.682***	3.018***
	(0.678)	(0.711)	(0.572)	(0.537)
NAFTAj_EUk	1.676	4.915***	-0.558	-1.325
	(1.743)	(1.889)	(1.423)	(1.250)
Mercoj_EUk	1.307	7.466***	2.372**	1.509*
	(1.231)	(1.636)	(1.143)	(0.883)
Mercoj_NAFTA	3.213	-5.845***	6.850	1.188
	(5.513)	(0.942)	(5.098)	(3.070)
LPkj	-0.474	0.0746	0.500	-1.279***
	(0.579)	(0.649)	(0.476)	(0.453)
GMOJ	3.715***	2.713***	1.435***	0.789***
	(0.367)	(0.388)	(0.320)	(0.291)
GMOk	0.923***	0.0555	0.373	0.143
	(0.318)	(0.334)	(0.283)	(0.250)
LnR&Dj	-0.468***	-0.532***	0.0427	-0.131*
	(0.0990)	(0.115)	(0.100)	(0.0741)
LnR&Dk	-0.117	-0.348***	-0.315***	-0.0778
	(0.113)	(0.129)	(0.0999)	(0.102)
Constant	-61.25***	-76.17***	-69.30***	-56.77***
	(4.445)	(5.012)	(4.264)	(3.680)
Observations	4971	4971	4971	4971
R-squared	0.272	0.281	0.197	0.197

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.56: Disaggregate bilateral trade estimates (Specification 3.6)

	Animal feed		
VARIABLES/Industries	5	6	7
Log($GDPPC_j$)	0.665***	1.380***	0.323***
	(0.0859)	(0.152)	(0.0873)
Log(pop_j)	0.486***	1.436***	0.387***
	(0.0600)	(0.0940)	(0.0579)
Log($GDPPC_k$)	0.316***	1.019***	0.596***
	(0.0705)	(0.149)	(0.0865)
Log(pop_k)	0.245***	0.578***	0.352***
	(0.0503)	(0.0925)	(0.0596)
Log($Dist_{jk}$)	-0.559***	-1.722***	-1.257***
	(0.136)	(0.222)	(0.167)
$Cont_{jk}$	7.308***	8.351***	8.092***
	(1.224)	(1.459)	(1.373)
RTA_jk	0.395	3.693***	2.172***
	(0.357)	(0.660)	(0.484)
NAFTAj_EUk	0.385	-1.876	-2.008***
	(1.115)	(1.423)	(0.258)
Mercoj_EUk	-0.191	10.65***	-0.159
	(0.562)	(1.842)	(0.418)
Mercoj_NAFTA	-1.325***	0.541	-1.431***
	(0.334)	(3.542)	(0.357)
LPkj	0.705***	-0.543	0.170
	(0.270)	(0.534)	(0.307)
GMOJ	0.843***	1.817***	0.747***
	(0.194)	(0.340)	(0.234)
GMOk	-0.274*	-0.0443	-0.0727
	(0.164)	(0.301)	(0.187)
LnR&Dj	-0.188***	0.0206	0.0603
	(0.0548)	(0.0861)	(0.0517)
LnR&Dk	-0.0922	-0.163	-0.150**
	(0.0671)	(0.121)	(0.0611)
Constant	-41.73***	-63.94***	-33.46***
	(2.776)	(4.541)	(2.655)
Observations	4971	4971	4971
R-squared	0.142	0.233	0.211

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.57: Disaggregate bilateral trade estimates specification 3.6

	Seed oil		
VARIABLES/Industries	8	9	10
$Log(GDPPC_j)$	1.707***	1.067***	0.366***
	(0.162)	(0.134)	(0.0820)
$Log(pop_j)$	1.583***	0.579***	0.284***
	(0.102)	(0.0687)	(0.0473)
$Log(GDPPC_k)$	1.513***	1.128***	0.362***
	(0.154)	(0.125)	(0.0708)
$Log(pop_k)$	0.895***	0.525***	0.246***
	(0.0950)	(0.0803)	(0.0484)
$Log(Dist_{jk})$	-1.408***	-1.815***	-0.0940
	(0.221)	-0.221	(0.101)
$Cont_{jk}$	11.96***	7.811***	4.229***
	(1.416)	(1.384)	(1.010)
RTA_jk	2.970***	3.872***	0.521
	(0.629)	(0.646)	(0.333)
NAFTAj_EUk	6.852***	-0.813	0.950
	(2.128)	(1.347)	(1.083)
Mercoj_EUk	6.740***	-1.051**	-0.868***
	(1.666)	(0.521)	(0.184)
Mercoj_NAFTA	11.60**	0.973	-1.255***
	(5.649)	(4.027)	(0.252)
LPkj	0.317	-0.593	0.188
	(0.564)	(0.497)	(0.243)
GMOJ	1.950***	1.183***	0.562***
	(0.352)	(0.330)	(0.167)
GMOK	-0.233	0.553*	-0.0853
	(0.317)	(0.285)	(0.161)
$Log(R\&D_j)$	-0.100	0.274***	-0.216***
	(0.0986)	(0.0794)	(0.0665)
$Log(R\&D_k)$	-0.249**	-0.00473	-0.169***
	(0.122)	(0.0919)	(0.0554)
Constant	-83.48***	-42.54***	-41.12***
	(4.893)	(3.787)	(2.770)
Observations	4971	4971	4971
R-squared	0.253	0.222	0.066

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.58: Disaggregate bilateral trade estimates specification 3.6

	Fat/Veg. oil			
VARIABLES/Industries	11	12	13	14
$Log(GDPPC_j)$	2.450***	0.722***	1.436***	2.002***
	(0.164)	(0.0947)	(0.133)	(0.153)
$Log(pop_j)$	1.740***	0.542***	1.149***	1.420***
	(0.0980)	(0.0628)	(0.0868)	(0.0884)
$Log(GDPPC_k)$	0.785***	0.340***	0.943***	1.787***
	(0.170)	(0.0906)	(0.135)	(0.153)
$Log(pop_k)$	0.718***	0.187***	0.437***	0.811***
	(0.102)	(0.0504)	(0.0790)	(0.0920)
$Log(Dist_{jk})$	-2.448***	-0.416***	-1.440***	-2.000***
	(0.249)	(0.131)	(0.190)	(0.227)
$Cont_{jk}$	9.208***	5.425***	9.346***	7.446***
	(1.393)	(1.117)	(1.356)	(1.390)
RTA_jk	3.870***	0.358	2.930***	4.913***
	(0.729)	(0.379)	(0.598)	(0.699)
NAFTAj_EUk	-4.621***	-2.186***	-1.406	1.059
	(1.283)	(0.547)	(1.199)	(1.773)
Mercoj_EUk	5.524***	0.170	1.495	-2.082***
	(1.542)	(0.700)	(0.912)	(0.461)
Mercoj_NAFTA	0.203	-1.293***	1.585	-3.857***
	(4.056)	(0.385)	(3.274)	(1.061)
LPkj	0.330	0.413	-0.892*	-0.794
	(0.627)	(0.301)	(0.528)	(0.566)
GMOJ	2.119***	0.607***	0.280	0.866**
	(0.394)	(0.211)	(0.295)	(0.351)
GMOK	-0.548*	-0.157	0.290	-0.0690
	(0.316)	(0.173)	(0.254)	(0.304)
$Log(R\&D_j)$	-0.235**	-0.167***	-0.330***	0.0689
	(0.0997)	(0.0549)	(0.0818)	(0.0890)
$Log(R\&D_k)$	-0.250*	0.00382	-0.429***	-0.206*
	(0.130)	(0.0647)	(0.106)	(0.112)
Constant	-74.89***	-42.43***	-64.77***	-77.23***
	(4.870)	(2.871)	(3.978)	(4.495)
Observations	4971	4971	4971	4971
R-squared	0.257	0.097	0.209	0.267

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.59: Aggregate and subaggregate bilateral trade (Exports) estimates specification 3.7

VARIABLES	Aggregate	Foodstuffs	Animal feed
$Log(GDPPC_j)$	3.622***	2.255***	1.609***
	(0.230)	(0.202)	(0.162)
$Log(GDPPC_k)$	3.712***	2.310***	1.190***
	(0.238)	(0.205)	(0.157)
$Log(pop_j)$	3.404***	2.270***	1.710***
	(0.126)	(0.115)	(0.102)
$Log(pop_k)$	2.316***	1.505***	0.804***
	(0.132)	(0.116)	(0.0984)
$Log(Dist_{jk})$	-4.422***	-3.054***	-2.298***
	(0.313)	(0.277)	(0.240)
$Conti_{jk}$	8.677***	11.94***	9.232***
	(1.202)	(1.308)	(1.470)
RTA_{jk}	6.388***	6.352***	4.498***
	(0.799)	(0.763)	(0.714)
$NAFTA_j\_EU_k$	2.039	2.310	-1.977
	(1.746)	(1.877)	(1.569)
$Merco_j\_EU_k$	10.86***	7.339***	9.846***
	(1.750)	(1.687)	(1.915)
$Merco_j\_NAFTA_k$	14.52***	10.18*	-0.983
	(3.725)	(5.322)	(3.513)
LP_{kj}	-23.69***	-6.670	-4.215
	(5.847)	(4.626)	(3.490)
GMO_j	4.952***	4.513***	2.457***
	(0.505)	(0.464)	(0.393)
GMO_k	0.379	0.377	-0.228
	(0.442)	(0.399)	(0.325)
$Log(R\&D_j)$	-0.239	-0.526***	0.0278
	(0.184)	(0.153)	(0.107)
$Log(R\&D_k)$	-0.378**	-0.316**	-0.259**
	(0.179)	(0.155)	(0.128)
$GMO_j \times LP_{kj}$	0.590	-1.840	1.967
	(1.716)	(1.545)	(1.232)
$GMO_k \times LP_{kj}$	0.947	1.402	-0.365
	(1.400)	(1.168)	(0.813)
$R\&D_j \times LP_{kj}$	-1.397***	0.0103	-0.389*
	(0.403)	(0.296)	(0.233)
$R\&D_k \times LP_{kj}$	-0.751*	-0.600*	-0.0522
	(0.403)	(0.320)	(0.242)
Constant	-146.8***	-106.1***	-71.45***
	(6.599)	(5.858)	(4.874)
Observations	4971	4971	4971
R-squared	0.416	0.346	0.276

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.60: Subaggregate bilateral trade (Exports) estimates specification 3.7

VARIABLES	Seed oil	Fat/Veg. oil
$Log(GDPPC_j)$	2.122***	3.341***
	(0.186)	(0.190)
$Log(GDPPC_k)$	2.289***	1.897***
	(0.179)	(0.203)
$Log(pop_j)$	1.785***	2.510***
	(0.108)	(0.113)
$Log(pop_k)$	1.285***	1.291***
	(0.109)	(0.116)
$Log(Dist_{jk})$	-2.239***	-3.380***
	(0.263)	(0.273)
$Conti_{jk}$	11.18***	9.998***
	(1.371)	(1.306)
RTA_{jk}	4.808***	5.097***
	(0.734)	(0.780)
$NAFTA_j\_EU_k$	5.474***	-3.054*
	(2.091)	(1.764)
$Merco_j\_EU_k$	5.967***	4.199***
	(1.719)	(1.588)
$Merco_j\_NAFTA_k$	13.76**	0.660
	(5.664)	(4.438)
LP_{kj}	-11.42***	-19.91***
	(4.289)	(4.540)
GMO_j	2.642***	2.714***
	(0.434)	(0.456)
GMO_k	0.131	-0.246
	(0.376)	(0.383)
$Log(R\&D_j)$	0.268**	-0.191
	(0.129)	(0.142)
$Log(R\&D_k)$	-0.181	-0.451***
	(0.138)	(0.149)
$GMO_j \times LP_{kj}$	-0.655	-0.570
	(1.444)	(1.510)
$GMO_k \times LP_{kj}$	-1.751*	0.889
	(1.028)	(1.072)
$R\&D_j \times LP_{kj}$	-1.395***	-1.285***
	(0.313)	(0.280)
$R\&D_k \times LP_{kj}$	0.180	-0.742**
	(0.286)	(0.326)
Constant	-92.45***	-107.8***
	(5.390)	(5.724)
Observations	4971	4971
R-squared	0.296	0.336

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.61: Disaggregate bilateral trade estimates (Specification 3.7)

	Foodstuffs			
VARIABLES	1	2	3	4
Log($GDPPC_j$)	1.236***	1.666***	1.323***	1.017***
	(0.154)	(0.172)	(0.146)	(0.122)
Log($GDPPC_k$)	0.885***	1.486***	1.229***	0.905***
	(0.150)	(0.171)	(0.135)	(0.131)
Log(pop_j)	1.032***	1.476***	1.071***	1.053***
	(0.0865)	(0.100)	(0.0846)	(0.0817)
Log(pop_k)	0.831***	0.822***	0.594***	0.466***
	(0.0919)	(0.100)	(0.0793)	(0.0750)
Log($Dist_{jk}$)	-1.999***	-2.426***	-0.777***	-1.240***
	(0.227)	(0.246)	(0.185)	(0.179)
$Conti_{jk}$	11.84***	12.00***	8.580***	7.365***
	(1.448)	(1.418)	(1.318)	(1.302)
RTA_{jk}	4.588***	4.371***	3.689***	3.039***
	(0.674)	(0.711)	(0.571)	(0.536)
$NAFTA_j\_EU_k$	1.850	5.086***	-0.701	-1.302
	(1.744)	(1.884)	(1.427)	(1.254)
$Merco_j\_EU_k$	1.773	8.049***	1.887	1.546
	(1.293)	(1.707)	(1.199)	(0.942)
$Merco_j\_NAFTA_k$	3.713	-5.398***	6.266	1.210
	(5.449)	(1.020)	(5.081)	(3.089)
LP_{kj}	-2.752	-2.455	2.072	-6.443**
	(3.181)	(3.764)	(2.842)	(2.869)
GMO_j	3.529***	2.550***	1.575***	0.780***
	(0.376)	(0.413)	(0.344)	(0.300)
GMO_k	0.981***	0.0244	0.292	0.137
	(0.328)	(0.337)	(0.285)	(0.260)
Log($R\&D_j$)	-0.476***	-0.464***	0.0384	-0.0552
	(0.110)	(0.122)	(0.106)	(0.0802)
Log($R\&D_k$)	-0.201*	-0.270**	-0.244**	-0.0621
	(0.120)	(0.132)	(0.0983)	(0.0929)
$GMO_j \times LP_{kj}$	-1.356	-2.166*	1.603*	-0.0660
	(1.107)	(1.311)	(0.950)	(0.995)
$GMO_k \times LP_{kj}$	-1.370*	1.192	1.777**	0.145
	(0.800)	(0.966)	(0.775)	(0.629)
$R\&D_j \times LP_{kj}$	0.127	-0.282	0.0416	-0.411**
	(0.218)	(0.229)	(0.171)	(0.188)
$R\&D_k \times LP_{kj}$	-0.437*	-0.00186	0.184	-0.142
	(0.229)	(0.274)	(0.199)	(0.191)
Constant	-61.73***	-74.53***	-68.62***	-55.56***
	(4.520)	(4.987)	(4.235)	(3.667)
Observations	4971	4971	4971	4971
R-squared	0.272	0.281	0.197	0.198

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.62: Disaggregate bilateral trade estimates (Specification 3.7)

	Animal feed		
VARIABLES	5	6	7
Log($GDPPC_j$)	0.652***	1.381***	0.322***
	(0.0849)	(0.152)	(0.0866)
Log($GDPPC_k$)	0.309***	0.985***	0.551***
	(0.0684)	(0.148)	(0.0855)
Log(pop_j)	0.479***	1.447***	0.409***
	(0.0609)	(0.0957)	(0.0592)
Log(pop_k)	0.242***	0.565***	0.346***
	(0.0501)	(0.0924)	(0.0599)
Log($Dist_{jk}$)	-0.562***	-1.722***	-1.275***
	(0.136)	(0.222)	(0.168)
$Conti_{jk}$	7.309***	8.330***	8.029***
	(1.224)	(1.460)	(1.374)
RTA_{jk}	0.400	3.677***	2.123***
	(0.355)	(0.660)	(0.483)
$NAFTA_j\_EU_k$	0.395	-1.995	-2.172***
	(1.120)	(1.436)	(0.280)
$Merco_j\_EU_k$	-0.234	10.21***	-0.796*
	(0.586)	(1.922)	(0.484)
$Merco_j\_NAFTA_k$	-1.296***	0.0954	-1.953***
	(0.374)	(3.539)	(0.419)
LP_{kj}	0.180	-4.480	-0.962
	(2.243)	(3.141)	(1.452)
GMO_j	0.854***	1.943***	0.925***
	(0.204)	(0.364)	(0.262)
GMO_k	-0.249	-0.0705	-0.0562
	(0.168)	(0.309)	(0.192)
Log($R\&D_j$)	-0.144***	0.0637	0.0796
	(0.0496)	(0.0945)	(0.0567)
Log($R\&D_k$)	-0.0489	-0.149	-0.133**
	(0.0632)	(0.118)	(0.0658)
$GMO_j \times LP_{kj}$	0.149	1.648	2.350***
	(0.574)	(1.177)	(0.606)
$GMO_k \times LP_{kj}$	-0.395	0.393	-0.537
	(0.499)	(0.731)	(0.401)
$R\&D_j \times LP_{kj}$	-0.249*	-0.266	-0.169*
	(0.149)	(0.215)	(0.0880)
$R\&D_k \times LP_{kj}$	0.189	-0.125	0.0739
	(0.154)	(0.214)	(0.104)
Constant	-40.60***	-63.11***	-32.80***
	(2.722)	(4.530)	(2.675)
Observations	4971	4971	4971
R-squared	0.143	0.234	0.213

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.63: Disaggregate bilateral trade estimates (Specification 3.7)

	Seed oil		
VARIABLES	8	9	10
$Log(GDPPC_j)$	1.670***	1.018***	0.340***
	(0.161)	(0.133)	(0.0819)
$Log(GDPPC_k)$	1.500***	1.131***	0.350***
	(0.154)	(0.126)	(0.0693)
$Log(pop_j)$	1.554***	0.561***	0.276***
	(0.103)	(0.0701)	(0.0481)
Log(popk)	0.884***	0.543***	0.249***
	(0.0950)	(0.0813)	(0.0485)
$Log(Dist_{jk})$	-1.403***	-1.835***	-0.105
	(0.222)	(0.221)	(0.100)
$Conti_{jk}$	11.99***	7.775***	4.207***
	(1.419)	(1.384)	(1.008)
$RTA\_{}_{jk}$	3.011***	3.853***	0.513
	(0.628)	(0.645)	(0.333)
$NAFTA_j\_EU_k$	6.943***	-0.808	0.938
	(2.129)	(1.352)	(1.093)
$mercoj\_EU_k$	6.883***	-1.172**	-1.016***
	(1.715)	(0.578)	(0.269)
$Merco_j\_NAFTA_k$	11.88**	1.001	-1.283***
	(5.628)	(4.041)	(0.314)
LP_{kj}	-1.797	-7.449***	-2.542
	(3.218)	(2.697)	(2.061)
GMO_j	1.903***	1.217***	0.602***
	(0.376)	(0.340)	(0.185)
GMO_k	-0.183	0.626**	-0.0349
	(0.321)	(0.300)	(0.166)
$Log(R\&D_j)$	0.0163	0.388***	-0.148**
	(0.105)	(0.0885)	(0.0605)
$Log(R\&D_k)$	-0.117	-0.0250	-0.140**
	(0.122)	(0.0924)	(0.0570)
$GMO_j \times LP_{kj}$	-0.535	0.615	0.605
	(1.318)	(0.873)	(0.495)
$GMO_k \times LP_{kj}$	-0.684	-1.550**	-0.950*
	(0.823)	(0.679)	(0.506)
$R\&D_j \times LP_{kj}$	-0.626***	-0.679***	-0.401*
	(0.203)	(0.158)	(0.218)
$R\&D_k \times LP_{kj}$	0.382	-0.0785	0.0993
	(0.253)	(0.165)	(0.109)
Constant	-80.26***	-41.15***	-39.78***
	(4.852)	(3.809)	(2.704)
Observations	4971	4971	4971
R-squared	0.254	0.224	0.068

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.64: Disaggregate bilateral trade estimates (Specification 3.7)

	Fat/Veg. oil			
VARIABLES	11	12	13	14
Log($GDPPC_j$)	2.406***	0.738***	1.414***	1.981***
	(0.164)	(0.0954)	(0.131)	(0.152)
Log($GDPPC_k$)	0.845***	0.321***	0.931***	1.762***
	(0.170)	(0.0907)	(0.135)	(0.153)
Log(pop_j)	1.686***	0.556***	1.134***	1.413***
	(0.0982)	(0.0644)	(0.0861)	(0.0896)
Log(popk)	0.736***	0.176***	0.433***	0.801***
	(0.104)	(0.0511)	(0.0787)	(0.0930)
Log($Dist_{jk}$)	-2.426***	-0.417***	-1.427***	-2.006***
	(0.248)	(0.131)	(0.190)	(0.226)
$Conti_{jk}$	9.285***	5.415***	9.359***	7.431***
	(1.393)	(1.117)	(1.359)	(1.389)
RTA_{jk}	3.947***	0.345	2.953***	4.904***
	(0.728)	(0.379)	(0.598)	(0.698)
$NAFTA_j\_EU_k$	-4.402***	-2.277***	-1.422	0.912
	(1.288)	(0.557)	(1.204)	(1.781)
$mercoj\_EU_k$	6.254***	-0.144	1.402	-2.743***
	(1.614)	(0.747)	(0.961)	(0.541)
$Merco_j\_NAFTA_k$	0.773	-1.636***	1.412	-4.542***
	(4.049)	(0.444)	(3.301)	(0.993)
LP_{kj}	-11.37***	0.531	-10.88***	-13.31***
	(3.496)	(2.026)	(2.927)	(3.254)
GMO_j	1.924***	0.697***	0.312	1.063***
	(0.404)	(0.231)	(0.304)	(0.364)
GMO_k	-0.537	-0.192	0.277	-0.0973
	(0.327)	(0.177)	(0.266)	(0.314)
Log($R\&D_j$)	-0.0891	-0.167***	-0.220**	0.269***
	(0.114)	(0.0593)	(0.0941)	(0.104)
Log($R\&D_k$)	-0.316**	0.00990	-0.445***	-0.217**
	(0.130)	(0.0670)	(0.101)	(0.110)
$GMO_j \times LP_{kj}$	-2.446*	1.093	0.506	2.518**
	(1.315)	(0.721)	(0.903)	(1.004)
$GMO_k \times LP_{kj}$	0.235	0.614	0.417	0.574
	(0.849)	(0.463)	(0.692)	(0.791)
$R\&D_j \times LP_{kj}$	-0.744***	-0.00730	-0.608***	-1.135***
	(0.223)	(0.102)	(0.187)	(0.201)
$R\&D_k \times LP_{kj}$	-0.555**	0.0474	-0.456**	-0.168
	(0.257)	(0.148)	(0.188)	(0.232)
Constant	-74.00***	-42.40***	-63.47***	-74.86***
	(4.908)	(2.925)	(3.969)	(4.514)
Observations	4971	4971	4971	4971
R-squared	0.258	0.098	0.209	0.270

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

3.7.7 Conclusion

With regard to the non-traditional endowments, the results in this chapter mirror the discussions of Chapter 2 (trade to the ROW). The impact of biotech land on bilateral trade in GMO-sensitive industries indicates that having a positive amount of biotech land in the source countries increases bilateral trade of GMO-based industries. The effect is consistent across subaggregates and in the entire GMO-based individual product trades sampled in this dissertation. However, the importance of R&D is less informative.

On the institutional and policy front, it appears there are two opposing forces that point to an indeterminate effect of genetic modification and regulatory policies on trade. On one hand, unprecedented adoptions of biotechnology increase yields. On the other hand, the global divergence in GMO regulatory policies cause shifts in consumer demands. Stronger IPRs in the destination country relative to the source country reduces export trade in GMO-based industries. In addition, the results show that even when there are marked regulatory differences and policies (labeling, threshold tolerance levels or total moratorium, and other forms of regulations), trade in GMO-sensitive industries is not necessarily diverted.

CHAPTER 4: CONCLUSION AND POLICY IMPLICATIONS

4.1 Conclusion and Summary of the Results

This dissertation utilized international trade models to study the extent to which non-traditional endowments (R&D stock and GMO land) affect international trade in genetically modified (GMO)-based industries. The role played by these non-traditional endowments in terms of their relationships with trade in GMO-sensitive industries has simply been considered correlation and often discussed in an anecdotal and qualitative manner. Within the framework of the Heckscher-Ohlin (H-O) economists have studied comparative advantage of traditional endowments such as capital and labor as a basis of trade for many decades. But the role played by R&D stock and GMO land in explaining trade in GMO-sensitive industries in the last decade has not been accorded due attention. The present study also explored differences in institutional endowments, including protections offered by relevant regulatory regimes and intellectual property right systems, as they affect GMO-sensitive industries.

The specific research questions I asked were (1) whether 'non-traditional' endowments confer comparative advantage to a country in exporting to the rest of the world, (2) whether a patent strength of the destination country relative to a source country has an impact on the bilateral trade flows of GMO-based industries (3) whether impact of relative strength of intellectual protection (IPRs) on trade in GMO-sensitive industries varies with 'non-traditional endowments (4) whether countries' regulatory differences in GMO-based industries distort (divert or create) bilateral trade in GMO-sensitive industries, especially in the wake of heightened regulation in GMOs and consumer shifts associated with potential health and environmental concerns.

First, I examined countries' exports and net exports of GMO-based industries to the rest of the world under the maintained hypothesis that a country's true abundance of R&D and GMO land correspond with services of net exports of R&D and GMO land, an indication of comparative advantage. The underlying theoretical framework for testing this hypothesis is the factor-content expression of the Heckscher-Ohlin-Vanek (HOV) model. The empirical implementation and method included examination of this relationship via non-parametric and parametric methods using 2006 cross-section data of a three-digit level (also called revision three) of the Standard International Trade Classification (SITC).

In the non-parametric estimation, I examined whether countries with higher non-traditional endowment than the world average also have net exports of embodied endowments. Although ranking of countries according to their relative true R&D endowments does not completely match with ranking according to their net exports of embodied R&D (Table 2.23), there is a significant relationship between trade revealed and true R&D endowment (Table 2.24). Therefore, countries that have revealed relative abundance of R&D also have revealed comparative advantage in goods that make intensive use of the R&D endowment.

In addition, using a non-parametric method, I show that ranking of countries according to their relative true biotech land endowments matches ranking according to their net exports of biotech land embodied trade (Table 2.26). Like R&D stock, I also show that there is significant relationship between trade revealed and relative true biotech land endowment.

In the parametric method, I estimated the effect of the non-traditional and traditional endowments on trade using several methods for comparability and robustness. The methods included various specifications of ordinary least square, Tobit, two-stage least square, and Heckman selection models models. For the ordinary least square case I consider the dependent variable as the actual trade value as well as a trade orientation index. The use of the index takes care of concerns relating to the non-trivial number of trade flows where SITC 3 (exports or imports) were zeros. I found that the results fairly correspond with the results of the non-parametric estimations. With regard to the biotech land, I found that this endowment does confer comparative advantage to a country in exporting to the ROW. This is true for aggregate trade of GMO-sensitive industries as well as for subaggregate industries such as foodstuff, animal feed, oil seeds, and fat/vegetable oil industries. However, I found that R&D stock does not confer comparative advantage or disadvantage to a country in exporting to the ROW, at least in the aggregate trade of GMO-sensitive industries. However, it does moderately confer comparative advantage in predicting countries' exports to the ROW in some subaggregates such as foodstuff and fat/vegetable oil industries. A possible explanation is that R&D stock (knowledge capital) does not fit the traditional immobility of endowments of a particular country, hence is not showing up in the statistical estimations.

Using a three-digit level of the Standard International Trade Classification (SITC) for 2006, I also examined the relationship between the non-traditional endowment and bilateral trade in GMO-based industries via a Gravity model. I employed Bergstrand

(1989) general equilibrium model of world trade. Informed by the literature showing that differences in resource endowments in agricultural industry are also reflected by differences in institutional endowments, I further examined the relationship between regulatory and institutional measures of policy and bilateral trade in GMO-based industries.

Like trade to the ROW, the impact of biotech land on bilateral trade in GMO-sensitive industries indicates that having a positive amount of biotech land in the source countries increases trade of GMO-based industries. The effect is consistent across subaggregates and in the entire GMO-based individual product trades sampled in this dissertation.

I found mixed evidence of the effects of the variables I used as proxies for institutional endowments (protections offered by relevant regulatory regimes and intellectual property right systems) on bilateral trade in GMO-based industries. First, using different levels of data aggregations (for comparability and concordance) and estimation methods (for robustness checks), I show that stronger IPRs in the destination country relative to the source country reduces export trade across GMO-based industries. This effect is consistent at all levels of aggregation. Clearly, this demonstrates market power effect where strengthening IPRs grants monopoly power to importing country firms. This might be the case when countries begin to adjust their regulatory regimes in favor of GMOs by raising the tolerance threshold for products that are produced using GMOs as intermediates. Since biotechnology involves patenting, in the long run this might spark a patent race curtailing trade further.

Using export data, I further show that even when there are marked regulatory differences and policies (labeling, threshold tolerance levels, partial or total moratorium) trade in GMO-sensitive industries is not necessarily diverted. On the face of it, this result appears strange. However, many countries still have transitional laws in regulating GMOs. Accordingly, even when such countries appear to be vigorously opposed to trade in GMOs or related products, they do not have mechanisms in place to fully regulate these products. The result appears to be supported by some studies. For example, Hobbs et al. (2007) write that inability of the regulatory regimes governing international trade makes such trade difficult to monitor. To the extent that such inability exists, trade in GMOs-based industries is not fully curtailed. The uncertainty regarding the level of tolerance of GMOs and forms in which these products cross borders add to the ineffectiveness of the laws governing GMOs. Besides, the absence of clarity in the current international trade regimes and agreements including those governing agricultural biotechnology (the WTO, NAFTA, MERCOSUR) were negotiated before GMOs were released into the international market (Gaisford, 2002). Thus, the result showing that trade is not diverted does not come as a surprise.

In Section 3.7.6, I found that the results are robust both in terms of alternative variables used and method employed. For example, I found that the use of contemporaneous R&D investment or lagged R&D investment yield similar results. But because of the difficulty associated with identifying appropriate lag structure and optimal lag length, I used R&D stock instead. In fact, the use of R&D stock (knowledge capital) which also accounts for past R&D investments renders the search for R&D lag structure and lag length redundant. This is because R&D stock would have taken into consideration past investments as well. With regard to alternative methods, both seeming unrelated regression (SUR) in Chapter 2 and the Heckman selection bias model in Chapter 3 (see Appendix), yielded similar results to linear-log specification.

4.2 Policy implications

One of the key findings of this dissertation is that the non-traditional endowments confer comparative advantage in goods that make intensive use of them, especially in embodied net exports to the ROW. Despite terming these factors endowment in conformity with theory, they are deliberately accumulated. Accordingly, they can have far reaching policy implications. From a policy perspective a shift towards permitting GMOs (increasing GMO land stock) could be effective in increasing the share of GMO land in agricultural land as well as enhancing trade.

In addition, from the results we see that the policy frameworks of countries affect trade in GMO-sensitive industries. The strengthening of patents protection for example interacts with GMO commercialization and R&D stock (knowledge capital. However, given that economic theory conjectures that the effect of IPRs protection on bilateral trade is ambiguous, the direction of influence largely remains an empirical question. In other words, one cannot predict a *priori* whether stronger or weaker IPRs protection increases or reduces bilateral trade. In such a scenario, it becomes difficult to normatively draw a conclusion, especially with regard to what kind of institutional endowment systems to pursue. From the conclusion of the empirical findings of the present chapter, one can see that strengthening of patent protection in the destination country relative to the source country reduces trade in GMO-based industries.

As discussed in Section 3.2, divergent regulatory regimes have made issues related to agricultural biotechnology one of the most contentious issues before the WTO dispute settlement. However, it is not an issue that is limited to board rooms and trade negotiation debates. Rather, in practice, agricultural biotechnology-related exports have been plagued by numerous interruptions in the international markets as evidenced by trade restrictions across the Atlantic and in Asia. For example, the United States corn exports to Europe were effectively outlawed because of European restrictions on GMO corn (Tothova & Oehmke, 2004). In the wake of GMO commercialization, there is greater scrutiny of trade flows occasioned by concerns that GMO-sensitive industries might be "contaminated" with GMOs. Thus, the findings of this dissertation inform the sensitivity of GMO-based industries' trade and whether or not differences in relevant regulatory regimes have enhanced or curtailed trade. But the finding might lend credence to (as pointed out by Drezner, 2007) "the realist approach that assumes America's hegemony would predict the global regulatory outcome to mirror American preferences on GMOs."

4.3 Limitations and areas of further research

The commercialization of GMOs is just a decade old. Although there are many accomplishments in terms of the spread of the technology, empirical literature on trade in GMOs has not rigorously developed. The few rigorous studies that come close tend to use different methodological approaches - simulation and calibration. This may explain the relative paucity of theoretical and empirical studies of GMOs related to the present study. Thus, in analyzing trade in GMO-sensitive industries, many studies accordingly rely on anecdotal and qualitative materials and analyses.

The present study utilized cross-section data for the empirical analysis. Therefore, the study might have missed dynamic changes relating to long-term predictions and cumulative effects of R&D and biotech land. However, changes of these non-traditional endowments were somewhat implicitly addressed. The non-traditional endowments represent stocks containing both contemporaneous and past quantities. Although I measure them at one specific time period, the stock measures take into the cumulative effect. For example, cumulative effect of R&D stock on trade in GMO-sensitive industries takes into account the influence of past R&D investment. The advantage of such measure is that it potentially minimizes any correlation between R&D stock and unmeasured characteristics, and hence ensuring the parameter estimate on R&D is both unbiased and consistent. In addition, the use of panel across time was less relevant. The panel across time was not feasible given that some relevant data was either available for limited number of years or missing altogether. Besides, the descriptive statistics of Chapter 1 showed greater variability across countries than across time. That said, pooled data containing both cross-time effects invariably presents richer estimations. Therefore, one can gain more insight about testing whether there is any unobserved heterogeneity across exporting and importing countries in unmeasured determinants of the bilateral flows of GMO-based industries.

Finally, the Rybczynski estimates for the non-traditional factors as well as traditional factors confirm that some of them confer neither comparative advantage nor disadvantage. However, the explanatory power of these factors is strong for the aggregate, subaggregates, and in most of the individual GMO-based industries. In cases where the explanatory power is modest there is indication that much of the trade prediction is unexplained. It is beyond the scope of the present study for the unexplained trade variations. A further study that disaggregates factors such as labor into subaggregates may account for this unexplained trade. But as discussed in Section 3.6 the data in the present study is limited, and further disaggregation may not possible at this point.

REFERENCES

Abramovitz, M. (1962). Economic growth in the United States. *The American Economic Review, 52*(4), 762-782.

Acar, M., Alpay, S., Bakimli, E., & Koc, Z. Z. (2009). South-East Asian integration in the context of OIC: Implications of free trade among Malaysia, Indonesia and Bangladesh. *Journal of Economic Integration*, *24*(1), 1-18.

Alston, J. M., Norton, G. W., & Pardey, P. G. (1995). *Science under scarcity: Principles and practice for agricultural research evaluation and priority setting* Cornell University Press, Ithaca, NY, 1995.

Anderson, K., Damania, R., & Jackson, L. A. (2006). Trade, standards, and the political economy of genetically modified food. *World Bank Policy Research Working Paper,* No. 3395.)

Anderson, K., Kurzweil, M., Martin, W., Sandri, D., & Valenzuela, E. (2008). Measuring distortions to agricultural incentives, revisited. C.E.P.R. Discussion Papers, CEPR Discussion Papers). *CEPR Discussion Papers, DP6924* ([URL:http://www.cepr.org.floyd.lib.umn.edu/pubs/dps/DP6924.asp] URL)

Anderson, J. E. (1979). A theoretical foundation for the gravity equation. *The American Economic Review, 69*(1), 106-116.

Armington, P. S. (1969). A theory of demand for products distinguished by place of production (une théorie de la demande de produits différenciés d'après leur origine) (una teoría de la demanda de productos distinguiéndolos según el lugar de producción). *Staff Papers - International Monetary Fund, 16*(1), 159-178.

Arrow, K. J. (1962). Economic welfare and the allocation of resources for invention. In R. R. Nelson (Ed.), *The rate and direction of inventive activity* (pp. 609-625). Princeton: Princeton University Press.

Arvanitis, S., Kubli, U., & Woerter, M. (2008). University-industry knowledge and technology transfer in switzerland: What university scientists think about co-operation with private enterprises. *Research Policy, 37*(10), 1865-1883.

Audretsch, D. B., & Keilbach, M. (2008). Resolving the knowledge paradox: Knowledge-spillover entrepreneurship and economic growth. *Research Policy, 37*(10), 1697-1705.

Babatunde, M. A. (2009). Can trade liberalization stimulate export performance in sub-Saharan Africa? *Journal of International and Global Economic Studies, 2*(1), 68-92.

Balassa, B. (1986). Comparative advantage in manufactured goods: A reappraisal. *Review of Economics & Statistics, 68*(2), 315.

Baldwin, R. E. (2008). The development and testing of Heckscher-Ohlin trade models: A review., 227.

Baldwin, R. E. (1971). Determinants of the commodity structure of U.S. trade. *American Economic Review, 61*(1), 126-146.

Bekkers, R., & Bodas Freitas, I. M. (2008). Analyzing knowledge transfer channels between universities and industry: To what degree do sectors also matter? *Research Policy, 37*(10), 1837-1853.

Bergstrand, J. H. (1985). The gravity equation in international trade: Some microeconomic foundations and empirical evidence. *The Review of Economics and Statistics, 67*(3), 474-481.

Bergstrand, J. H. (1989). The generalized gravity equation, monopolistic competition, and the factor-proportions theory in international trade. *The Review of Economics and Statistics, 71*(1), 143-153.

Bergstrand, J. H. (1990). The Heckscher-Ohlin-Samuelson model, the Linder hypothesis and the determinants of bilateral intra-industry trade. *The Economic Journal, 100*(403), 1216-1229.

Binenbaum, E., Nottenburg, C., Pardey, P.G., Wright, B.D.,Zambrano, P. (2000). South-North Trade, Intellectual Protection Jurisdictions, and Freedom to Operate in Agricultural Research on Staple Crops. Environmental and Production Technology Division, IFPRI, Washington D.C.

Bouare, O. (2009). An evaluation of David Ricardo's theory of comparative costs: Direct and indirect critiques. *Journal of Economic Development, 34*(1), 99-125.

Bouwman, A. F., & Booij, H. (1998). Global use of and trade of feedstuffs and consequences for nitrogen cycle. *Nutrient Cycling Agroecosystems, 52*(2-3), 261-267.

Bowen, H. P., & Sveikauskas, L. (1992). Judging factor abundance. *Quarterly Journal of Economics, Vol. 107*(No. 2), 599-620.

Bowen, H. P., Leamer, E. E., & Sveikauskas, L. (1987). Multicountry, multifactor tests of the factor abundance theory. *American Economic Review, 77*(5), 791.

Brander, J. A. (2007). Intellectual property protection as strategic trade policy. *Asia-Pacific Journal of Accounting and Economics, 14*(3), 195-217.

Brecher, R. A., & Choudhri, E. U. (1982). The factor content of international trade without factor-price equalization. *Journal of International Economics, 12*(3), 277-283.

Brecher, R. A., Choudhri, E. U., & Schembri, L. L. (1996). International spillovers of knowledge and sectoral productivity growth: Some evidence for Canada and the United States. *Journal of International Economics, 40*(3-4), 299-321.

Chaudhuri, K., & Das, S. (2006). WTO, the TRIPs and Indian pharmaceutical industry. *Indian Journal of Quantitative Economics, 20*(1), 97-110.

Chaudhuri, S., Goldberg, P. K., & Jia, P. (2006). Estimating the effects of global patent protection in pharmaceuticals: A case study of Quinolones in India. *American Economic Review, 96*(5), 1477-1514.

Chaudhuri, A. (2000). Endogenous quality choice and the impact of quantitative restrictions. *International Trade Journal, 14*(4), 377-397.

Chiang, E. P. (2004). Determinants of cross-border intellectual property rights enforcement: The role of trade sanctions. *Southern Economic Journal, 71*(2), 424-440.

Chitiga, M., Kandiero, T., & Ngwenya, P. (2008). Agricultural trade policy reform in South Africa. *AGREKON, 47*(1), 76-101.

Choi, E. K. (2003). In Choi E. K., Harrigan J. (Eds.), *Implications of many industries in the Hechscher-Ohlin trade model,* Oxford: Blackwell Publishing.

Choi, C. (2002). Linder hypothesis revisited. *Applied Economics Letters, 9*(9), 601-605.

Coe, D. T., & Helpman, E. (1995). International R&D spillovers. *European Economic Review, 39*(5), 859-887.

Connolly, Michelle. (2006). Review of: Intellectual property and development: Lessons from recent economic research. *Journal of Economic Literature, 44*(2), 457-458.

Cörvers, F., & Ted Reininga. (1998). *The Dutch factor content of human and physical capital: A test of the HOV model.*

Costinot, A. (2009). An elementary theory of comparative advantage. *Econometrica, 77*(4), 1165-1192.

Criscuolo, P., & Verspagen, B. (2008). Does it matter where patent citations come from? inventor vs. examiner citations in European patents. *Research Policy, 37*(10), 1892-1908.

Das, G. G. (2009). Intra-industry trade and development: Revisiting theory, measurement and new evidences. *Indian Journal of Economics and Business, 8*(1), 79-115.

Davis, D. R. (1997). Critical evidence on comparative advantage? North-North trade in a multilateral world. *The Journal of Political Economy, 105*(5), 1051-1060.

Deardorff, A. V. (1980). The general validity of the law of comparative advantage. *Journal of Political Economy, 88*(5), 941-957.

Deardorff, A. V. (1984). Chapter 10 testing trade theories and predicting trade flows. In Ronald W. Jones and Peter B. Kenen (Ed.), *Handbook of international economics* (pp. 467-517) Elsevier.

Deardorff, A. V. (1995). Determinants of bilateral trade: Does gravity work in a neoclassical world? *NBER Working Paper,* (No. 5377)

Deardorff, A. V. (1982). The general validity of the Heckscher-Ohlin theorem. *American Economic Review, 72*(4), 683.

Debaere, P. (2003). Relative factor abundance and trade. *Journal of Political Economy, 111*(3), 589-610.

Desai, M. A., & Hines, J. R.,Jr. (2008). Market reactions to export subsidies. *Journal of International Economics, 74*(2), 459-474.

Drezner, D. W. (2007). Rival standards and genetically modified organisms. In D. W. Drezner (Ed.). *All politics is global: Explaining international regulatory regimes* (pp. 149-175)

Eaton, J., & Kortum, S. (1996). Trade in ideas patenting and productivity in the OECD. *Journal of International Economics, 40*(3-4), 251-278.

Egger, H., Egger, P., & Greenaway, D. (2007). Intra-industry trade with multinational firms. *European Economic Review, 51*(8), 1959-1984.

Eichengreen, B., & Irwin, D. A. (1998). The role of history in bilateral trade flows. In J. A. Frankel (Ed.), *The regionalization of the world economy* (pp. 33-57). Chicago and London: The University of Chicago Press.

Feenstra, R., Markusen, J. A., & Rose, A. (1998). Understanding the home market effect and the gravity equation: The role of differentiating goods." *NBER Working Papers, No. W6804.*

Feldman, M. P., & Lichtenberg, F. R. (2000). The impact and organization of publicly-funded research and development in the european community. In Encaoua et al. (Eds), The economics of and econometrics of innovation., P177.

Ferratino, M. J. (1993). The effects of intellectual property rights on international trade and investment. *Weltwirtschaftliches Archiv, 129*, 300-331.

Frankel, J. A. (1997). *Regional trading blocs in the worm economic system* .

Fujiwara, K. (2009). Why environmentalists resist trade liberalization. *Environmental and Resource Economics, 44*(1), 71-84.

Gaisford, J. D. (2002). Agricultural biotechnology and the FTAA: Issues and opportunities. *The Estey Centre Journal of International Law and Trade Policy.*

Geishecker, I., Gorg, H., & Taglioni, D. (2009). Characterizing Euro area multinationals. *World Economy, 32*(1), 49-76.

Geroki, P. (1994). Market structure, corporate performance and innovative activity.

Giannakas, K. (2001). The economics of intellectual property rights under imperfect enforcement: Developing countries, biotechnology and the TRIPs agreement. *Environment and Production Technology Division; IFPRI.*

Ginarte, J. C., & Park, W. G. (1997). Determinants of patent rights: A cross-national study. *Research Policy, 26*(3), 283-301.

Gittleman, M., & Wolff, E. N. (1998). In Archibugi D., Michie J. (Eds.), *Research and development activity and cross-country growth comparison.* Cambridge:

Gold, E. R., Castle, D., Cloutier, L. M., Daar, A. S., & Smith, P. J. (2002). Needed: Models of biotechnology intellectual property. *Trends in Biotechnology, 20*(8), 327-329.

Goldsmith, P., Ramos, G., & Steiger, C. (2006). Intellectual property piracy in a north-south context: Empirical evidence. *Agricultural Economics, 35*(3), 335-349.

Graff, G. D., Hochman, G., & Zilberman, D. (2009). The political economy of agricultural biotechnology policies. *AgBioForum, 12(1), 34-46, 12*(1)

Griliches, Z. (1994). Productivity, R&D, and the data constraint. *The American Economic Review, 84*(1), 1-23. Retrieved from http://www.jstor.org.floyd.lib.umn.edu/stable/2117968

Griliches, Z., & Lichtenberg, F. (1984). Interindustry technolgy flows and productivity growth: A reexamination. *Review of Economic Statistics, 66*, 324-329.

Griliches, Z. (1985). Data and econometricians - the uneasy alliance. *The American Economic Review, 75*(2, Papers and Proceedings of the Ninety-Seventh Annual Meeting of the American Economic Association), 196-200.

Griliches, Z. (1990). Patent statistics as economic indicators: A survey. *Journal of Economic Literature, 28*(4), 1661-1707.

Griliches, Z. (1992). The search for R&D spillovers. *The Scandinavian Journal of Economics, 94*(, Supplement. Proceedings of a Symposium on Productivity Concepts and Measurement Problems: Welfare, Quality and Productivity in the Service Industries), S29-S47.

Grossman, G. M., & Helpman, E. (1991). Trade, knowledge spillovers, and growth. *European Economic Review, 35*(2-3), 517-526.

Grossman, G. M., & Helpman, E. (1994). Endogenous innovation in the theory of growth. *The Journal of Economic Perspectives, 8*(1), 23-44.

Gruere, G. P. (2006). Analysis of the trade related international regulations of GM food and their effects on developing countries.

Gupta, B. (2001). The international tea cartel during the great depression, 1929-1933. *The Journal of Economic History, 61*(1), 144-159.

Hakura, D. S. (2001). Why does HOV fail? The role of technological differences within the EC. *Journal of International Economics, 54*(2), 361-382.

Hall, P., Markowski, S., & Thomson, D. (1998). Defence procurement and domestic industry: The australian experience. *Defence and Peace Economics, 9*(1-2), 137-165.

Hamanaka, S. (2009). The building block versus stumbling block debate of regionalism: From the perspective of service trade liberalization in Asia. *Journal of World Trade, 43*(4), 873-891.

Hamilton, C., & Svensson, L. E. O. (1984). Do countries' factor endowments correspond to the factor contents in their bilateral trade flows? *Scandinavian Journal of Economics, 86*(1), 84.

Harrigan, J. (1995). Factor endowments and the international location of production: Econometric evidence for the OECD, 1970–1985. *Journal of International Economics, 39*(1-2), 123-141.

Harrigan, J. (1995). The volume of trade in differentiated intermediate goods: Theory and evidence. *The Review of Economics and Statistics, 77*(2), 283-293.

Hashimoto, A., & Haneda, S. (2008). Measuring the change in R&D efficiency of the Japanese pharmaceutical industry. *Research Policy, 37*(10), 1829-1836.

Heckman, J. J. (1979). Sample selection bias as a specification error. *Econometrica, 47*(1), 153-161.

Helpman, E. (1984). The factor content of foreign trade. *Economic Journal, 94*(373), 84-94.

Helpman, E., & Krugman, P. (1985). *Market structure and foreign trade. increasing returns, imperfect competition, and the international economy*. Cambridge Massachusetts: MIT Press.

Helpman, E., Melitz, M., & Rubinstein, Y. (2008). Estimating trade flows: Trading partners and trading volumes*. *Quarterly Journal of Economics*, *123*(2), 441-487.

Hobbs, J. E., Faisford, J. D., & Kerr, W. A. (2007). Will the TRIPS agreement foster appropriate biotechnologies for developing countries? *Journal of Agricultural Economics, vol. 58*(2), 199-217.

Huang, J., Hu, R., van Meijl, H., & van Tongeren, F. (2004). Biotechnology boosts to crop productivity in china: Trade and welfare implications. *Journal of Development Economics, 75*(1), 27-54.

Irwin, D. A., & Klenow, P. J. (1996). High-tech R&D subsidies estimating the effects of sematech. *Journal of International Economics, 40*(3-4), 323-344.

Isaac, G. E., & Kerr, W. A. (2003). Genetically modified organisms at the world trade organization: A harvest of trouble. *Journal of Trade Law, 37*, 1083-1095.

Isaac, G., E. (2002). *Agricultural biotechnology and transatlantic trade: Regulatory barriers to GM crops*. New York: CABI Publishing.

Ishikawa, J., & Kuroda, T. (2007). Export subsidies versus export quotas with incompletely informed policy makers. *Japanese Economic Review, 58*(1), 118-126.

Ivus, O. (2009). Trade-related intellectual property rights: Theory and empirics. Department of Economics, University of Calgary, Working Papers.

Jaffe, A. (1996). Economic analysis of research spillovers implications for the advanced technology program.

James, A. M., & Elmslie, B. T. (1996). Testing Heckscher-Ohlin-Vanek in the G-7. *Weltwirtschaftliches Archiv, 132*, 139-159.

James, C. (1999). Global review of commercialized transgenic crops. *International Service for the Acquisition of Agri-Biotech Applications, ISAAA Briefs, No. 12*

James, C. (2007). Global status of commercialized Biotech/GM crops. *ISAAA Brief, 37*

Jones, C. I., & Williams, J. C. (1998). Measuring the social return to R&D*. *Quarterly Journal of Economics, 113*(4), 1119-1135.

Kang, J., & Seo, J. H. (2006). Do intellectual property rights induce more patents? In C. Peeters, & B. P. de la Potterie (Eds.), *Economic and management perspectives on intellectual property rights.* (pp. 129-144). Hampshire, England: Palgrave Macmillan.

Kasch, S., & Dowling, M. (2008). Commercialization strategies of young biotechnology firms: An empirical analysis of the U.S. industry. *Research Policy, 37*(10), 1765-1777.

Kono, D. Y. (2007). When do trade blocs block trade? *International Studies Quarterly, 51*(1), 165-181.

Koo, W. W., & Anderson, C. A. (1988). *Effects of resource endowments on agricultural trade* No. 239)University of North Dakota.

Krugman, P. R., & Obstfeld, M. (2003). *The standard trade model". international economics - theory and policy (6th ed.).chapter 5. p. 103.*

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. *American Economic Review, 70*(5), 950-959.

Leamer, E. E. (1974). The commodity composition of international trade in manufactures: An empirical analysis. *Oxford Economic Papers, 26*(3), 350-374.

Leamer, E. E. (1980). The Leontief paradox, reconsidered. *Journal of Political Economy, 88*(3), 495.

Leamer, E. E. (1984). *Sources of international comparative advantage: Theory and evidence*. Cambridge, Massachussets: MIT Press.

Leamer, E. E. (1993). Factor-supply differences as a source of comparative advantage. *The American Economic Review, 83*(2, Papers and Proceedings of the Hundred and Fifth Annual Meeting of the American Economic Association), 436-439.

Leamer, E. E., & Bowen, H. P. (1981). Cross-section tests of the Heckscher-Ohlin theorem: Comment. *The American Economic Review, 71*(5), 1040-1043.

Lee, J., Park, I., & Shin, K. (2008). Proliferating regional trade arrangements: Why and whither? *World Economy, 31*(12), 1525-1557.

Lee, H., Owen, R. F., & van der Mensbrugghe, D. (2009). Regional integration in Asia and its effects on the EU and North America. *Journal of Asian Economics, 20*(3), 240-254.

Leontief, W. (1953). Domestic production and foreign trade; the American capital position re-examined. *Proceedings of the American Philosophical Society, 97*(2), 332-349.

Lichtenberg, F. R., & Pottelsberghe de la Potterie, Bruno van. (1998). International R&D spillovers: A comment. *European Economic Review, 42*(8), 1483-1491.

Linders, G., & De Groot, Henri L. F. (2006). *Estimation of the gravity equation in the presence of zero flows. Tinbergen institute discussion paper no. 06-072/3.*

Lundberg, L. (1992). Economic integration, inter- and intra-industry trade: The case of Sweden and the EC. *The Scandinavian Journal of Economics, 94*(3), 393-408.

Lutz, M. A. (2008). Revisiting the relevance of international trade theory. *Forum for Social Economics, 37*(2), 147-164.

Lutz, S. (2007). Strategic export subsidies. In W. A. Kerr, & J. D. Gaisford eds (Eds.), *Handbook on international trade policy* (pp. 302-310). In association with the Estey Centre for Law and Economics in International Trade. Elgar Original Reference series. Cheltenham, U.K. and Northampton, Mass.: Elgar.

MacIntosh, J. G., & Cumming, D. J. (2007). The determinant of R&D expenditures: A study of the canadian biotechnology industry. *Review of Industrial Organization, 17*(4)

Mannering, F., & Winston, C. (1998 [1987]). Economic effects of voluntary export restrictions. In B. Saffran, & F. M. Scherer eds (Eds.), *Price theory and its applications* (pp. 294-300). Elgar Reference Collection. International Library of Critical Writings in Economics, vol. 89. Cheltenham, U.K. and Northampton, Mass.: Elgar; distributed by American International Distribution Corporation, Williston, Vt.

Markusen, J. R. (1986). Explaining the volume of trade: An eclectic approach. *American Economic Review, 76*(5), 1002.

Martin, W., & Anderson, K. (2008). Agricultural trade reform under the Doha agenda: Some key issues. *Australian Journal of Agricultural and Resource Economics, 52*(1), 1-16.

Martin, M. F. (2007). *U.S. clothing and textile trade with china and the world: Trends since the end of quotas* Federation of American Scientists.

Martincus, C. V., & Estevadeordal, A. (2009). Trade policy and specialization in developing countries. *Review of World Economics, 145*(2), 251-275.

Maskus, K. E. (1985). A test of the Heckscher-Ohlin-Vanek theorem: The Leontief commonplace. *Journal of International Economics, 19*(3-4), 201-212.

Maskus, K. E. (1989). Comparing international trade data and product and national characteristics data for the analysis of trade models. In P. Hooper, & J. D. Richardson (Eds.), *International economics transactions* (pp. Pp 42) The University of Chicago Press.

Maskus, K. E., & Penubarti, M. (1995). How trade-related are intellectual property rights? *Journal of International Economics, 39*(3-4), 227-248.

McCalman, P. (2005). International diffusion and intellectual property rights: An empirical analysis. *Journal of International Economics, 67*(2), 353-372.

Melitz, J. (2007). North, South and distance in the gravity model. *European Economic Review, 51*(4), 971-991.

Miraglia, M., Berdal, K. G., Brera, C., Corbisier, P., Holst-Jensen, A., Kok, E. J., et al. (2004). Detection and traceability of genetically modified organisms in the food production chain. *Food and Chemical Toxicology, 42*(7), 1157-1180.

Mitchener, K. J., & Weidenmier, M. (2008). Trade and empire. National Bureau of Economic Research, Inc, NBER Working Papers). *NBER Working Paper Series, w13765* ([URL:http://www.nber.org.floyd.lib.umn.edu/papers/w13765.pdf] URL)

Moraes, M. (. D.). (2008). Assessing comparative advantage in soybean production: A global perspective.

Nielson, C. P., Robinson, S., & Thierfelder, K. (2002). Trade in genetically modified food: A survey of empirical studies. *Trade and Macroeconomic Division; IFPRI,*

Nielson, C., & Anderson, K. (2001b). GMOs, trade policy and welfare in rich and poor countries. In K. E. Maskus, & J. S. Wilson (Eds.), *Quantifying the impact of technical barriers to trade: Can it be done?* (pp. 155-184). Michigan: University of Michigan Press.

Nishioka, S. (2007). *An explanation of OECD factor trade with knowledge capital and the HOV model* West Virginia University.

Nottenburg, C., Pardey, P. G., & Wright, B. D. (2003). South-north trade, intellectual property jurisdictions and freeom to operate in agricultural research on staple crops. *Economic Development and Cultural Change,*

Nottingham, S. (Ed.). (1998). *East your genes: How genetically modified food is entering our diet.* (2nd ed.)

Pant, M., & Sadhukhan, A. (2009). Does regionalism hinder multilateralism: A case study of india. *Journal of Economic Integration, 24*(2), 222-247.

Park, W. G., & Ginarte, J. C. (1997). Intellectual property rights and economic growth. *Contemporary Economic Policy. Vol. XV, XV*

Park, W. G. (2008). International patent protection: 1960–2005. *Research Policy, 37*(4), 761-766.

Pearlberg, R., Hopkins, R. F., & Ladewski, L. (2007). Regulation of GM crops: Shaping an international regime. In R. E. Evenson, & T. Ransey (Eds.), *The political economy of genetically modified foods.* (pp. 23-46)

Pénin, J., & Wack, J. (2008). Research tool patents and free-libre biotechnology: A suggested unified framework. *Research Policy, 37*(10), 1909-1921.

Plahe, J. K. (2009). The implications of India's amended patent regime: STRIPping away food security and farmers' rights? *Third World Quarterly, 30*(6), 1197-1213.

Polaski, S., Bento, J., Ferreir, d. S., Berg, J., McDonald, S., Thierfelder, K., et al. (2009). *Brazil in the global economy: Measuring the gains from trade* Carnegie Endowment for International Peace.

Poyhonen, P. (1963). A tentative model for the volume of trade between countries. *Weltwirtschaftilches, 90*(93), 99.

Pullen, J. (2006). Did Ricardo really have a law of comparative advantage? A comparison of Ricardo's version and the modern version. *History of Economics Review,* (44), 59-75.

Rafiquzzaman, M. (2002). The impact of patent rights on international trade: Evidence from canada. *The Canadian Journal of Economics / Revue Canadienne d'Economique, 35*(2), 307-330.

Ramazani, R. M., & Maskus, K. E. (1993). A test of the factor endowments model of trade in a rapidly industrializing country: The case of Korea. *The Review of Economics and Statistics, 75*(3), 568-572.

Rassekh, F., & Thompson, H. (2002). Measuring factor abundance across many factors and countries. *Open Economic Review, 13*(3), 219-311.

Richards, D. G. (2002). The ideology of intellectual property rights in the international economy. *Review of Social Economy, 60*(4), 521-541.

Richards, D. G. (2005). Trade-related intellectual property rights. *Review of International Political Economy, 12*(3), 535-551.

Romer, P. (1990). Endogenous technological change. *Journal of Political Economy, 98*, S71-S102.

Rude, J. (2007). Direct and indirect export subsidies. In W. A. Kerr, & J. D. Gaisford eds (Eds.), *Handbook on international trade policy* (pp. 282-291). In association with the Estey Centre for Law and Economics in International Trade. Elgar Original Reference series. Cheltenham, U.K. and Northampton, Mass.: Elgar.

Runge, C. F., & Ryan, B. (2004). *The global diffusion of plant biotechnology: International adoption and research in 2004.*University of Minnesota.

Ruttan, V. W. (1999). Biotechnology and agriculture: A skeptical perspective. *AgBioForum, 2*(1), 54-60.

Ruttan, V. W. (2000). The biotechnology industries', in technology growth and development. In V. W. Ruttan (Ed.), *Technology, growth and development: An induced innovation perspective* (pp. 368-418). New York, NY: Oxford University Press.

Rybczynski, T. M. (1955). Factor endowment and relative commodity prices. *Economica, 22*(88), 336-341.

Saggi, K. (2002). International technology transfer and economic development. In B. Hoekman, A. Mattoo & P. English (Eds.), *Development, trade and the WTO: A hand book.* (pp. 351-358). Washington DC.: The World Bank.

Sanso, M., Cuairan, R., & Sanz, F. (1993). Bilateral trade flows, the gravity equation, and functional form. *The Review of Economics and Statistics*, *75*(2), 266-275.

Scandizzo, S. (2006). The labelling of genetically modified products in a global trading environment. In R. E. Evenson, & V. Santaniello (Eds.), *International trade and policies for genetically modified products.* (pp. 34-42)

Schittecatte, C. (2007). Opposing trade-related intellectual property rights and dependency: Back to the future? *Canadian Journal of Development Studies*, *28*(1), 119-136.

Sedjo, A. R. (2006). Regulation of biotechnology for forestry products. In R. E. Just, J. M. Alston & D. Zilberman (Eds.), *Regulating agricultural biotechnology: Economics and policy* (pp. 663-681) Springer US.

Sharma, R. (2007). Developing country experience with the key policy issues of the Uruguay round agreement on agriculture. In A. McCalla F., & J. Nash (Eds.), *Reforming agricultural trade for developing countries* (1st ed., pp. 74-99) The World Bank.

Smith, P. J. (2001). Do geographic scale economies explain disturbances to Heckscher–Ohlin trade? *Review of International Economics*, *7*(1), 20-36.

Smith, P. J. (1999). Are weak patent rights a barrier to U.S. exports? *Journal of International Economics*, *48*(1), 151-177.

Smith, P. J. (2001). How do foreign patent rights affect U.S. exports, affiliate sales, and licenses? *Journal of International Economics, 55*(2), 411-439.

Smyth, S., Kerr, W. A., & Davey, K. A. (2004). Commercialized products of biotechnology and trade pattern effects. In R. E. Evenson, & V. Santaniello (Eds.), *International trade and policies for genetically modified products.* (). Oxfordshire, UK: CABI Publishing.

Spielman, D. J. (2007). Pro-poor agricultural biotechnology: Can the international research system deliver the goods? *Food Policy, 32*(2), 189-204.

Stamm, O. (1993). Intellectual property rights and competitive strategy: A multinational pharmaceutical firm. in: Wallerstein, M., Mogee, M., Schoen, R., (Eds), Global dimesions of intellectual property rights in science and technology. *National Academic Press*, 220-228.

Stock, J. H. and Watson, M. W. (2002). Forecasting using principal components from a large number of predictors. *Journal of the American Statistical Association*, 97(460):1167–1179.

Stock, J. H. and Watson, M. W. (2003). *Introduction to econometrics*. Addison-Wesley Higher Education Group

Sveikauskas, L. (2007). R&D and productivity growth: A review of the literature. *Division of Productivity Research and Program Development, Bureau of Labor Statistics, Working Paper 408,*

Tan, L. (1992). A Heckscher-Ohlin approach to changing comparative advantage in Singapore's manufacturing sector. *Weltwirtschaftliches Archiv, 128*(2), 288-309.

Thursby, J. G., & Thursby, M. C. (1987). Bilateral trade flows, the linder hypothesis, and exchange risk. *The Review of Economics and Statistics, 69*(3), 488-495.

Tinbergen, J. (1962). An analysis of world trade flows. In J. Tinbergen (Ed), Shaping the world economy. *New York: Twenty Century Fund.*

Tobin, J. (1958). Estimation of relationships for limited dependent variables. *Econometrica, 26*(1), 24-36.

Torstensson, J. (1995). The factor-content of net trade for the OECD countries. *Journal of Economic Studies, 22*(6), 3-15.

Tothova, M., & Oehmke, J. F. (2004). Biotechnology and the emergence of club behaviour in agricultural trade. In R. E. Evenson, & V. Santaniello (Eds.), *International trade and policies for genetically modified products.* (pp. 22-33). Oxfordshire, UK: CABI Publishing.

Trefler, D. (1995). The case of the missing trade and other mysteries. *The American Economic Review, 85*(5), 1029-1046.

Vanek, J. (1968). The factor proportions theory: The N-factor case. *Kyklos, 21*(4), 749-756.

Wang, L. F. S., Wang, Y., & Zhao, L. (2009). Trade liberalization, intra-industry trade and the environment: Competition mode and the order of firms' moves. *International Review of Economics, 56*(2), 133-144.

Welsh, R., Glenna, L., Lacy, W., & Biscotti, D. (2008). Close enough but not too far: Assessing the effects of university–industry research relationships and the rise of academic capitalism. *Research Policy, 37*(10), 1854-1864.

Wooldridge, J. M. (2003). *Econometrics analysis of cross section and panel data*. Cambridge, MA.: The MIT Press.

Wu, J. Z., & Lee, M. (2009). Heterogeneous firms, monopolistic competition and trade policy. (in chinese. with english summary.). *Taiwan Economic Review, 37*(2), 213-234.

www.euroseeds.org. *Adventitiuos presence - bringing clarity to confusion.*

Yang, Y., & Gupta, S. (2007). Regional trade arrangements in Africa: Past performance and the way forward. *African Development Review/Revue Africaine De Developpement, 19*(3), 399-431.

Yang, C., & Kuo, N. (2008). Trade-related influences, foreign intellectual property rights and outbound international patenting. *Research Policy, 37*(3), 446-459.

Zachariadis, M. (2003). R&D, innovation, and technological progress: A test of the schumpeterian framework without scale effects. *Canadian Journal of Economics, 36*(3), 566.

Zarrilli, S. (2005). International trade in GMOs and GM products: National and multilateral legal frameworks., 24.

Zhang, Y., & Clark, D. P. (2009). Pattern and determinants of United States' intra-industry trade. *The International Trade Journal, 23*(3), 325-356.

Zigic, K. (1998). Intellectual property rights violations and spillovers in North–South trade. *European Economic Review, 42*(9), 1779-1799.

Zigic, K. (2000). Strategic trade policy, intellectual property rights protection, and North–South trade. *Journal of Development Economics, 61*(1), 27-60.

APPENDICES

Table A.65: Seemingly Unrelated Regression (SUR)

	Food			
	(1)	(2)	(3)	(4)
VARIABLES	x441	x449	x4711	x4721
$GMO06_j$	20.97**	317.2	3.081**	2.851
	(10.54)	(212.6)	(1.254)	(2.608)
Log ($R\&D_j$)	3.761	58.43	0.511	1.176
	(3.176)	(64.05)	(0.378)	(0.786)
Log($Capital_j$)	1.749	25.57	-0.0950	0.431
	(4.356)	(87.84)	(0.518)	(1.078)
Log($Labor_j$)	-3.131	-27.32	0.195	-0.237
	(4.578)	(92.32)	(0.544)	(1.133)
Log($AgLand_j$)	1.802	55.90	0.205	0.569
	(2.644)	(53.31)	(0.314)	(0.654)
Cons.	-73.69	-1,870	-10.65	-32.20**
	(62.99)	(1,270)	(7.491)	(15.58)
Observations	87	87	87	87
R-squared	0.181	0.156	0.241	0.220
Chi2	19.27	16.12	27.67	24.59
P	0.0017	0.0065	0	0.0002

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(x441) Maize seed; (x449) Other maize, unmilled; (x4711) Maize (corn) flour; (4721) Groats and meal of maize (corn

Table A.66: Seemingly Unrelated Regression (SUR)

	Feed		
VARIABLES	(5) x8124	(6) x8131	(7) x8136
$GMO06_j$	1.752**	360.3**	22.09**
	(0.809)	(151.4)	(9.519)
Log ($R\&D_j$)	0.354	-10.43	3.828
	(0.244)	(45.61)	(2.868)
Log($Capital_j$)	-0.106	51.01	-1.307
	(0.334)	(62.55)	(3.933)
Log($Labor_j$)	0.408	-19.17	2.886
	(0.351)	(65.73)	(4.134)
Log($AgLand_j$)	0.0273	38.92	-1.411
	(0.203)	(37.96)	(2.387)
Cons.	-9.246*	-1,345	-49.08
	(4.830)	(904.3)	(56.87)
Observations	87	87	87
R-squared	0.268	0.164	0.179
Chi2	31.78	17.08	18.98
P	0	0.0044	0.0019

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(x8124) Bran, sharps and other residues, of maize;
(x8131) Oilcake and other solid residues of oil from soybeans; (x8136)
Oilcake and other solid residues of oil from colza seeds (rape or colza);

Table A.67: Seemingly Unrelated Regression (SUR)

	Oil seed		
VARIABLES	(8) x2222	(9) x22261	(10) x2223
$GMO06_j$	503.6*	104.6**	2.460
	(259.5)	(48.84)	(3.531)
Log ($R\&D_j$)	43.23	19.07	0.627
	(78.18)	(14.71)	(1.064)
Log($Capital_j$)	46.18	-2.406	1.217
	(107.2)	(20.18)	(1.459)
Log($Labor_j$)	-27.22	-22.59	-1.850
	(112.7)	(21.21)	(1.533)
Log($AgLand_j$)	79.17	11.43	1.576*
	(65.07)	(12.25)	(0.885)
Cons.	-2,476	-30.85	-32.38
	(1,550)	(291.8)	(21.09)
Observations	87	87	87
R-squared	0.179	0.134	0.123
Chi2	18.94	13.48	12.19
P	0.002	0.0192	0.0323

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(x2222) Soybeans; (x2226) Rape or colza seeds; (x2223) Cottonseeds

Table A.68: Seemingly Unrelated Regression (SUR)

	Fat/veg oils			
	(11)	(12)	(13)	(14)
VARIABLES	x4211	x4212	x4216	x4217
$GMO06_j$	61.78	0.766	7.584	49.99*
	(39.65)	(0.690)	(8.350)	(27.86)
Log ($R\&D_j$)	5.759	0.0826	2.473	15.25*
	(11.95)	(0.208)	(2.516)	(8.394)
Log($Capital_j$)	5.396	0.183	0.855	3.162
	(16.38)	(0.285)	(3.450)	(11.51)
Log($Labor_j$)	3.536	0.00244	0.360	-8.741
	(17.22)	(0.300)	(3.626)	(12.10)
Log($AgLand_j$)	4.133	0.185	1.602	2.491
	(9.942)	(0.173)	(2.094)	(6.986)
Cons.	-324.2	-8.249**	-83.44*	-200.6
	(236.9)	(4.121)	(49.88)	(166.4)
Observations	87	87	87	87
R-squared	0.126	0.154	0.147	0.219
Chi2	12.49	15.85	14.94	24.43
P	0.0286	0.0073	0.0106	0.0002

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

(x4211) Soybean oil, fractions; (x4212) Cottonseed oil and its fractions;
(x4216) Maize (corn) oil, fractions; (x4217) Rape, colza, mustard oil

Table A.69: Heckman Selection (Exports)-Aggregate & subaggregates (Specification 3.9)

	Aggregate		Food		Feed	
VARIABLES	1	2	1	2	1	2
LogGDPPC06j	0.440***	2.659***	0.309***	1.323***	0.401***	1.134***
	(0.0328)	(0.164)	(0.0354)	(0.137)	(0.0483)	(0.0558)
LogGDPPC06k	0.494***	1.689***	0.407***	0.941***	0.324***	0.438***
	(0.0326)	(0.123)	(0.0360)	(0.119)	(0.0474)	(0.0491)
Lognpop06j	0.462***	2.445***	0.409***	1.487***	0.489***	1.280***
	(0.0179)	(0.138)	(0.0191)	(0.143)	(0.0256)	(0.0441)
Logpop06k	0.288***	1.322***	0.249***	0.782***	0.202***	0.390***
	(0.0166)	(0.0846)	(0.0180)	(0.0851)	(0.0233)	(0.0324)
LogDistjk	-0.410***	-2.603***	-0.358***	-1.742***	-0.497***	-1.495***
	(0.0328)	(0.148)	(0.0355)	(0.150)	(0.0453)	(0.0739)
Contjk	0.862***		0.929***		0.560***	
	(0.154)		(0.137)		(0.136)	
RTA_jk	0.659***	3.968***	0.693***	3.306***	0.585***	1.866***
	(0.0819)	(0.288)	(0.0823)	(0.291)	(0.0933)	(0.186)
NAFTAj_EUk	0.206	1.892***	0.260	1.724***	-0.211	-1.042**
	(0.182)	(0.579)	(0.174)	(0.491)	(0.207)	(0.424)
Mercoj_EUk	1.389***	8.904***	1.229***	5.192***	1.774***	6.613***
	(0.160)	(0.600)	(0.158)	(0.561)	(0.176)	(0.369)
Mercoj_NAFTA	2.255***	9.155***	1.532***	5.529***	0.341	-0.313
	(0.662)	(1.700)	(0.490)	(1.453)	(0.689)	(1.204)
LPkj	-0.660***		-0.481***		-0.408**	
	(0.114)		(0.126)		(0.168)	
Invmills		2.645***		1.477***		0.0507***
		(0.369)		(0.406)		(0.00289)
Constant	-18.64***	-81.94***	-15.96***	-44.98***	-16.09***	-29.56***
	(0.735)	(5.660)	(0.781)	(5.618)	(1.015)	(1.524)
Observations	5113	5113	5113	5113	5113	5113
R-squared		0.403		0.303		0.283

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

1 = Selection equation; 2= Outcome equation

Table A.70: Heckman Selection (Exports)-Subaggregates (Specification 3.9)

	Seed Oil		Fat/Veg. oils	
VARIABLES	1	2	1	2
LogGDPPC06j	0.440***	1.154***	0.641***	1.726***
	(0.0411)	(0.0674)	(0.0425)	(0.0727)
LogGDPPC06k	0.521***	0.975***	0.318***	0.458***
	(0.0431)	(0.0682)	(0.0374)	(0.0560)
Lognpop06j	0.393***	0.891***	0.486***	1.149***
	(0.0208)	(0.0375)	(0.0213)	(0.0385)
Logpop06k	0.241***	0.545***	0.211***	0.458***
	(0.0200)	(0.0365)	(0.0188)	(0.0368)
LogDistjk	-0.294***	-1.026***	-0.467***	-1.486***
	(0.0381)	(0.0754)	(0.0375)	(0.0794)
Contjk	0.970***		0.791***	
	(0.137)		(0.140)	
RTA_jk	0.525***	1.868***	0.504***	1.952***
	(0.0877)	(0.205)	(0.0844)	(0.213)
NAFTAj_EUk	0.261	2.567***	-0.523***	-0.811*
	(0.173)	(0.465)	(0.192)	(0.486)
Mercoj_EUk	0.988***	3.544***	0.865***	2.935***
	(0.166)	(0.397)	(0.181)	(0.416)
Mercoj_NAFTA	1.701***	4.709***	0.495	0.832
	(0.478)	(1.319)	(0.576)	(1.379)
LPkj	-0.401***		-0.442***	
	(0.143)		(0.136)	
Invmills		0.0904***		0.0490***
		(0.0121)		(0.00455)
Constant	-18.70***	-34.08***	-18.09***	-32.95***
	(0.919)	(1.904)	(0.869)	(1.674)
Observations	5113	5113	5113	5113
R-squared		0.267		0.315

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

1 = Selection equation; 2= Outcome equation

Table A.71: Heckman Selection (Exports)-Aggregate & Subaggregates (Specification 3.9)

	Aggregate		Foodstuffs		Animal Feed	
VARIABLES	1	2	1	2	1	2
LogGDPPC06j	0.484***	3.073***	0.362***	2.040***	0.413***	4.274***
	(0.0364)	(0.202)	(0.0397)	(0.240)	(0.0534)	(0.328)
LogGDPPC06k	0.492***	2.272***	0.407***	1.787***	0.325***	3.128***
	(0.0354)	(0.158)	(0.0397)	(0.222)	(0.0520)	(0.237)
Logpop06j	0.428***	2.526***	0.365***	1.958***	0.437***	4.483***
	(0.0193)	(0.151)	(0.0207)	(0.214)	(0.0279)	(0.336)
Logpop06k	0.288***	1.642***	0.249***	1.279***	0.215***	2.207***
	(0.0182)	(0.103)	(0.0200)	(0.145)	(0.0256)	(0.164)
LogDistjk	-0.486***	-3.433***	-0.446***	-2.972***	-0.564***	-6.188***
	(0.0352)	(0.173)	(0.0384)	(0.253)	(0.0491)	(0.419)
RTA_jk	0.549***	3.610***	0.582***	3.659***	0.507***	5.519***
	(0.0848)	(0.325)	(0.0856)	(0.382)	(0.0973)	(0.427)
NAFTAj_EUk	-0.0918	0.00223	-0.0624	0.123	-0.398*	-4.403***
	(0.185)	(0.655)	(0.176)	(0.634)	(0.210)	(0.574)
MERCOj_EUk	1.011***	7.446***	0.805***	4.800***	1.496***	17.17***
	(0.163)	(0.748)	(0.160)	(0.720)	(0.180)	(1.343)
MERCOj_NAFTAk	1.698***	7.412***	0.961**	4.705***	0.0782	0.224
	(0.649)	(1.459)	(0.482)	(1.808)	(0.678)	(1.039)
LogR&D06j	-0.0782***	-0.270***	-0.112***	-0.480***	0.0125	0.144***
	(0.0283)	(0.0619)	(0.0315)	(0.0763)	(0.0459)	(0.0394)
LogR&D06k	-0.0291	-0.312***	-0.0297	-0.245***	-0.0603	-0.662***
	(0.0260)	(0.0614)	(0.0296)	(0.0557)	(0.0385)	(0.0641)
GMO06j	0.469***	3.545***	0.582***	3.658***	0.460***	4.903***
	(0.0585)	(0.229)	(0.0630)	(0.354)	(0.0801)	(0.354)
GMO06k	0.0716	0.164	0.0780	0.420***	-0.0356	-0.346***
	(0.0578)	(0.156)	(0.0625)	(0.140)	(0.0814)	(0.121)
Contjk	0.921***		0.922***		0.514***	
	(0.166)		(0.144)		(0.141)	
LPkj	-0.481***		-0.251*		-0.0942	
	(0.125)		(0.141)		(0.186)	
Invmills		3.892***		3.880***		10.18***
		(0.434)		(0.692)		(0.858)
Constant	-18.91***	-98.78***	-16.42***	-77.21***	-15.55***	-157.5***
	(0.990)	(7.359)	(1.084)	(10.36)	(1.419)	(12.55)
Observations	4971	4971	4971	4971	4971	4971
R-squared		0.438		0.343		0.309

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1; 1 = Selection equation; 2= Outcome equation

Table A.72: Heckman Selection (Exports)-Subaggregates (Specification 3.9)

	Seed oil		Fat/Veg. oil	
VARIABLES	1	2	1	2
LogGDPPC06j	0.443***	2.148***	0.702***	4.593***
	(0.0447)	(0.309)	(0.0476)	(0.353)
LogGDPPC06k	0.526***	2.213***	0.327***	1.787***
	(0.0472)	(0.325)	(0.0402)	(0.139)
Logpop06j	0.348***	1.697***	0.459***	2.984***
	(0.0227)	(0.229)	(0.0231)	(0.216)
Logpop06k	0.246***	1.220***	0.220***	1.429***
	(0.0219)	(0.161)	(0.0207)	(0.105)
LogDistjk	-0.359***	-2.332***	-0.524***	-3.951***
	(0.0406)	(0.241)	(0.0402)	(0.234)
RTA_jk	0.420***	2.751***	0.416***	3.181***
	(0.0907)	(0.357)	(0.0875)	(0.315)
NAFTAj_EUk	0.0784	2.134***	-0.720***	-4.359***
	(0.177)	(0.788)	(0.194)	(0.700)
MERCOj_EUk	0.735***	4.624***	0.651***	4.681***
	(0.171)	(0.815)	(0.183)	(0.675)
MERCOj_NAFTAk	1.366***	6.710***	0.242	0.825
	(0.479)	(2.069)	(0.568)	(1.410)
LogR&D06j	0.00754	0.0537	-0.0952**	-0.511***
	(0.0369)	(0.0441)	(0.0370)	(0.0559)
LogR&D06k	-0.0513	-0.277***	-0.0470	-0.420***
	(0.0335)	(0.0573)	(0.0299)	(0.0552)
GMO06j	0.370***	2.358***	0.357***	2.848***
	(0.0685)	(0.274)	(0.0660)	(0.213)
GMO06k	0.0190	0.138	-0.00729	-0.127
	(0.0679)	(0.134)	(0.0671)	(0.132)
Contjk	0.931***		0.796***	
	(0.141)		(0.146)	
LPkj	-0.187		-0.299**	
	(0.155)		(0.149)	
Invmills		3.574***		5.538***
		(0.747)		(0.544)
Constant	-18.04***	-78.05***	-19.33***	-117.7***
	(1.244)	(12.33)	(1.192)	(9.681)
Observations	4971	4971	4971	4971
R-squared		0.285		0.342

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1; 1 = Selection equation; 2= Outcome equation

Table A.73: Heckman Selection (Exports)-Aggregate & subaggregates (Specification 3.9)

	Aggregate		Foodstuffs		Animal feed	
VARIABLES	1	2	1	2	1	2
LogGDPPC06j	0.488***	2.918***	0.368***	2.023***	0.413***	3.369***
	(0.0371)	(0.204)	(0.0403)	(0.252)	(0.0548)	(0.255)
LogGDPPC06k	0.492***	2.732***	0.417***	2.137***	0.318***	2.442***
	(0.0358)	(0.193)	(0.0403)	(0.280)	(0.0534)	(0.189)
LogPop06j	0.427***	2.618***	0.363***	2.054***	0.438***	3.589***
	(0.0196)	(0.159)	(0.0209)	(0.235)	(0.0281)	(0.264)
LogPop06k	0.287***	1.750***	0.249***	1.390***	0.214***	1.729***
	(0.0184)	(0.110)	(0.0202)	(0.164)	(0.0259)	(0.128)
LogDistjk	-0.491***	-3.597***	-0.439***	-3.111***	-0.575***	-5.056***
	(0.0355)	(0.181)	(0.0385)	(0.276)	(0.0497)	(0.331)
Contjk	0.927***		0.938***		0.510***	
	(0.167)		(0.144)		(0.141)	
RTA_jk	0.556***	3.752***	0.597***	3.899***	0.509***	4.568***
	(0.0851)	(0.333)	(0.0859)	(0.417)	(0.0983)	(0.373)
NAFTAj_EUk	-0.111	0.116	-0.0449	0.308	-0.423**	-3.741***
	(0.187)	(0.656)	(0.177)	(0.631)	(0.211)	(0.560)
Mercoj_EUk	0.936***	7.862***	0.886***	5.725***	1.402***	13.46***
	(0.170)	(0.784)	(0.170)	(0.829)	(0.186)	(1.152)
Mercoj_NAFTA	1.569**	7.709***	0.986**	5.323***	0.0286	-0.236
	(0.647)	(1.460)	(0.486)	(1.821)	(0.677)	(1.018)
LPkj	-2.465**		-0.393		-2.205	
	(0.978)		(1.166)		(1.552)	
LogR&D06j	-0.0410	-0.317***	-0.114***	-0.589***	0.0527	0.224***
	(0.0309)	(0.0650)	(0.0349)	(0.0899)	(0.0500)	(0.0454)
LogR&D06k	-0.0241	-0.111*	-0.0346	-0.222***	-0.0476	-0.285***
	(0.0294)	(0.0647)	(0.0327)	(0.0582)	(0.0441)	(0.0485)
GMO06j	0.502***	3.547***	0.563***	3.624***	0.506***	4.248***
	(0.0613)	(0.241)	(0.0652)	(0.365)	(0.0827)	(0.307)
GMO06k	0.0674	0.355**	0.0614	0.480***	-0.0372	-0.221*
	(0.0585)	(0.160)	(0.0638)	(0.144)	(0.0820)	(0.122)
GMO06j×LPkj	0.226	0.276	-0.351	-2.171***	0.444	3.277***
	(0.196)	(0.658)	(0.217)	(0.635)	(0.279)	(0.514)
GMO06k×LPkj	0.199	0.705	0.428*	1.661***	-0.0443	-0.816***
	(0.201)	(0.491)	(0.229)	(0.491)	(0.336)	(0.315)
R&D06j×LPkj	-0.232***	-0.420***	0.0479	0.324***	-0.302**	-1.322***
	(0.0719)	(0.110)	(0.0884)	(0.0820)	(0.124)	(0.128)
R&D06k×LPkj	0.0211	0.685***	-0.0649	-0.213***	0.0766	1.373***
	(0.0711)	(0.119)	(0.0876)	(0.0738)	(0.109)	(0.132)
Invmills		4.300***		4.314***		7.731***
		(0.467)		(0.776)		(0.658)
Constant	-18.52***	-103.0***	-16.67***	-84.21***	-14.94***	-119.4***
	(1.007)	(7.673)	(1.112)	(11.67)	(1.444)	(9.453)
Observations	4971	4971	4971	4971	4971	4971
R-squared		0.441		0.345		0.297

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1; 1 = Selection equation; 2= Outcome equation

Table A.74: Heckman Selection (Exports) – Subaggregates (specification 3.9)

	Seed oil		Fat/Veg. oil	
VARIABLES	1	2	1	2
LogGDPPC06j	0.427***	1.681***	0.712***	4.140***
	(0.0458)	(0.228)	(0.0487)	(0.328)
LogGDPPC06k	0.562***	1.932***	0.322***	1.812***
	(0.0492)	(0.273)	(0.0407)	(0.150)
LogPop06j	0.337***	1.384***	0.458***	2.765***
	(0.0229)	(0.172)	(0.0233)	(0.205)
LogPop06k	0.252***	1.036***	0.217***	1.331***
	(0.0223)	(0.126)	(0.0209)	(0.0996)
LogDistjk	-0.372***	-2.056***	-0.530***	-3.744***
	(0.0415)	(0.196)	(0.0406)	(0.226)
Contjk	0.973***		0.799***	
	(0.143)		(0.146)	
RTA_jk	0.443***	2.523***	0.419***	3.049***
	(0.0922)	(0.331)	(0.0880)	(0.314)
NAFTAj_EUk	0.103	2.276***	-0.751***	-4.039***
	(0.180)	(0.794)	(0.195)	(0.700)
Mercoj_EUk	0.807***	4.322***	0.579***	4.247***
	(0.180)	(0.804)	(0.188)	(0.696)
Mercoj_NAFTA	1.481***	6.338***	0.142	0.452
	(0.488)	(1.989)	(0.555)	(1.444)
LPkj	-3.129**		-2.474**	
	(1.232)		(1.253)	
LogR&D06j	0.113***	0.248***	-0.0693*	-0.512***
	(0.0418)	(0.0626)	(0.0389)	(0.0601)
LogR&D06k	-0.0197	-0.0372	-0.0435	-0.228***
	(0.0381)	(0.0478)	(0.0356)	(0.0538)
GMO06j	0.375***	2.011***	0.408***	2.780***
	(0.0715)	(0.232)	(0.0707)	(0.221)
GMO06k	0.0556	0.283**	-0.00860	0.000483
	(0.0688)	(0.139)	(0.0675)	(0.136)
GMO06j×LPkj	-0.242	-0.865	0.286	1.006*
	(0.239)	(0.585)	(0.222)	(0.539)
GMO06k×LPkj	-0.404	-1.807***	0.405	1.574***
	(0.259)	(0.435)	(0.258)	(0.390)
R&D06j×LPkj	-0.501***	-1.019***	-0.243**	-0.506***
	(0.0885)	(0.186)	(0.102)	(0.0918)
R&D06k×LPkj	0.163*	0.989***	0.0114	0.654***
	(0.0936)	(0.179)	(0.0843)	(0.102)
Invmills		2.607***		4.990***
		(0.561)		(0.515)
Constant	-16.90***	-59.44***	-19.04***	-107.5***
	(1.262)	(8.903)	(1.217)	(9.082)
Observations	4971	4971	4971	4971
R-squared		0.284		0.338

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1; 1 = Selection equation; 2= Outcome equation

LINEAR-LOG EQUATION ESTIMATED (2SLS)

$$T_j = \beta_0 + \beta_1 \log GMO_j + \beta_2 \log R\&D_j + \beta_3 \log Capital_j + \beta_4 \log Labor_j + \beta_5 \log Agland_j + \varepsilon_j$$

$$LogGMO_j = \beta_2 \log GDP06 + \beta_2 \log R\&D_j + \beta_3 \log Capital_j + \beta_4 \log Labor_j + \beta_5 \log Agland_j + \varepsilon_j$$

(A.1)[41]

Table A.75: Two-Stage Least-Squares Regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
Trade	86	5	3737.829	-2.1956	5.39	0.3701
$LogGMO_j$	86	5	4.937972	0.2582	29.94	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Trade						
$LogGMO_j$	-533.596	1842.896	-0.29	0.772	-4145.607	3078.414
Log ($R\&D_j$)	285.005	440.6775	0.65	0.518	-578.707	1148.717
Log($Capital_j$)	466.3727	1311.716	0.36	0.722	-2104.543	3037.288
Log($Labor_j$)	-76.9334	500.902	-0.15	0.878	-1058.683	904.8165
Log($AgLand_j$)	709.3085	1692.746	0.42	0.675	-2608.413	4027.03
_cons	-23476.8	53700.1	-0.44	0.662	-128727.1	81773.44
$LogGMO_j$						
LogGDP	-0.51448	1.252568	-0.41	0.681	-2.969471	1.940505
Log ($R\&D_j$)	0.273165	0.530417	0.52	0.607	-0.7664326	1.312763
Log($Capital_j$)	0.959339	0.936547	1.02	0.306	-0.8762587	2.794936
Log($Labor_j$)	-0.03677	0.645696	-0.06	0.955	-1.302315	1.228769
Log($AgLand_j$)	0.939362	0.368297	2.55	0.011	0.2175144	1.66121
_cons	-26.4146	10.36573	-2.55	0.011	-46.73105	-6.09812

Endogenous variables: Trade and $LogGMO_j$
Exogenous variables: R&D, Capital, Labor, AgLand, and GDP

[41] Unlike in the earlier estimations in Chapter 1 and 2, where I treated biotech land as binary variable, in this estimation I added small negligible values to biotech land because it is both independent and dependent variable. This makes interpretation easier.

LINEAR-LOG EQUATION ESTIMATED

$$T_j = \beta_0 + \beta_1 GMO_j + \beta_2 \log R\&D_j + \beta_3 \log Capital_j + \beta_4 \log Labor_j + \beta_5 \log Agland_j + \varepsilon_j$$

Table A.76: Linear-Log Equation

Linear regression	Number of obs = 86 F(5, 80) = 0.98 Prob > F = 0.4361 R-squared = 0.2982 Root MSE =1816.2

Trade	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
$LogGMO_j$	134.435	63.47985	2.12	0.037	8.106056	260.7639
$Log (R\&D_j)$	181.8852	113.6676	1.6	0.114	-44.32049	408.0909
$Log(Capital_j)$	21.07122	101.6187	0.21	0.836	-181.1565	223.2989
$Log(Labor_j)$	-32.5233	157.0897	-0.21	0.837	-345.1418	280.0952
$Log(AgLand_j)$	103.6879	102.577	1.01	0.315	-100.4469	307.8226
_cons	-4146.46	2597.19	-1.6	0.114	-9315.032	1022.112

Table A.77: Difference between the 2SLS and Linear-Log coefficients

	Coefficients			
	(b) Ivreg	(B) log_Log	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
$LogGMO_j$	-8893.98	134.44	-9028.42	254365.90
Log (R&D $_j$)	1576.15	181.89	1394.27	39504.24
Log(Capital $_j$)	6066.80	21.07	6045.73	170399.70
Log(Labor $_j$)	-705.82	-32.52	-673.29	19840.00
Log(AgLand $_j$)	8436.09	103.69	8332.40	234629.10

b = consistent under Ho and Ha; obtained from ivreg
B = inconsistent under Ha, efficient under Ho; obtained from regress

Test: Ho: difference in coefficients not systematic

chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 0.00
Prob>chi2 = 1.0000

* There is no significant difference between the 2SLS and Linear-Log coefficients, indicating that Linear-Log model is indeed consistent and that there is no endogeneity due to biotech land.

Table A.78: Countries in the sample with reported general R&D investment in 2006

Algeria	India†	Serbia & Montenegro
Argentina†	Indonesia†	Seychelles
Armenia	Iran†	Singapore
Australia†	Ireland	Slovakia†
Austria	Israel	Slovenia
Azerbaijan	Italy	South Africa†
Belarus	Japan	Spain†
Belgium	Kazakhstan	Sudan
Bolivia	Korea Republic	Sweden
Botswana	Kuwait	Switzerland
Brazil†	Kyrgyzstan	Tajikistan
Brunei Darussalam	Latvia	Thailand
Bulgaria	Lesotho	Trinidad & Tobago
Burkina Faso	Lithuania	Tunisia
Canada†	Luxembourg	Turkey
Chile	Macao China	Uganda
China†	Macedonia FYR	Ukraine
Colombia	Madagascar	United Kingdom
Congo DR	Malaysia	United States†
Costa Rica	Malta	Uruguay†
Croatia	Mauritius	Venezuela
Cyprus	Mexico†	Zambia
Denmark	Mongolia	
Ecuador	Morocco	
Egypt	Netherlands	
Estonia	New Zealand	
Ethiopia	Norway	
Finland	Pakistan	
France†	Panama	
Georgia	Paraguay†	
Germany†	Peru	
Greece	Philippines†	
Guatemala	Poland	
Honduras†	Portugal†	
Hong Kong	Romania†	
Hungary	Russia	
Iceland	Senegal	

†† and †Countries with positive amount of biotech land in 1998 and 2006 respectively

Table A.79: Data description and sources

VARIABLE BY COUNTRY	Year	UNITS	SOURCE
Endowments			World bank, WDI
Land area (sq. km)	2006	sq. KM/Ha	World bank, WDI
Land under cereal production (hectares)	2006	Ha	World bank, WDI
Agricultural land (% of land area)	2006	% of land area	World bank, WDI
Agricultural land (sq. km)	2006	sq. KM	World bank, WDI
Land under agricultural biotechnology	2006	Ha	ISAAA
Labor force, total	2006	# of persons	World bank, WDI
R&D expenditure (% of GDP)	2006	%	World bank, WDI
Research and development expenditure	1996 to 2006	$	UNESCO
Research and development expenditure PPP	1996 to 2006	$	UNESCO
Gross fixed capital formation (% of GDP)	2006	%	World bank, WDI
Gross fixed capital formation (annual % growth)	2006	%	World bank, WDI
Gross fixed capital formation (current US$)	2006	$	World bank, WDI
Agriculture, value added (% of GDP)	2006	%	World bank, WDI
Agriculture, value added (annual % growth)	2006	%	World bank, WDI
Agriculture, value added (constant 2000 US$)	2006	$	World bank, WDI
Agriculture, value added (current LCU)	2006	$	World bank, WDI
Agriculture, value added (current US$)	2006	$	World bank, WDI
GDP per capita, PPP (current international $)	2006	$	World bank, WDI
Population	2006	# of persons	World bank, WDI
Trade (Exports & Imports) to the ROW	2006	$	UN Comtrade
Bilateral trade	2006	$	UN Comtrade
Distance	2006	sq. KM	Helman/CEPII
Border	2006	-	Helman/CEPII
Regional FTAs	2006	-	Helman/CEPII
GMO policies and regulation	2006	-	WTO/Various literature
Intellectual property rights (IPRs) – Patent	2000 & 2005	Index	Ginarte & Park Index