EVALUATING THE COMPETITIVENESS OF US AGRICULTURAL MARKET COMMODITIES

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EVALUATING THE COMPETITIVENESS OF US AGRICULTURAL MARKET COMMODITIES

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DISSERTATION ABSTRACT

EVALUATING THE COMPETITIVENESS OF US AGRICULTURAL

MARKET COMMODITIES

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This dissertation is organized into three different topics in the field of international trade and economics that look at the competitiveness of US agricultural export commodities using different economic models and techniques. The first topic determines the impact of public R&D investments, Human Capital, and the competitiveness of US agricultural export commodities. The study generates an R&D and human capital index that is used to analyze the competitiveness of four US agricultural export commodities against the competitors. The results of the study indicate that investments in R&D influence agricultural commodity exports while the effect of human capital on agricultural commodities exports is mixed.

The second topic uses specific factor model of production to predict the effects of projected output and price adjustment on the competitiveness of US genetically modified

(GM) crops. The findings of the study demonstrate a positive relationship between successful adoption of GM technology and the projected adjustments in output and prices. Soybeans and corn sectors which have been most successful in adopting GM technology are found to have low elasticities of supply with respect to prices. While supply elasticity is an indicator of speed and magnitude of output adjustments as a result to changes in commodity price, lower elasticities make it possible for soybeans and corn sectors to lower their prices, without significant reduction in output. This makes them more competitive than crops that have not successfully adapted to GM technology.

The third topic uses Almost Ideal Demand System (AIDS) model approach to evaluate the competitiveness of US wheat. Using the AIDS model approach to generate price and income elasticities as indicators of product differentiation, the study evaluates US wheat competitiveness against Australian wheat in the Egyptian market. The study also evaluates if the AIDS model can be used as a measure of agricultural export commodities competitiveness especially for commodities from different origins with perceived quality differences.

Results from the study find that Australia has defended its market share and maintained higher prices by differentiating its wheat through creating a perception that its wheat is of better quality. Also, the US has a lower own-price elasticity may be an advantage in the short to medium term when the Egyptian economy is weak and foreign exchange has been especially tight. However, for US wheat to be competitive in the longer term it is necessary for the wheat industry to maintain lower prices, and improve its quality and quality image through effective promotional campaigns.

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INTRODUCTION

The United States (US) has incurred large and persistent agricultural and food trade surpluses over the past two decades (CAST, 1995). The agriculture share of US GDP is only slightly over 1% but its share of exports was 8% in 2002. This export performance came about despite falling terms of trade and declining real prices at the farm level (Gopinath and Roe, 2000). Colyer and Jolly (2000) attribute the exports to a highly productive and internationally competitive agricultural industry.

The concept of competitiveness encompasses a variety of factors including changes in nominal exchange rates, relative prices, and production costs. Product differentiation, for instance, has an important role when competitive strategies of enterprises are considered. Productivity growth, reliability, timely delivery, quality, after-sales service, financing arrangements, technological innovation, investment in physical and human capital, management style, and the institutional and structural environment play important roles in competitiveness. Many of these factors are qualitative in nature and research has typically focused on easily quantifiable indicators such as export price indices and unit labor costs (Tweeten and Pai, 1990; Agénor, 1997; Dohlman, Schnepf, and Bolling, 2001).

The strong export performance of US agriculture in recent years is an indication that the sector is highly competitive in international markets, as Colyer and Jolly (2000) point out. They also note that the world's economic and trading systems are undergoing change and many factors can affect the competitive position of particular products. A competitive edge for US agriculture, therefore, may not prevail in the future. Changes in US agriculture competitiveness can change due to research, trading alternatives, economic and agricultural subsidies, amended or new trade agreements, international politics, protectionism, economic and social development, expanding production and adopted technologies in other countries.

Regmi and Pompelli (2002) note that as economies become more interrelated with globalization and trade liberalization, US agricultural and food processing sectors will be more exposed to global markets. The ability of the US to maintain exports depends on competitiveness which in turn hinges on improved productivity, willingness to adapt to changing forces in demand and supply of agricultural products, and continued evolution of trade-oriented policies and programs (Colyer and Kennedy, 2000). With expanding regional and international trade agreements, countries enjoy the better access to foreign markets but have to contend with new competition (Cockburn, 1998).

ERS, Agricultural Baseline Projections to 2013 (2004) predicts that US agriculture exports will continue to face strong trade competition, from traditional exporters, such as Argentina, Australia, and Canada, and countries that have ability to invest in their under-developed resources that include Brazil, Hungary, Romania, Russia, Ukraine, and Kazakhstan. A relatively strong trade weighted US dollar will also remain a constraining factor on US agricultural exports.

Several studies concur with these predictions. Tweeten and Pai (1990) construct domestic resource cost coefficients for a number of US agricultural commodities under alternative resource and public policy scenarios. They conclude that the US is losing competitiveness in major agricultural commodities such as soybeans due to farm policies and lagging technology relative to the rest of the world. They also conclude that for the US to be competitive, government support should shift from protectionism, which by its nature lowers competitiveness, to increased public research on technology.

Dohlman, Schnepf, and Bolling (2001) examine the export cost competitiveness of US, Brazilian, and Argentine soybean producers by comparing the components and distribution of farm level production costs, internal marketing and transportation costs, and shipping costs to a common export destination using data from 1998/99 marketing years. Their study reveals that Brazil and Argentina maintained lower total production costs than the US mainly due to higher imputed US land values.

However, while traditional studies of competitiveness focus on comparative costs or market participation of countries or industries, subsidies distort costs and market shares, especially in agriculture. The present study, therefore, includes quantitative factors, such as technological innovation measured by research and development (R&D), seldom included in studies of competitiveness to analyze the competitiveness of US agricultural export commodities.

The study's contribution to the body of economic literature is three-fold. First, the study develops a R&D and human capital index measures that are used to evaluate US agricultural commodities competitiveness. Second, the study uses general equilibrium model to empirically test the impact of biotechnology adoption on the competitiveness of US agricultural sector as well as US agricultural exports. Finally, the study uses the AIDS model to evaluate the importance of agricultural commodities differentiation as a tool for measuring US agricultural export commodities competitiveness.

The overall goal of this dissertation is, therefore, to evaluate the competitiveness of US agricultural market commodities. The study is organized into three chapters. Chapter 1 investigates the role of R&D and human capital on the ability of a country to expand exports of selected agricultural commodities. The analysis looks at the relationship between changes in R&D investments and human capital in terms of competitiveness expressed as changes in export elasticities and a Michaely index.

Chapter 2 is an extension of Chapter 1. A case study is used to investigate US agricultural commodities competitiveness from the production side. Biotechnology adoption (a product of R&D investment) is used to evaluate the effects of R&D on US agricultural crops competitiveness. Chapter 3 uses a case study approach to investigate US agricultural competitiveness from the marketing side. The chapter uses the AIDS model to examine the impact of product differentiation on the competitiveness of US agricultural commodity export.

CHAPTER 1. R&D, HUMAN CAPITAL, AND THE COMPETITIVNESS OF US AGRICULTURAL EXPORT COMMODITIES

1. Introduction

The competitiveness of US agriculture ultimately determines exports, a stimulant to other sectors of the economy. According to the Foreign Agriculture Service (2003), export revenues accounted for 20% to 30% of US farm income over the past 30 years, with farmers and agricultural firms relying heavily on exports to maintain stable prices and revenue. Agriculture exports also have significant links to the rest of the economy through their effects on employment and business activity. Every dollar of export is associated with $1.47 in supporting activities to process, package, ship, and finance agricultural products. Using this reasoning, the $53.5 billion agriculture exports in 2002 generated an additional $79 billion in supporting activity.

Studies have shown that public policies such as R&D affect US competitiveness in agriculture (Yee et al., 2002) and that technology is a determinant of economic performance (Dosi, Pavitt and Soete, 1990; Fagerberg, 1998; Laursen, 1999; Montobbio, 2003). However, such inferences are largely based on studies that looked at the whole economy or industrial classifications. To my knowledge, no previous studies of specific agricultural sectors have empirically tested the influence of R&D and human capital on exports, and its impact on the US and competitor agricultural trade.

The current state of knowledge on the impact of R&D and human capital as it relates to specific agricultural commodities warrants further investigations and it is against this background that the present study is undertaken. This study proposes to extend the literature by testing empirically how R&D investments and human capital affect agricultural commodities trade. With this goal, an empirical model is proposed that allows us to estimate the effect of R&D investments and human capital on agricultural trade for US and its competitors in corn, cotton, wheat, and soybeans export sectors. The main contribution to the academic literature in this field is that the analysis is performed for individual agricultural crops. The analysis is appropriate as it incorporates the impact of R&D and human capital on the agricultural exports for each crop and within each country.

1.1 Study Objectives

The general objective of the study is to investigate the role of technology-related measures on US agricultural competitiveness in international markets. Research into the role of technological change in economic growth indicates that technological change is important for productivity growth. Declines in productivity lead to concerns that levels of technological change and entrepreneurship are diminishing, stimulating increased efforts to assess the importance of R&D and skilled labor in productivity across countries. Specific objectives of the study include:

- Estimate the impact of R&D and human capital on selected agricultural export commodities including wheat, corn, soybeans, and cotton.
- Analyze competitiveness indicators including export shares and Michaely indices of US and competitor's wheat, corn, soybeans, and cotton.

- Evaluate the use of R&D and human capital as a measure of US agricultural competitiveness.

2. Literature Review

2.1 Competitiveness

Debate continues over the concept of competitiveness. Banse, Gorton, Hartell, Hughes, Köckler, Möllman, and Munch (1999) point out that "no single measure or definition of competitiveness has gained the universal acceptance of either economists or management theorists." There has been a profusion of definitions applied to different organizational and spatial entities like firms, sectors, industries, regions, and states, and to proxies such as the balance of payments, market shares, costs, and job creation.

For the nation, competitiveness seems to imply potential to achieve or maintain a high standard of living based on resource and labor productivity (Enright, Frances, Saavedra, 1996). Labor productivity depends on underlying economic fundamentals of firms and industries, and analyzing a nation's competitiveness requires examining these fundamentals (Porter, 1990).

Stanovnik (2000) takes a broad view of international competitiveness as the ability to achieve long term economic growth and an economic structure that readily adapts to changes in world markets. He notes that long-term international economic competition depends on human and natural resources, infrastructure, management, capital, government intervention, and technological capability of firms. Efficient allocation of resources improves productivity, the scope and structure of trade in products and services, and the ability to generate, adapt, and diffuse innovation.

There are questions, however, about the importance of competitiveness at the macroeconomic level, particularly in floating exchange rate regimes. Krugman (1994) sees competitiveness as a dangerous obsession while Porter (1990) claims that productivity is the only meaningful concept of competitiveness. Certainly, trade is not a zero sum game and no country can be competitive (have lower relative costs or a comparative advantage) in every economic activity. The term "competitiveness" however, goes beyond comparative advantage.

Competitiveness can apply to a firm or industry. Enright, Frances, Saavedra (1996) define competitiveness at the industry level as the ability of firms to achieve sustained success relative to foreign competitors without protection or subsidies. Cockburn (1998) notes that to be competitive a firm must offer lower prices or better quality, and maintain average cost no greater than price. If an activity is profitable, local production and revenue will increase due to expansion of existing firms or entry of new ones and losing firms will shrink through firm contraction or exit. Production ultimately depends on the shape and position of the average cost curve. Conditions, such as the level of education, productivity, natural resource endowments, and economic policies can have significant impacts on the costs of particular firms and industries.

Cockburn (1998) sees differences in factor productivities, relative factor endowments, returns to scale, price distortions, and government policies as the fundamental determinants of competitiveness. On the other hand, CAST (1995) sees domestic agricultural policies, trade agreements, processed and differentiated products, and biotechnology as contemporary issues that will influence US agricultural competitiveness.

Dohlman, Osborne, and Lohmar (2003) point out that research on South America, the former Soviet Union, and China reveals that government policies national institutions, and cultural values can profoundly affect resource productivity and have implications for international agricultural markets. Policy changes can result in rapid changes in competitiveness.

2.11 Agricultural policies

Agriculture production depends in part on international economic conditions. Changes in interest rates, exchange rates, or demand and supply in the importing countries affect US agricultural exports (Batten and Belongia, 1986; Bahmani-Oskooee, and Ltaifa, 1992). Policymakers may improve the quality of the labor force with subsidized education, creating a tax structure favorable to investments in infrastructure and equipment, and establishing legal institutions such as property rights that encourage entrepreneurship and optimal resource allocation (Dohlman, Schnepf, and Bolling, 2003).

Kennedy (2000) notes that the Federal Improvement and Reform Act (FAIR) of 1996 will affect competitiveness of US agriculture due to its orientation toward market forces. On the surface, falling commodity prices result in reduced profits but encourage competitiveness and serve as a catalyst for producers to adopt new technologies and reduce their cost of production.

Tweeten and Pai (1990) note that US government commodity programs reduce competitiveness by idling resources, artificial production, inefficient mixes of inputs and outputs, and raising costs. Commodity programs may also remove land from production that could produce exports. Policies that subsidize production of raw commodities directly affect prices paid by food processors. Lowering the price of agricultural commodities leads to lower costs for downstream firms and increases their competitiveness relative to foreign firms (Dohlman, Schnepf, and Bolling, 2003).

2.12 Agricultural trade agreements

Touted as a "road to prosperity" agricultural trade agreements between industrialized and developing countries have become a fixture in the global trade arena. Advocates of regional trade agreements (RTAs) contend that they can serve as building blocks for multilateral trade liberalization. The US can benefit from participating in RTAs since recent ones have been more comprehensive in their liberalization of agricultural trade (Burfisher and Jones, 1998).

2.13 Processed and differentiated products

The US traditionally exports primarily bulk commodities with little value added. Although US exports of processed food products have been increasing in recent times, it still lags relative to world trade of these products. The declining market share may be due to the tendency of large US firms to invest in foreign countries rather than to export (Abbot, Brehal, and Reed, 1995).

According to Reed (2000) most large food manufacturers rely more on foreign direct investment (FDI) than exports as their strategy to access foreign markets. In 2000, the FDI sale of US processed food was five times the US exports, $150 billion versus $30 billion (Marchant, Manukyan, and Koo, 2002). Leading US multinational food processors are clearly expanding US exports even as they increase investment in foreign food processing facilities. The US food manufacturing firms have been successful in increasing exports due to high labor productivity and capital intensity (Henderson, Voros, and Herschberg, 1996; McDonald and Lee, 1994).

Hughes (1992) notes free trade will increase trade (imports and exports) in differentiated food products but also increase competition on international markets from newly industrializing countries. Given a symbiotic relationship between primary agriculture and processed foods, the strategic policy should aim at coordination between the two sectors rather than specialization in one (Gopinath, Roe, and Shane, 1996).

2.15 Development and adoption of technology

Mechanical, chemical, and biological revolutions represent fundamental changes in agriculture, and have had social and economic impact over the past century. Biotechnological innovations played a significant role in enhancing competitiveness and economic development in the second half of the 20th century. Disease free seedlings, new animal vaccines, growth hormones, and transgenic plants opened a new era in agricultural production and altered comparative advantage (Kalaitzandonakes, 2000; Heboyan and House, 2003).

Over the years, the ability to maintain a competitive position depended on improved technologies that enable farmers to produce high quality products efficiently, and agribusiness to process and market those products. Many countries are gaining the ability to develop and adapt efficient technologies, and the US with its strong public and private research should strive to be a leader in technological innovations (Colyer and Jolly, 2000).

2.2 Underlying factors influencing competitiveness

Some of the underlying factors that influence competitiveness include technology, attributes of purchased inputs, product differentiation, production economies, and external factors (Harrison and Kennedy, 1997; Dohlman, Schnepf, and Bolling, 2003; Cockburn, 1998).

2.21 Technology

Technology-based theories of trade have long emphasized the role of innovation and technological differences in determining the pattern of trade. One attempt to do so is Posner's (1961) technology-gap trade model. For Posner, countries placed at the technological frontier would enjoy an export advantage in technologically advanced products. Empirical studies on technological factors affecting trade have found a strong impact of domestic innovation efforts on competitiveness (Fagerberg, 1988 and Soete, 1987). Product and process innovation seems to be a crucial factor in gaining market share in international markets at least those in developed countries.

According to Agénor (1997) technological innovation influences trade flows and export market shares by changing quality characteristics of products and determining the emergence of new products. A firm's adoption of productivity or quality enhancing technology will enhance its competitiveness and cause a shift of either supply or demand, linking technology to profits.

Dosi, Pavitt, and Soete (1990) find evidence that absolute differences in technology are more important than endowment based comparative advantage in explaining trade patterns. While comparative cost considerations may be relevant, absolute differences in technology predominate. Knowledge from R&D, other industries, and trade, affect exports as shown in a study across industries and countries by Fagerberg (1997).

In agriculture, the development and use of new technology has brought about continued increases in productivity. These technologies are mechanical, chemical, or biological, and substitute for land and labor in the process of increasing crop and livestock production (Schimmelpfennig, Lewandrowski, Reilly, Tsigas, Parry, Darwin, Li, Mendelsohn, and Mount, 1994). Gopinath and Roe (2000) compare US agriculture with Europe and find that total factor productivity (TFP) is the primary driver of growth. Public R&D may have the potential to increase living standards of farm households and consumers while sustaining the US competitive edge in foreign markets.

2.22 Human Capital

"Human capital" is a set of specialized skills that agents can acquire by devoting time to an activity called "schooling." An important form of human capital is knowledge. Knowledge leads to a particular form of technology, the means by which resources are transformed into output. This "production" technology is important for agricultural development. Knowledge is imbedded in human beings by means of education and training, as well as through a diversity of informal learning. Hence the level of literacy, the level of educational attainment, and the amount of training provided to a country's population are important measures of its investment in human capital (Schuh and Angeli-Schuh, 1989; Grossman and Helpman, 1991).

Human capital has a number of distinguishing features. First, like the more familiar forms of physical capital, it too yields a stream of income over time. Second, like physical capital, it has replacement capacity. Societies can alter their stock of human capital by investing in it, just as is in the case of physical capital. Third, human capital is also subject to obsolescence, depreciation, and refurbishing, just as in the case of physical capital (Schuh and Angeli-Schuh, 1989).

Physical and human capital tends to be complementary to each other. However, research has shown that investments in human capital tend to yield high social rates of return, much higher than on ordinary commercial ventures, or on investments in physical capital. This is due in part to its ability to raise the productivity of more conventional resources such as land, labor, and capital. A more educated populace may provide better services to agriculture, improving productivity and competitiveness (Schuh and Angeli-Schuh, 1989; Wiebe, Soule, and Schimmelpfennig, 1998; Gallacher, 1999).

Similarly, the various forms of human capital are notably complementary. The introduction of new production technology, for example, tends to increase the demand for formal schooling and thus raises the rate of return to investments in schooling. Similarly, higher levels of education make it possible for new production technology to be diffused more rapidly; thus raising the rate of return to investments in the production of new technology. Gains in education accounted for 9% of the increased output from 1948 to 1994 according to Ahearn, Yee, Ball, and Nehring (1998).

An indirect measure of education may be school enrollment or adult literacy (Hayami and Ruttan, 1985). A measure of overall quality of the labor force may be life expectancy (Craig, Pardey and Roseboom, 1997) or calorie availability (Frisvold and Ingram, 1995). In an effort to focus more specifically on the education achievements of agriculture labor, Hayami and Ruttan (1985) also looked at the number of secondary school graduates as a proxy for the level of advanced technical education in agriculture.

2.23 Product quality and differentiation

R&D, quality control, and the use of higher quality inputs affect product quality. Reliability and timely delivery of goods and services are part of physical attributes of the product and are important in competitiveness. On the other hand, product differentiation refers to the degree of substitution between products of competing sellers. Firms differentiate their products from those of their rivals to increase market share and develop customer loyalty. Product differentiation has been suggested to boost farmer profits (Barkema, 1993; Levins, 2000; Schweikhardt, 2000; Babcock, 2002).

2.24 The exchange rate

The exchange rate is an important macro economic variable that influences the competitiveness of US agricultural products worldwide. A stronger dollar makes US exports more expensive in other countries, reduces the cost of imported products, lowers prices for US consumers, and increases import competition for some producers. A weaker dollar has the opposite effect, leading to increased exports and higher producer prices but lower imports and higher consumer prices (Rosson, Adcock, and Hobbs, 2001; Almarwani, 2003). The US captured a greater share of the world grain market in the early 1970s and mid 1980s, corresponding to sharp depreciation of the dollar in the international market (Vollrath, 1989).

According to a report by the USDA (2003) a strong US dollar reduces US agricultural competitiveness and constrains export growth. The decline of US agricultural exports in the early 1980s was due at least in part to US dollar appreciation (Baten and Belongia, 1984). Exchange rate risk has been detrimental to agricultural exports of all countries (Pick, 1990; Bahmani-Oskooee and Ltaifa, 1992). Depreciation increases US agricultural exports (Shane, 1990). Thompson (2000) notes that exchange rate effects may surface two to three years later due to the time required for planning, planting, and harvesting.

2.3 Measuring Competitiveness of Agricultural Commodities

Competitiveness in global markets affects the level of trade. A rise in competitiveness increases export volume, leading to increased farm income, capacity and land utilization, market prices, and reducing stocks and government farm support. The opposite chain of events occurs when competitiveness declines (Vollrath, 1989).

2.31 Market share

An indicator of competitiveness is market share, the percentage of a world commodity market held by an exporter. Shifts in market share reflect changing competitiveness across countries. Market share (*MS*) can be defined as

$$MS_a^i = XS_a^i \big/ XS_a^w \,, \tag{1}$$

where *XS* refers to exports, subscript *a* to a commodity, and *i* to home country, and *w* to world.

The disadvantage of this measure is that simple comparisons of market share may not describe an ability to compete because market share may be a result of export subsidies. An example is Saudi Arabia where large subsidies and not resource advantage have increased its market share in wheat production (Vollrath, 1989). Swann and Taghavi (1992) point out that market shares alone give no indication of how competitiveness will change with price, product redesign, change in price or design of substitute, or the exchange rate. Other measures of competitiveness may tell us more about competitiveness (Vollrath, 1989).

2.32 Export share ratio

An index of export share ratios reflects the extent of trade specialization. Aggregation and policy effects may distort any measure of revealed comparative advantage (*RCA*) and selection of a particular level of aggregation may obscure the pattern of comparative advantage. There are three measures of *RCA*. Letting *i* denote country and *j* commodity, one measure of RCA is

$$RCA_j = \frac{X_{ij}}{X_{iW}} \bigg/ \frac{X_{Wj}}{X_W}, \tag{2}$$

where X_{ij} is exports by country *i* of commodity *j*, X_{iw} is total exports of country *i* (summed over *j*), X_{wj} is the total world trade in commodity *j* (summed over *i*), and X_W is total world trade (summed over *i* and *j*). This measure gauges a country's world export share of a commodity with its total export share of total world exports. If country *i*'s share of world exports of commodity *j* is greater than that country *i*'s share of world exports of all goods, *RCA* > 1, suggesting a country has revealed a comparative advantage in the production of that commodity.

Vollrath (1989) uses *RCA* to show that from 1982 to 1986 the US had a 53% share of world soybean exports compared to an 11% share of all exports, making the relative export share of the US in soybeans almost 5, suggesting that US was 5 times better at exporting soybeans than at exporting all agricultural products. The US, Australia, and Canada showed relative export advantages for wheat, and Pakistan and Thailand had higher relative export advantages than the US in rice.

One problem with the export share ratio is the influence of country size. If exports of commodity *j* form a large share of total exports but *j* is a small component of total world exports, a high *RCA* results. One solution is to estimate the share of commodity *j* in exports relative to the unweighted average share of *j* in total exports of all countries in the world rather than the weighted average share, changing (1) to

$$RCA_j = \left(\frac{X_{ij}}{X_{i.}}\right) \Big/ \frac{1}{n}\sum_{i=1}^{n}\left(\frac{X_{ij}}{X_{i.}}\right) \tag{3}$$

The denominator is now a simple unweighted average of all export share ratios of commodity *j*, giving an equal weight irrespective of the volume of exports by a country. By using average share, small and large countries are treated symmetrically and the influence of trade volume is removed. If the share of commodity *j* in exports is greater than the unweighted average for the world as a whole, *RCA* > 1 and the country has an *RCA* in commodity *j*. A further advantage of (3) is that the average *RCA* is 1, providing a reference for comparison across countries.

2.33 Net to total trade ratio

A third measure of revealed comparative advantage is

$$RCA_j = \frac{X_{ij} - M_{ij}}{X_{ij} + M_{ij}} \tag{4}$$

where M_{ij} are imports by country *i* of commodity *j*. The net to total trade ratio evaluates trade performance and considers simultaneous exports and imports of a particular product category. The ratio ranges from -1 when there are no exports ($X_{ij} = 0$) which reveals comparative disadvantage, to +1 when there are no imports ($M_{ij} = 0$) which reveals comparative advantage.

One problem with this measure is that net exports may change as a result of fluctuations in the overall trade balance, a macroeconomic issue not indicative of comparative advantage (Wolff, 1997).

2.34 Revealed symmetric comparative advantage

Revealed symmetric comparative advantage is the ratio of the share of that product in world trade

$$RCA_{ij} = \frac{X_{ij} \Big/ \sum_i X_{ij}}{\sum_j X_{ij} \Big/ \sum_i \sum_j X_{ij}} \tag{5}$$

The numerator is the share of a given sector in exports where X_{ij} are exports of sector *i* from country *j*. The denominator is the share of a given export sector in a set of countries. RCA_{ij} presents a comparison of national export structure with a set of countries. If $RCA_{ij} = 1$ the share of that sector is identical with the set of countries. If $RCA_{ij} > 1$, the country has revealed a comparative advantage (Yeats, 1989). This measure cannot be compared on both sides of 1, however, and is made symmetric by Revealed Symmetric Comparative Advantage $RSCA = (RCA-1)/(RCA+1)$ which ranges from -1 to +1.

2.35 Revealed patent advantage

A similar measure to *RSCA* is Revealed Patent Advantage *RPA* (Grupp, 1994) derived from a Technological Revealed Comparative Advantage (*TRCA)* analogous to the *RCA*, but based on patent activity. *TRCA* is based on patents granted and measures of specialization in country *i* in activity *j*. *TRCA* is defined as

$$TRCA_{ij} = \left(c_{ij} \Big/ \sum_i c_{ij} \right) \Big/ \left(\sum_j c_{ij} \Big/ \sum_i \sum_j c_{ij} \right) \quad (6)$$

The numerator is the share of a given sector in patents where c_{ij} is patents of sector *i* from country *j*. The denominator represents the share of a given sector in set of countries.

RPA is

$$RPA_{ij} = (TRCA^2 - 1 / RTA^2 + 1) * 100 \quad (7)$$

2.36 Alternative Specifications of Revealed Comparative Advantage

Vollrath (1991) offers three specifications of revealed comparative advantage. The first is relative trade advantage (*RTA*) which is the difference between the Balassa relative export advantage

$$RXA = (X_{ij}/X_{it} / X_{nj}/X_{nt}) \quad (8)$$

where n is a set of countries, and its counterpart relative import advantage

$$RMA = (m_{ij}/m_{it} / m_{nj}/m_{nt}) \quad (9)$$

where *m* represents imports. Then

$$RTA = RXA – RMA \quad (10)$$

Vollrath's second measure is the logarithm of the relative export advantage (*lnRXA).* His third measure *revealed competitiveness (RC)* is

$$RC = lnRXA - lnRMA \quad (11)$$

The advantage of these last two indices in log form is that they are symmetric through the origin. Positive values of *RTA, lnRXA*, and *RC* reveal comparative or competitive advantage. A problem with these and similar indices, noted by Vollrath (1989), is that observed trade patterns are likely to be distorted by government policies and may misrepresent underlying comparative advantage.

2.37 Trade specialization

While *RCA* is perhaps a measure for comparative advantage, other measures have been used, including the Michaely (1962, 1967) index and the Chi Square measure. The Michaely index is

$$M_{ij} = X_{ij} \Big/ \sum_i X_{ij} - M_{ij} \Big/ \sum_i M_{ij} \tag{12}$$

where X_{ij} are exports of sector i from country j, and M_{ij} are imports for sector i to country j. The first part represents the share of a given sector in exports and the second part the share of a sector in imports. The Michaely index ranges from -1 to1 with a neutral value of zero. If it is positive (negative) the country is specialized (under-specialized) in that sector. The Michaely index is an index of dissimilarity according to Laursen (1998). Summing over sectors for each country, the higher the value implies less similar commodity composition of exports and imports. It takes a value of zero in the case of perfect similarity. Kol and Mennes (1985) and Webster and Gilroy (1995) apply the Michaely index as a measure of trade specialization at the sector level.

Laursen (1998) points out that another measure is the Contribution to the Trade Balance (*CTB*) defined as

$$CTB_{ij} = \frac{X_{ij} - M_{ji}}{\left(\sum X_{ij} + \sum M_{ij}\right) \Big/ 2} - \frac{\sum X_{ij} - \sum M_{ji}}{\left(\sum X_{ij} + \sum M_{ji}\right) \Big/ 2} * \frac{X_{ji} + M_{ji}}{\sum X_{ij} + \sum M_{ji}} \tag{13}$$

The *CTB* ranges between -4 and 4. A *CTB* greater (less) than zero indicates that a sector contributes more (less) than its share of total trade. The Michaely and CTB indices are almost identical in application but only differ if there are large trade imbalances. Since, CTB is weighted; we would expect it to handle trade imbalances better when compared to the Michaely index.

Compared to the *RSCA*, the Michaely index is a measure of relative net export in a sector. When comparing the *RSCA* to the Michaely index, the type and size of intra industry-trade become relevant. One advantage of *RSCA* is the elimination of re-export as a source of distortion when calculating comparative advantage. If intra-industry trade is due to importation of equipment by firms in other sectors, the Michaely index underestimates comparative advantage (Laursen, 1998).

The Chi-Square (χ^2) index measures the sum of the squared difference between the export distribution of a given country and a set of countries, divided by the set's export distribution,

$$\chi^2 = \left[\left(X_{ij} \Big/ \sum_i X_{ij}\right) - \left(\sum_j X_{ij} \Big/ \sum_i \sum_j X_{ij}\right)\right]^2 \Big/ \left(\sum_j X_{ij} \Big/ \sum_i \sum_j X_{ij}\right) \tag{14}$$

The size of the χ^2 index indicates how strongly each country is specialized.

2.38 Benefit-cost analysis

Another method to measure competitiveness is benefit-cost ratio (*BCR*) used in the analysis of policies and projects. The financial benefit-cost ratio (*FBCR*) uses market or financial prices for costs and benefits. The economic benefit-cost ratio (*EBCR*) uses shadow or economic prices for costs and benefits. The *BCR* divides the present value of all benefits by the present value of all costs expressed in domestic currency (Kannapiran and Fleming, 1999).

The *BCR* models used to estimate competitiveness and comparative advantage are in (1) and (2). The *FBCR* is

$$\left(\sum_{i=1}^{n}\frac{P_m}{(1+r)^t}\right)\div\left(\sum_{i=1}^{n}\frac{f_m}{(1+r)^t}+\frac{d_m}{(1+r)^t}\right) \tag{15}$$

where d_m and f_m are domestic and foreign resource costs in foreign currency market prices, p_m is the actual fob foreign currency export price, and r is the discount rate.

The *EBCR* is

$$\left(\sum_{i=1}^{n}\frac{P_s}{(1+r)^t}\right)\div\left(\sum_{i=1}^{n}\frac{f_s}{(1+r)^t}+\frac{d_s}{(1+r)^t}\right) \tag{16}$$

where d_s and f_s are domestic and foreign resource costs per unit of production in foreign currency shadow prices and p_s is the fob foreign currency export shadow price.

2.39 Real exchange rate

The Real Exchange Rate (*RER*) is a measure of competitiveness generally applied to the entire economy but increasingly employed for specific sectors. The theoretical RER_t is the ratio of the price of tradable commodities (P^T) to non-tradable commodities (P^{NT}),

$$RER_t = \frac{P^T}{P^{NT}} \tag{17}$$

Non-traded commodity prices can differ due to local demand. Traded prices differ only due to trade policies or transport costs but the cost of producing tradable goods can differ due in part at least to prices of non-tradable inputs. A relative increase in the cost of non-tradable inputs is equivalent to an appreciation of the real exchange rate, leading to higher production costs (Lamy, Recalde, and Barraud, 2003).

Prices for non-tradable goods are not available and a ratio of foreign to domestic price indices has to approximate the *RER*. One method is to divide the nominal exchange rate by the Purchasing Power Parity (*PPP*). An alternative is to multiply the nominal exchange rate by the ratio of the foreign to domestic consumer price index or implicit GDP price deflator.

$$RER = \frac{NER}{PPP} = \frac{NER.P^F}{P^D} \tag{18}$$

where NER is the nominal exchange rate expressed in units of domestic currency per one unit of foreign currency, and P^F and P^D are the appropriate foreign and domestic price deflators.

2.311 Domestic resource costs and a competitiveness coefficient

One measure of international price competitiveness is the domestic resource cost (*DRC*) ratio that compares the opportunity costs of domestic production to the value added it generates (Tsakok, 1990). The numerator is the sum of the costs of using domestic primary resources including land, labor and capital (non-internationally traded inputs) valued in shadow prices. The denominator is the value-added (value of output minus tradable input cost per unit of output) in border prices,

$$DRC = \frac{\sum_{j=k+1}^{n} a_{ij} P_j^D}{P_j^B - \sum_{j=1}^{k} a_{ij} P_j^B} \tag{19}$$

where a_{ij} is the quantity of the j^{th} traded (if $j \le k$) or non-traded (if j > k) input (j = 1, 2, ..., n) used to produce one unit of output *i*; $P^D{}_j$ is the domestic (shadow) price of input *j*; $P^B{}_i$ is the border price of output *i*; and $P^B{}_j$ is border price of input *j*.

DRC is the shadow price of domestic non-tradable factors to produce a traded good per unit of tradable value added. If domestic value added is greater than the opportunity costs of the used domestic resources (*DRC* < 1) the alternative raises income. If *DRC* is greater than 1, the policy is inefficient (Tweeten, 1992 p61; Masters and Winter-Nelson, 1995 p243).

DRC is sensitive to the choice of shadow prices for non-tradable inputs and to the choice and changes in the exchange rate and international prices (Gorton and Davidova, 2001). In addition, the *DRC* may lead to biased results. Masters and Winter-Nelson (1995) show that it is often those alternatives that rely on a high level of non-tradable inputs that are inefficient, and this bias is larger if the various options include divergent combinations of traded and non-traded inputs. In addition, the distinction between costs of tradable and of non-tradable components is ambiguous. Finally, it is not easy to gather the necessary input/output coefficients for the analysis.

The inverse of the *DRC*, Competitiveness Coefficient, is also often used. It is intuitively more appealing since it reveals the highest values for those alternatives that indicate the largest returns to fixed resources and thus have a competitive advantage (Tweeten 1992, p62).

2.312 Import penetration rates

The Import Penetration Rate (*IPR*) characterizes the internal competitiveness of a sector by showing the magnitude of international competition in the domestic market (Agénor, 1997). The *IPR* is the ratio between imports and domestic consumption calculated as the sum of production plus imports minus exports and waste product:

$$IPR = \frac{M}{C} \times 100 \tag{20}$$

where M = imports and C = consumption.

2.313 Exposure to international competition

Exposure to International Competition (*EIC*) is the assumption that exports meet international competition within global markets and the production targeted at domestic demand experiences competition from imports measured by the previous import penetration ratio. This indicator measures the percentage of national production exposed to foreign competition (Agénor, 1997).

$$EIC = \frac{X}{P} + \left(1 - \frac{X}{P}\right) \times IPR \tag{21}$$

where X/P = percentage of exports over production and IPR = import penetration ratio.

3. Theoretical Background

The theory of international trade and specialization rests in part on the doctrine of comparative costs originally articulated by Heckscher and Ohlin (H-O), among others, in the early part of the 20th century. According to this theory, the pattern of specialization and trade depends not only on the relative costs of production but also on differences in factor endowments (Cohen, 1995). On the basis of its factor endowments, each country should produce and export goods that reflect the relative abundance or quality of its land, labor, and capital resources (Dohlman, Schnepf, and Bolling, 2003).

Since Leontief showed that American trade patterns could not be explained by the capital intensity of export- and import-competing production, the factor proportions explanation of trade has been suspect. Some attempts have been made to develop alternative models of trade and determination of comparative advantage and most research efforts have been focused upon the incorporation of either "technology" or "human capital" as an additional explanatory variable in trade theory (Krueger, 1970).

The H-O model regards labor as a homogeneous factor, but in the real world, the labor force of each country represents a continuum from unskilled to highly skilled labor. Countries differ not only in physical capital, but also in the training and education of the labor force. For example, developed countries are endowed with a relatively large number of scientists, engineers, and technicians whereas developing countries tend to have few scientific investigators. The productivity of labor varies depending on the skill of the labor force (Mitcher, 1968). Accordingly, the commodities produced in a country are closely related to the intensive use of its skilled and educated labor force which makes it more competitive (Scherer, 1992).

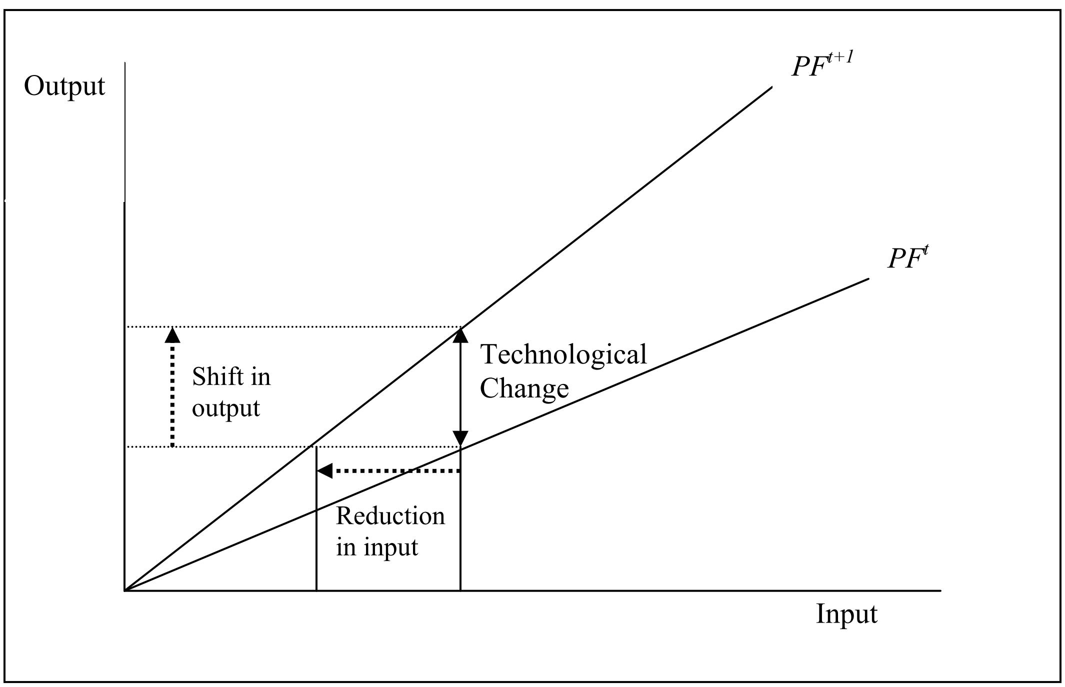
Also, the H-O model is based upon the assumptions that the same technologies are available for production in all countries. If technologies differ, it is quite possible that labor-abundant countries may export capital-intensive goods because of different technologies, and vice versa. If, on the other hand, technologies are the same between countries but some products require a relatively large input of skilled labor, the prospect for standard trade theory is far brighter. Because of this, the factor-proportions explanation of trade, in its empirical application, needs to be amended to cover more factors of production (Krueger, 1970).

3.1 Theoretical Model

The conceptual framework for investigating the role of R&D and human capital on agricultural exports is adopted from Hughes (1986). As Walker (1974) notes, R&D as a factor of production generates new opportunities for expanding production while innovation can bring about an increase in the parent country's trade share, and a corresponding decrease in the share of competitors.

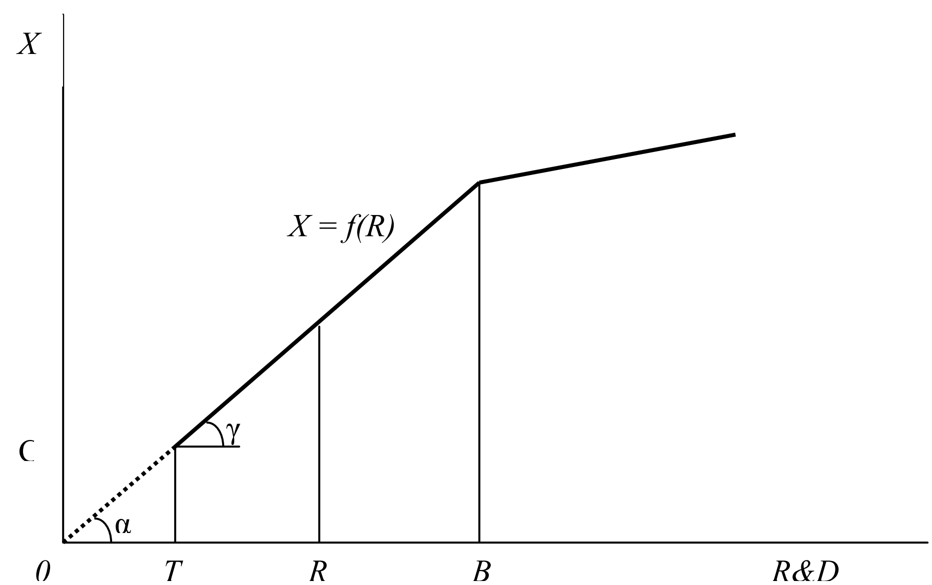
Adoption of R&D results in technological change that shifts the production frontier (*PF*) and can result in factor substitution or technical change as shown by Figure 1. Factor substitution means a change in the combination of inputs used to produce the same level of output which implies that higher levels of output can be obtained for the same level of inputs (Ellis, 1998). Technical change leads to more output for the same level of resources, which implies a reduction in factor requirements similar to reduction in inputs (Figure 1). This results in production of the same output with lower inputs and more output with the same inputs. An R&D investment which leads to technical change, therefore, enhances the country's competitiveness.

Figure 1. Technology Change and Output Change in the Production Frontier



It could be argued that the economy is potentially endowed with R&D. R&D employment will vary according to decisions of each sector and government. The maximum size of this potential R&D endowment, at any point in time, will vary across countries and depend, among other factors, on previous R&D expenditure. We assume that there may be some minimum point of R&D expenditure which must be spent over time in order to generate a surplus over domestic requirement or export in a given sector. If this minimum varies by sector, it would be possible to rank sectors. Exports would be greater in sectors with higher minimum R&D point, in countries well endowed with R&D (Figure 2). The existence of fixed costs and product differentiation would still mean no one sector or one country's sector dominated world markets completely.

Figure 2. Exports, R&D and Technological Opportunity



Source: Hughes, 1986

We assume that there is a range, above the minimum R&D point, over which R&D expenditure is observed. The precise level of R&D within the range will depend on the determinants of R&D. If these determinants vary across sectors and countries, there will be gaps between competitors R&D which will affect exports, in addition to the effect of "endowments." The range over which R&D is spread may be determined by the technological opportunity level of the sector. The technological opportunity level of a sector represents its ability and potential for exploiting the sector's production processes and products. This varies across sector and so can determine the level and width of the R&D region as depicted by Figure 2. The end points of each region may be such that beyond them there is no effect of R&D on exports or output. There may also be diminishing returns. For estimation purposes, it must be assumed that the relation of exports to R&D over the region is the same across sectors.

Point T in Figure 2 represents the minimum level of R&D necessary to generate a surplus or export over the domestic requirement. It is determined by technological opportunity. Technological opportunity refers to the ease of achievement of innovations and technical improvements given that even when two countries spend the same amount in R&D, they will not attain the same scope of research. The expected effect on exports, therefore, depends on both T and (R-T), where R is the effective or actual R&D. The relationship for one sector can be represented by Figure 2, where X=export revenue.

In the diagram, it is assumed R&D has no effect on exports until amount OT of R&D is spent, which after point B there are sharply diminishing returns. We can also assume that after point B there is no effect of R&D, and that exports up to point C can be achieved without any R&D input. The effect of R&D on exports is measured by $\alpha T + \gamma$

(R - T) as presented here α equals' γ, hence the overall effect is captured by αR, i.e. the effect of actual R&D expenditure. To predict an effect would be correct only in the case where $R = T$. It has already been assumed that γ is constant across sectors. Given this assumption, for a cross-section analysis, it is also necessary to assume $\alpha = \gamma$, otherwise α will vary across sectors. We assume that the effect, rather that the level, of T (or technological opportunity) should vary by sector.

It is expected that profit maximization will ensure that actual R&D is in the region TB, not beyond B. The technological opportunity level of a sector, the deviation of actual R&D from the technological opportunity level and the technology gap between countries can, therefore, affect exports. This can be expressed as follows:

$$X = \alpha T + \gamma(R - T) + \delta(R - FR) \text{ for } R \geq T, \text{ if } R < T, X = 0$$

Where

X = exports

T = technological opportunity

R = US R&D

FR = competitor's *R&D*

If, as argued above, $\alpha = \gamma$, this reduces to:

$$X = \alpha R + \delta(R - FR)$$

Exports depend on actual R&D expenditure and the gap between US and competitor's R&D. The model assumes that "vent for surplus" theory of trade that assumes countries may be able to gain by exporting the excess products of factors that would not be employed at all without trade does not apply.

The country's level of R&D "endowments" will, therefore, have an influence on which sectors it is specialized in and which goods will be exported. These sectors cannot, however, be ranked by technological opportunity. Across countries, R&D expenditures in a particular sector may vary. This will lead to trade. In addition, the same level of R&D across countries can lead to trade. Furthermore, R&D endowments are not static, and will not result in equilibrium patterns of trade. Thus, although it is possible to rank countries in terms of R&D expenditures or endowments, this is not enough to allow prediction on trade flows. Trade flows will be determined by the distribution and the level of domestic and foreign research across the exporting sectors. Trade flows is also influenced by the level of product differentiation and scale economies.

This study argues that US agricultural export performance is positively influenced by investments in R&D and human capital that induce changes in agricultural production resulting in efficient utilization of other inputs. The study, therefore, investigates the roles of R&D and human capital on the competitiveness of selected US agricultural exports. To accomplish this, the study builds on the estimated export model of Arize et al. (2000), de Vita and Abbott (2004), and Almarwani (2003), amongst others, specifically;

$$lnX = f\,(lnY,\ lnP,\ lnV) \tag{22}$$

where X is export volume, Y is real foreign income, P is the relative price as a measure of competitiveness, and V is a measure of exchange rate volatility. Almarwani (2003) modifies the model by including exchange rates and revealed comparative advantage. Almarwani (2003) model ignores R&D and human capital, both important determinants of exports. This study modifies Almarwani (2003) model to incorporate technical progress and human capital,

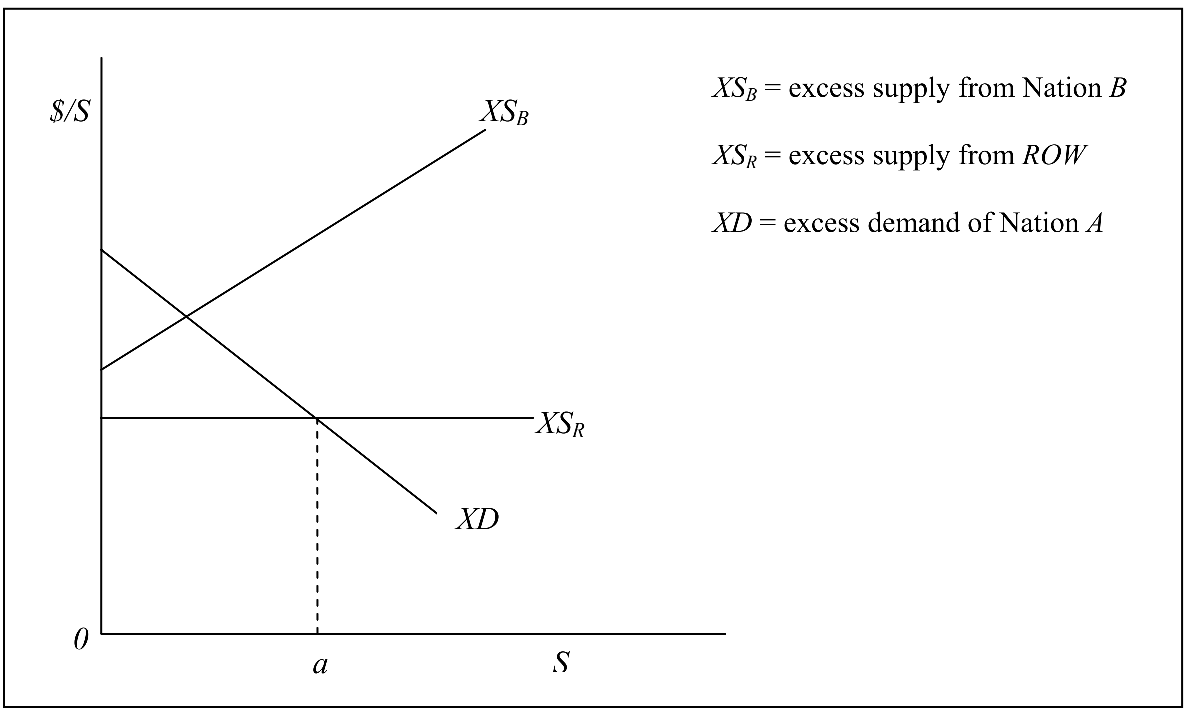
$$lnX = f\,(lnY,\ lnE,\ lnP,\ lnRD,\ H,\ Cp) \tag{23}$$

where E is the real exchange rate, RD is the R&D ratio to GDP of US and competitor i, H is human capital ratio (representing skilled labor) of US and competitor i, and Cp is the Michaely index of competitiveness.

Chapter 1 and Chapter 2 of the study assumes that R&D and human capital changes only affect the production side of the model. However, technological and human capital changes could also affect the demand side of the economy when it is directed to improve quality of a product instead of (or in addition to) reducing the input coefficients. Chapter 3 analyzes demand side effect on the competitiveness of US agricultural commodity exports.

The impact of technology and human capital on the production side enhances output and exports, and can be summarized in a simple but relatively general setting with one importer of wheat, Nation *A* and exporting Nation *B* and the rest of the world, *R*.

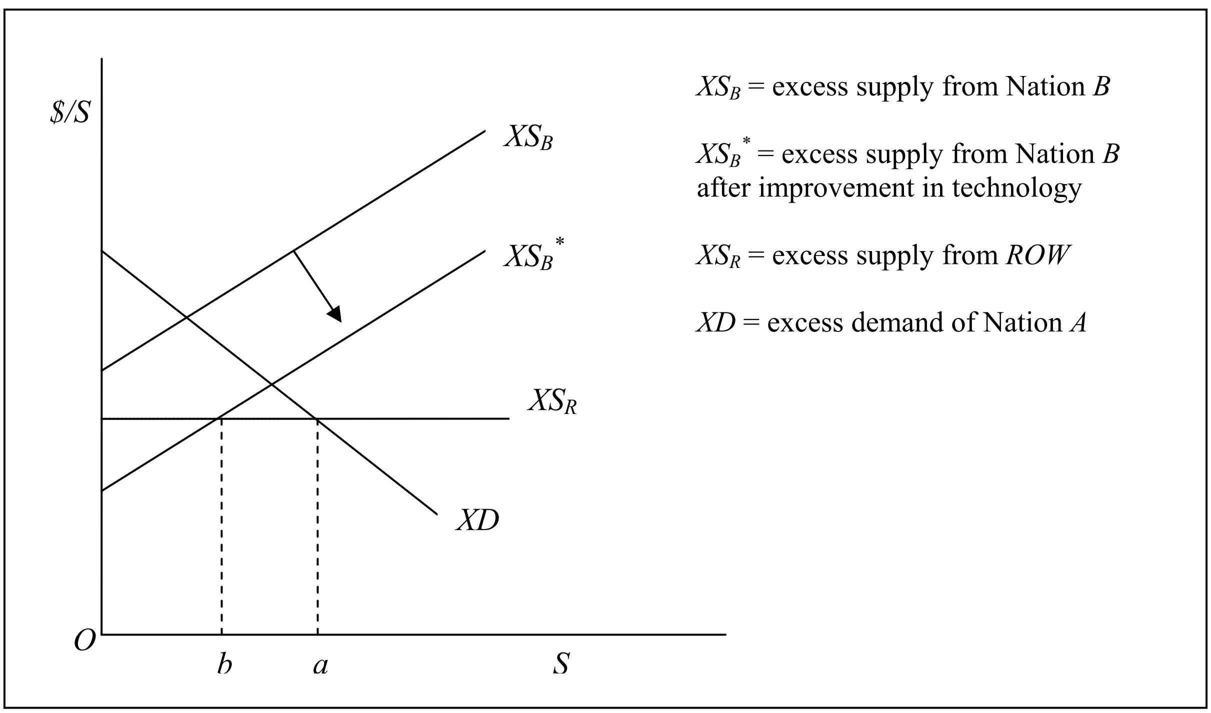
Figure 3. Three-Nation Trade Equilibrium with Nation B High Production Cost



Nation *B*'s cost of producing wheat is high enough so that it cannot compete as a wheat exporter on a free trade basis with the rest of the world, *R*. Nation *A,* therefore, imports wheat from *R* at a constant world price, but none from Nation *B* as indicated by Figure 3. *Oa* in Figure 3 depicts amount of wheat imported from Nation *R*.

Now suppose that Nation *B'*s production technology improves due to investment in R&D and Human capital. Nation *B,* therefore, becomes a more efficient, lower cost wheat producer than before. Its supply price for various export volumes falls. The total supply function, XS_B in Figure 3, would shift to XS_B^* on the right as depicted by Figure 4. When this occurs, wheat exports from Nation *B* to Nation *A* would increase while wheat exports from the rest of the world (R) fall. As depicted by Figure 4, after investments in R&D and human capital, Nation *A* will import quantity *Ob* of wheat from Nation *B* and quantity *ba* of wheat from Nation *R*. *Ob* is the volume of wheat exports that will shift

Figure 4. Three-Nation Trade Equilibrium after Investments in R&D and Human Capital in Nation B



from Nation *R* to Nation *B* as a result of fall in export price of Nation *B* that is attributable to R&D and human capital investments. In other words, Nation *B* will become more "competitive" while Nation *R* will be a less "competitive" exporter of wheat to Nation *A*.

4. Commodities Studied

The study focuses on four export commodities, wheat, corn, cotton, and soybeans from 1972 to 2002 (see Appendix Table 1). These commodities were selected because they form over 30% of US agriculture export revenue and according to USDA (2004) projections will face stiff competition in the future.

4.1 Wheat

Wheat accounts for the largest land area of all internationally traded grains and almost 22 percent of the world's croplands are devoted to its production. World wheat production has increased from around 300 million metric tons in 1970 to an estimated 627 million tons in 2006. Primary producers of wheat in the world include the United States (US), Australia, China, and India. Several countries maintain trade surpluses in wheat. These include the US, Canada, EU, Australia, and Argentina which together account for an average 90% of world wheat exports (Antle and Smith 1999).

Major importing countries are located mainly in North Africa, the Middle East, or Eastern Asia and accounted for more than 60% of net wheat trade in 2004/2005 period. They included Egypt, Brazil, Algeria, Japan, South Korea, Indonesia, Philippines, Mexico, Nigeria, Morocco, and Iraq (USDA, 2006).

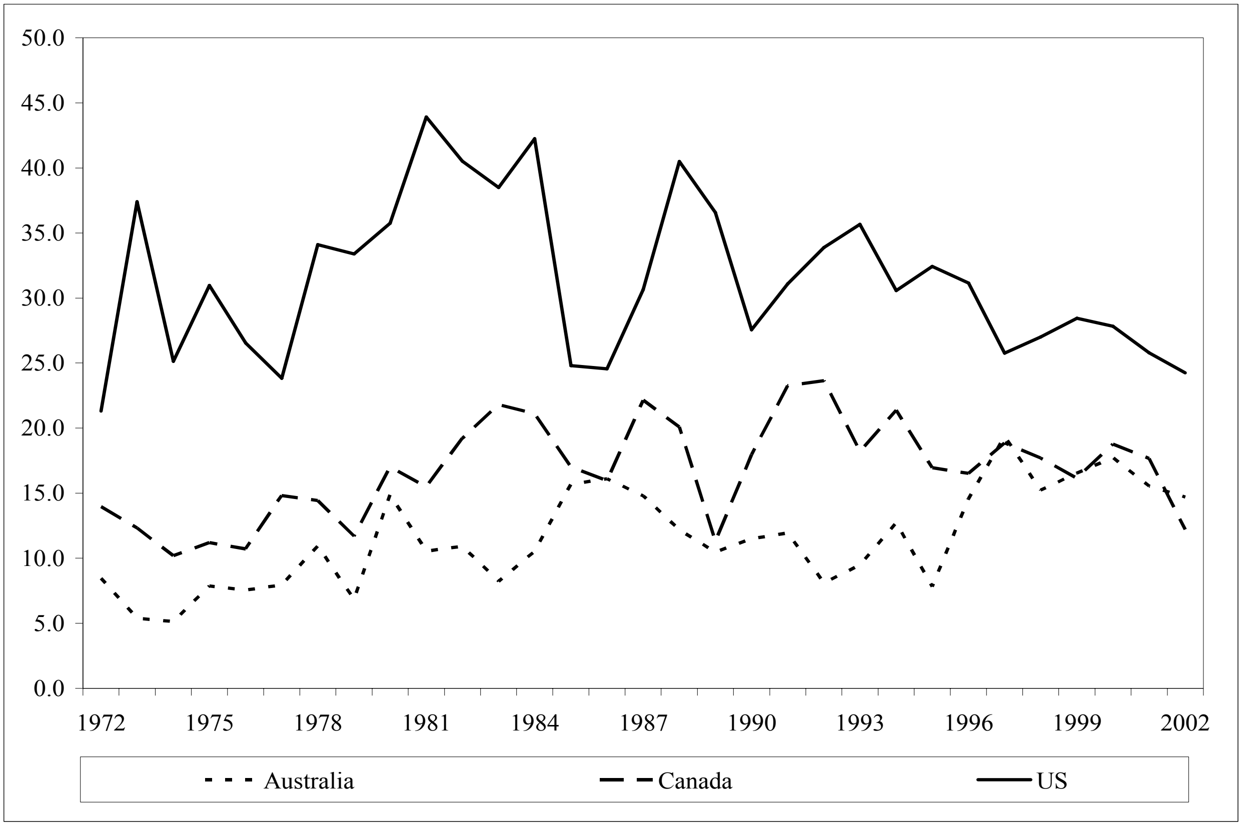
There are many factors that influence the global wheat market. Export demand for wheat fluctuates yearly, based on crop yields in importing countries. Domestic supply of wheat also is affected by climate fluctuations. The supply of competitors' wheat also plays a major role. In recent past Australia has boosted its production of wheat, and has begun to impinge a little upon American export markets. Other factors that influence the global wheat market include wheat quality, transaction costs, consumer income, and the political stability of the importing country (Todd and Gribbons, 1985*)*.

The US is the world's third largest wheat producer (following China and India). It is also the world's largest wheat exporter. During the early 2000s, wheat ranked third among US field crops in both planted acreage and gross farm receipts, behind corn and soybeans. The US relies heavily on exports to maintain the vitality of its wheat industry and presently almost half of the US wheat crop is exported and wheat is a positive contributor to the agricultural trade balance (ERS/USDA, 2005).

Increasing US wheat exports, both in existing and new markets, will help stabilize prices and generate income opportunities for US farmers. Figure 5 represents export volumes in metric tons for Canada, Australia, and US between 1972 and 2002.

The US wheat sector is facing challenges to its long-term profitability in the domestic market. Planted area has dropped as wheat loses its competitiveness to other US crops, particularly soybeans and corn. Coupled with this is the decline in domestic food use of wheat in recent years as a result of changing consumer preferences and improved bread preservation technology (USDA, 2005). This means that the US will continue to rely heavily on exports to maintain the vitality of its wheat industry. Australia and Canada are among US major competitors in the world wheat market.

Figure 5. Annual Wheat Exports (Mil. Metric tons) from Australia, Canada, and US



4.2 Corn

Corn is the number three agricultural commodity traded in the world market with an annual trade value of nearly $10 billion. Around 12% of corn produced in the world is internationally traded. In 2001, world trade amounted to US$8.87 billion. Three countries, the US, China, and Brazil, account for two-thirds of world production. The US is the dominant corn exporter with a two-thirds share of world markets. China and Argentina account for another 20% share of world trade. The Ukraine, Brazil, and the Republic of South Africa are inconsistent exporters, but have shown an increasing trend since 2000 (USDA, 2006; FAO, 2003).

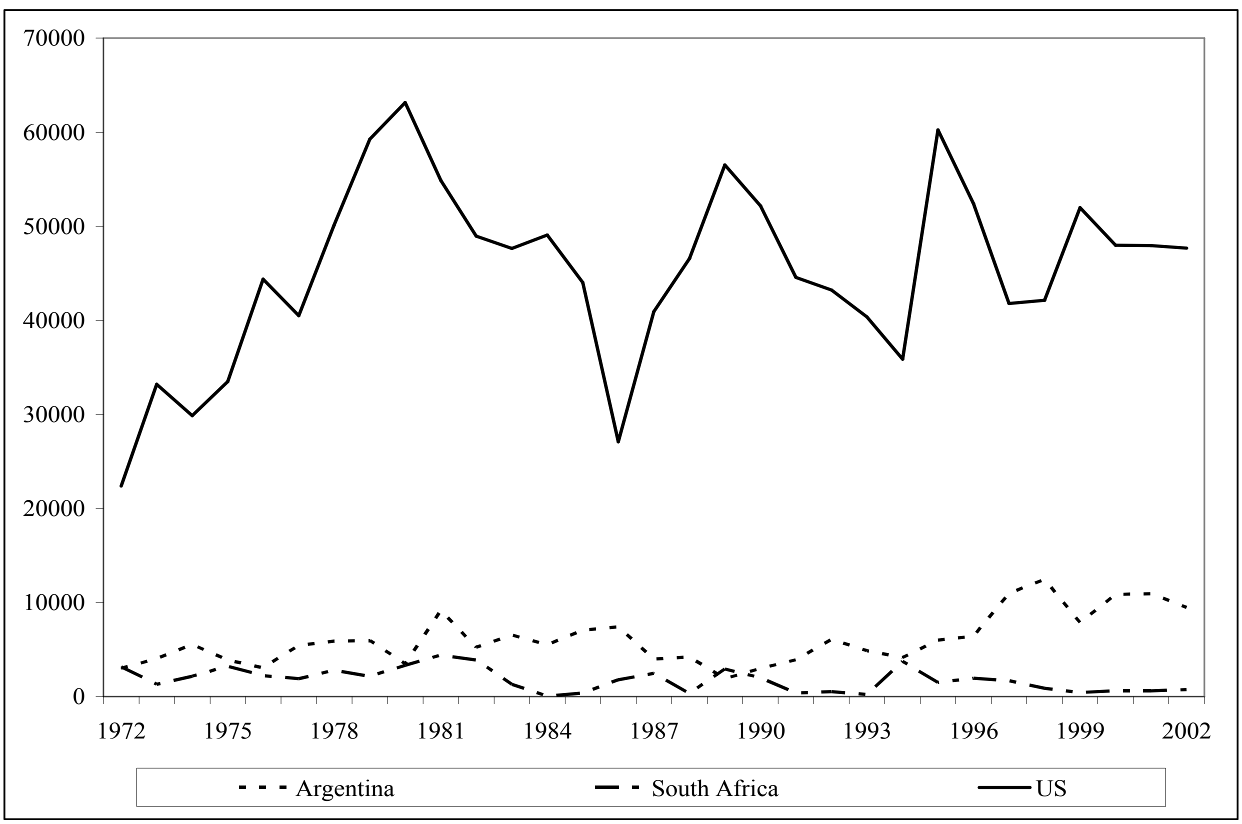
Latin America and the Caribbean accounted for 14-19% of world corn imports in the five years up to 2001 with the US, Argentina and South Africa as the major exporters to the region. North Africa accounts for about 6-10% of world maize imports (worth around $1 billion in 2001) with Egypt as the leading importer followed by Tunisia, Morocco and Sudan. Main exporters to the region are the US, Argentina, the EU (namely the Netherlands and France), Eastern Europe (Hungary, Romania, Croatia and Ukraine), and China. Asia imports about 47-53% of world corn imports, to a value of about $5 billion in 2001. The major importers from the region include Jordan, Yemen, Sri Lanka, and Bangladesh. The major exporters to the region include Argentina, the US, and Canada (FAO, 2003).

US corn exports for the period 1995 to 2001 declined from 53 million tons to 44 million tons, while world exports declined from 65 million to 63 million tons. The share of world corn exports shifted to US competitors. The export volume of corn for 2000 declined by $69 million compared to the previous year. Corn prices remain low due to a big US crop, generous world supplies, and modest demand from Japan, Russia, and the Middle East (Almarwani, 2003).

However, the US corn sector outlook has changed for the better in the recent past. US corn exports in the 2005/06 marketing year are anticipated to be strong because of record production and less competition from China and Argentina. In 2005/06, the US corn export was valued at $2.7 billion, representing over 90% of the revenue of all feed grains (USDA, 2006).

A factor of growing importance in US corn markets is the increasing use of corn for ethanol production. An increase in the share of total demand attributed to industrial use could lead to greater price variability in the face of weather-driven supply shortfalls. In the 2005-2006 marketing year, USDA projects that 15% of US corn production (or about 1,575 million bushels) will be used for ethanol production. This compares with a 4% share in 1990/1991 and a 6% share in 2000/01. Continued growth in corn based ethanol production without concomitant growth in corn production will tend to support prices and possibly squeeze US corn out of price-sensitive feed and export markets (Wisner and Baumel, 2004).

Figure 6. Annual Corn Exports (1,000 metric tons) from Argentina, South Africa, and US



Argentina and South Africa were chosen as US competitors in the corn market. The two competing entities were chosen for the sake of simplicity. While Argentina is among the major exporters of corn along with the US, South Africa has recently become an emerging exporter, especially in African corn market. Increasing US corn exports, both in existing and new markets, will help stabilize prices and generate income opportunities for US farmers. Figure 6 represents export volumes for the three countries from 1972 to 2002.

4.3 Cotton

Despite the declining trend of cotton's share in textile fibers since the 1970s, cotton remains by far the most important natural fiber of the 20th century representing 38% of the fiber market. Although cotton production is spread out all over the world (in 2004, cotton was grown in about 100 countries), six countries alone (China, the US, India, Pakistan, Uzbekistan, and Egypt) account for approximately three fourths of world cotton production. Cotton is one of the most traded agricultural raw materials and one third of cotton production (approximately 4.6 million tons of fiber) has been traded per annum since the 1960s (UNCTAD, 2006).

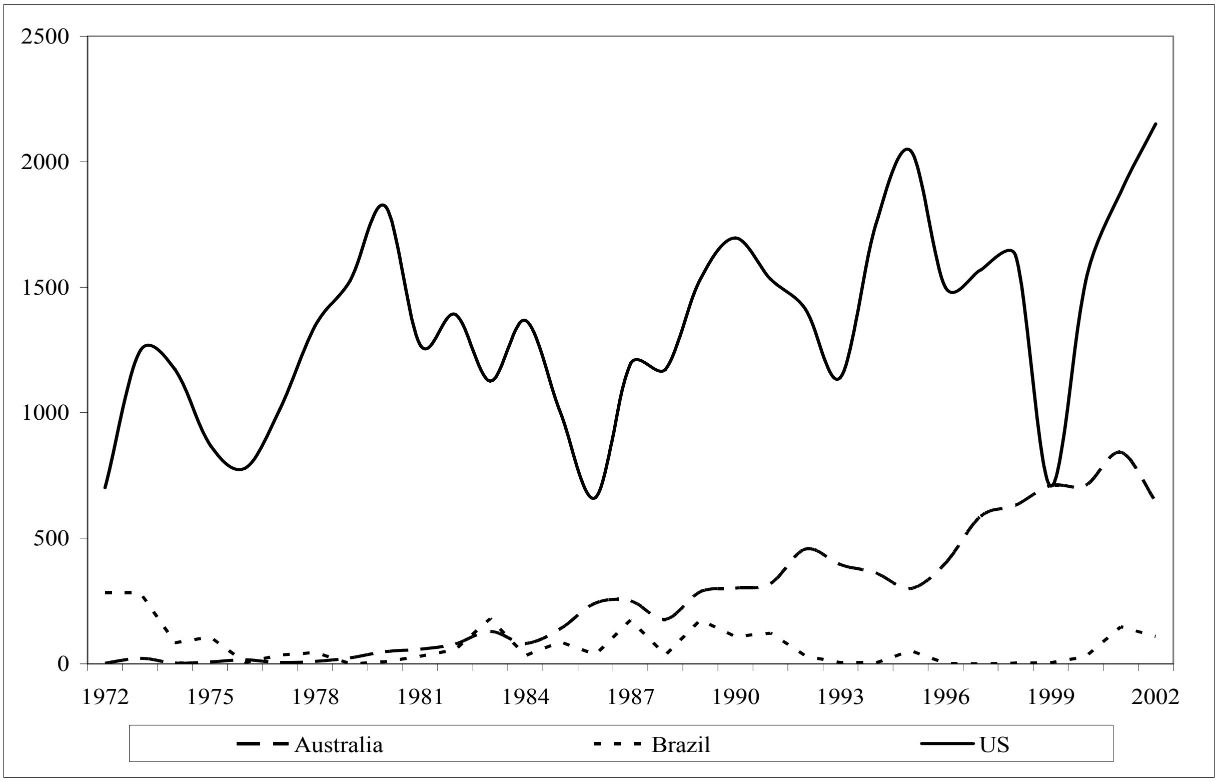
With an annual average export of 1.6 million tons since 1980 (that is, 26% of the world's cotton exports), the US is the dominant exporter of cotton fiber. While the world cotton exports for 2006/07 are projected to be 43.5 million bales, the US will account for nearly 39%, with a projected 16.8 million bales, maintaining the same export level as in 2005/06. India is forecast to be the world’s third leading exporter in 2006/07 exports improving 52% over 2005/06 period (USDA, 2006).

The main cotton producing economies also account for a large part of consumption. According to UNCTAD (2006), China, the United States, India, and Pakistan would account for approximately 56% of global cotton consumption over the period 1980 to 2007. China is the world's largest producer and consumer of cotton, and is believed to hold 30% of world ending stocks. India is the third-largest producer of cotton and the second-largest consumer. Pakistan has had the largest increase in cotton consumption volume which increased by a multiple of 4.5 between 1980 and 2007.

According to Meyer and MacDonald (2002), the future of US cotton exports will depend on markets relying largely on importers like Mexico and Southeast Asia, and the degree to which cotton producers like China, Turkey, and Brazil rely on imports rather than domestic production to meet the growing demand of their textile industries. Recent increases in cotton sales are due to much larger sales to South Asia, particularly India. Depressed cotton prices are the result of continued strong world production, especially by major exporting countries, slowing economic growth, and competition from other fabrics.

Since the collapse of the former Soviet Union, Uzbekistan has been the second major cotton exporter, accounting for 18% of world exports over the period 1991-2000, more than 1 million tons exported per annum over the reference period. Turkmenistan is the second-largest cotton producer in Central Asia and another major exporter in the world (Meyer and MacDonald, 2002; UNCTAD, 2006). For the sake of this study, Australia and Brazil are considered to be US competitors, and Figure 7 represents their volume of exports when compared with the US.

Figure 7. Annual Cotton Exports (1,000 metric tons) from Australia, Brazil, and US



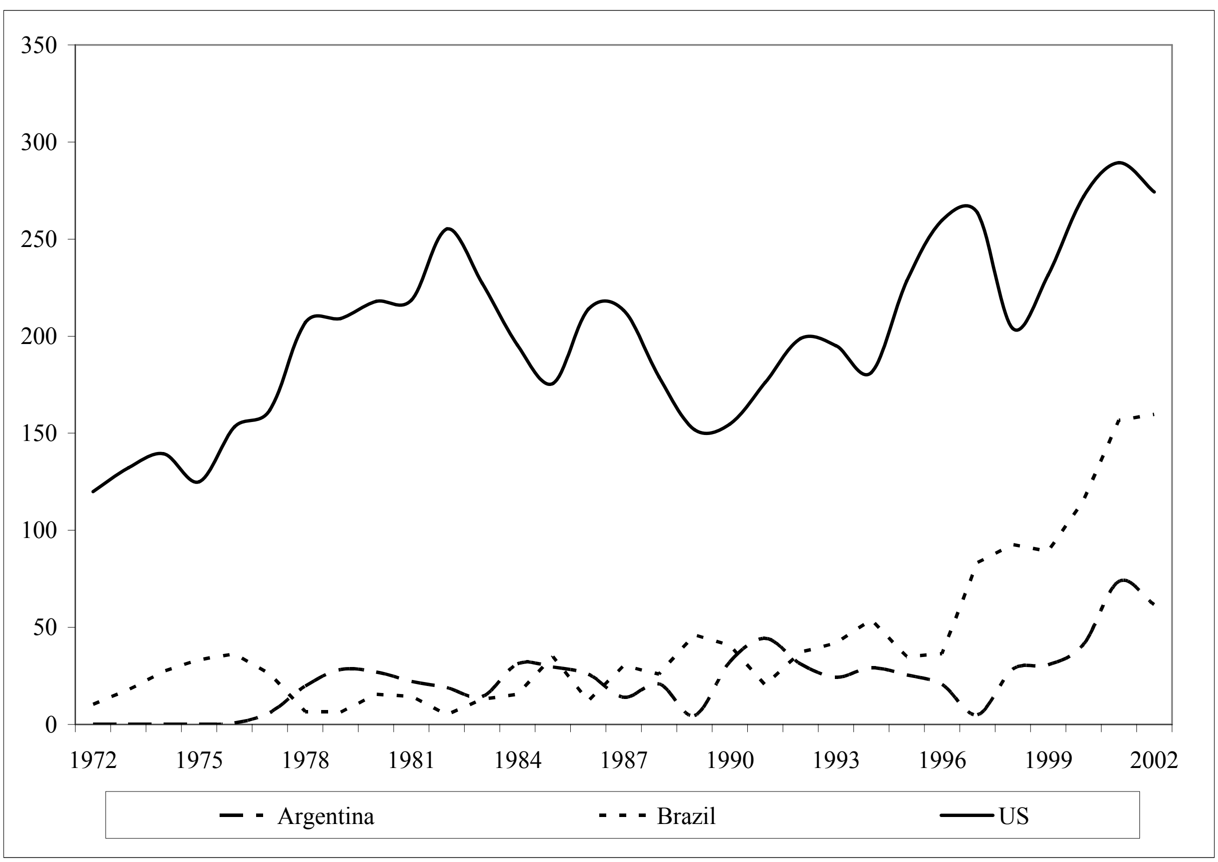
4.4 Soybeans

Soybean is the number one agricultural commodity traded in the world market, surpassing wheat and corn. The US is the world's leading soybean producer and exporter. The farm value of US soybean production in 2003/04 was $18 billion; the second-highest value among US produced crops, trailing only corn. Soybean and soybean product exports accounted for 43% of US soybean production in 2003. Soybeans equal about 90% of US total oilseed production. The US share of the export market is forecast to expand from 37% to 42% in 2007 (Ash and Dohlman, 2006).

The US is projected to retain the world dominant soybean trader status during the next decade encouraged by growing soybean meal supplies and a steady rate of domestic use. Soybean production in the world has increased from 125 million tons in 1995 to 222 million tons in 2007, while US output rose from 59 million tons in 1995 to almost 92 million tons in 2006. Most of the increase in world soybean production is recorded in the US. Soybeans and soybean products have enjoyed more rapid growth than other food grains in the world market (Ash and Dohlman, 2006).

US soybean and product exports were $8.0 billion in 2004. China was the largest customer for US soybeans with purchases totaling $2.3 billion. Japan was the second largest market for US soybeans with purchases of $1.0 billion. Other significant buyers included the European Union with purchases of $863 million and Mexico with purchases totaling $785 million. In 2006/07, China alone could dominate as much as 83% of the

Figure 8. Annual Soybean Exports (million metric tons) from Argentina, Brazil, and US



growth in world soybean imports and 45% of the entire volume of international trade (FAO, 2003; Ash and Dohlman, 2006).

Argentina and Brazil are considered US competitors in the study and Figure 8 represents their volume of exports compared with the US between 1972 and 2002 based on FAO data. The data indicate the seriousness of the competition facing the US soybean exports. Brazil soybean exports are growing rapidly, and Brazil has become a major competitor facing the US soybeans exports.

5. The Model and Modifications

The specification of an export demand function contains two arguments: relative prices and world income. Relative price tries to capture price competitiveness while world income is a normalization variable that accounts for other factors affecting export performance. In recent years some authors have introduced innovation as another argument in the export demand function accounting for non-price competitiveness arising from research activities. This is the usual specification in empirical applications of technology-based trade theories (Leon-Ledesma, 2002).

The present study builds on an export demand function and looks at how inclusion of R&D and human capital index in the measures of competitiveness affect US exports. The study follows Arize et al. (2000), and de Vita and Abbott (2004) amongst others to specify a demand equation that incorporates R&D and human capital in the following form

$$ln\, X_t = \beta_0 + ln\, Y_t + ln\, E_t + ln\, P_t + ln\, RD_{it} + H_{it} + Cp_t + t \qquad (24)$$

where E_t is the real exchange rate, RD_{it} is the R&D ratio of US and competitor *i,* H_{it} is skilled labor ratio of US and competitor *i,* Cp_t is the Michaely Index of competitiveness, and t is the time period. The study develops an R&D and human capital index based on Vonortas (1997) and Gallacher (1999), respectively.

The R&D variable used in the study is developed as described on Appendix (1B) while the RD ratio is generated as the ratio between the R&D expenditure of country *i* and its GDP at time *t*,

$$RD_{i,t} = \frac{R\&D_{it}}{Y_{it}} \tag{25}$$

where $R\&D_{it}$ = *R&D* spending of country *i* in year *t* (*t* = 1971-2002), and Y_{it} = value of GDP for country *i* in year *t*. Human capital serves as a proxy for Skilled labor (*H*). The index for *H* that is used in this study is developed from the economically active population in agriculture L_i in country *i*, estimated as the population engaged in agricultural occupations, L_i by

$$L_i = L_i' \frac{Y_{Ji}}{Y_{Ji}'} \tag{26}$$

where L_i' is the population engaged in agricultural occupations, Y_{Ji} is gross output in agricultural crops sector, Y_{Ji}' is gross output of agriculture, forestry, and fishing. This method assumes that labor productivities are equal across these agricultural occupations.

Human capital index (H_i) is developed as;

$$H_i = \frac{G_i}{L_i} \tag{27}$$

where G_i = the number of secondary graduates in the labor force. The quotient will take a value between 0 and 1. The assumption is that secondary school graduates would be more inclined and better equipped to organize their own business (Hayami and Ruttan, 1985). Other variables used in the study are explained in Appendix (1B).

In our specification we will test both the influence of domestic R&D and that of human capital. Given the nature of the data, especially for R&D, and the problems involved with estimating the equations in levels, the regressions are run using pooled data for the US and two other competitors for each of the export commodity using panel cointegration techniques. Four specifications of the export demand function are estimated:

$$lnX_{it} = \beta_0 + \beta_1 \, lnY_{it} + \beta_2 \, lnE_{it} + \beta_3 \, lnP_{it} + \beta_4 RD_{it} + \varepsilon \tag{28}$$

$$lnX_{it} = \beta_0 + \beta_1 \, lnY_{it} + \beta_2 \, lnE_{it} + \beta_3 \, lnP_{it} + \beta_4 RD_{it} + \beta_5 H_{it} + \varepsilon \tag{29}$$

$$lnX_{it} = \beta_0 + \beta_1 lnY_{it} + \beta_2 lnE_{it} + \beta_3 lnP_{it} + \beta_4 RD_{it} + \beta_5 H_{it} + \beta_6 Cp_{it} + \varepsilon \tag{30}$$

$$\begin{aligned} lnX_{it} = {} & \beta_0 + \beta_1 \, lnY_{it} + \beta_2 \, lnE_{it} + \beta_3 \, lnP_{it} + \beta_4 RD_{it} + \beta_5 H_{it} + \beta_6 Cp_{it} + \beta_7 (D_2 RD_{it}) \\ & + \beta_8 (D_3 RD_{it}) + \beta_9 (D_2 H_{it}) + \beta_{10} (D_3 H_{it}) + \beta_{11} (D_2 Cp_{it}) + \beta_{12} (D_3 Cp_{it}) + \varepsilon \end{aligned} \tag{31}$$

where X_t is the export volume, i is a country index, Y_t is a measure of income activity, E_t is the real exchange rate volatility, P_t is the relative price as a measure of competitiveness, RD_{it} is R&D ratio of US and competitor *i,* H_{it} is skilled labor ratio of US and competitor *i,* Cp_t is the Michaely index (a measure of competitiveness), *D2* (1=US, 0=otherwise), and *D3* (1=competitor 1, 0=otherwise) are dummy variables for US and its competitors, and t is the year of observation.

Equation (28) is the basic specification for testing the effect of *RD* on export performance. The estimations are in levels, and an *RD* variable as in equation (25) is taken as the innovation variable. It is assumed that the level of exports depends on continued flow of new innovations. Equation (29) introduces *H* to measure the extent to which skilled labor affects a country's exports. Equation (30) introduces *Cp*, as a competitiveness measure, and its effect on a country's exports. Finally, in (31) we introduce an interaction term between *RD*, *H*, *Cp*, and a dummy for the US and its competitors to allow for different elasticities of *RD*, *H*, and *Cp* between the US and the competitors considered.

In total, four alternate regression models explore the linkage between R&D, skilled labor, and competitiveness of agriculture exports. Results of the estimation bring forth sensitivity of R&D or skilled labor and other variables included in the model.

The exchange rate volatility is the foreign exchange price and its expected effect is negative, consistent with earlier studies such as that by Assery and Peel (1991), Chambers and Just (1982), Grigsby and Arnade (1986). A negative sign would indicate that home currency appreciation reduces commodity competitiveness. The relative price coefficient *P/P** should have a positive effect.

Exports of normal goods are positively related to the GDP of importing countries as found by ERS (2003), Roe (2000), Klitgaard and Orr (1998) and others. The R&D coefficient should have a positive effect, consistent with studies by Trefler (1993, 1995), Harrigan (1995), Moreno (1997), and others. An increase in R&D spending in a sector should boost output and exports. The coefficient of comparative advantage of competitors should be negative indicating that when comparative advantage of a competing country increases the country's competitiveness declines.

6. Data and Variables

The analysis considers annual data of four export commodities, wheat, corn, cotton, and soybeans from 1972 to 2002 (see Appendix Table 1). These commodities form over 30% of US agriculture exports and according to the USDA (2004) these commodities will face stiff competition in the future. Argentina, Brazil, and South Africa are competitors in the export markets of North Africa, West Africa, and South Africa. Argentina and Brazil are traditional US competitors especially in grains and soybeans. South Africa is emerging as a competitor in the corn market. Australia exports about 80% of its wheat and has of late offered US competition especially in its traditional North African wheat market. Also, Canada is considered one of the US competitors in the global wheat market.

Export revenue is defined as the real value of international sales in US dollars of the selected commodities. Annual data on gross agriculture exports from US and selected competitors are from *The Production, Supply, and Distribution (PS&D)* database of the USDA and the FAO statistical database. The *PS&D* database contains information on most major agricultural commodities in the producing and exporting countries but country and time coverage differs across commodities. These data are published periodically by the Foreign Agricultural Services (FAS) and can be downloaded from the FAS website using the “Time Series by Commodity” (TSC) program. Real exchange rates are obtained from ERS Agricultural Exchange Rate database that contains annual and monthly data for exchange rates important to US agriculture.

Data on aggregate GDP is defined as the sum of the income of the 10 largest importers of each commodity in constant 2000 US dollars from the ERS/USDA macroeconomic database and defined as $GDP_i = \sum_{j=1}^{10} y_j$ *with* $j \neq i$, *where* y is the gross domestic product of importer j and commodity i. R&D expenditure data for selected countries are from Organization for Economic Co-operation and Development (OECD) Fact Book, US National Science Foundation, Division of Science Resources Statistics

(NSF/SRS), Research and Development in Industry and UNESCO Institute for Statistics.

R&D expenditures are used because of the relative ease when comparing across countries and the availability of detailed data. R&D data suffer nevertheless from various drawbacks. In particular, they are an input measure and do not therefore account for variations in effectiveness of R&D, or for duplication of R&D. The effects of R&D are also cumulative and so, ideally, a stock measure should be used, but there are inevitably major measurement problems (Schott, 1978).

Also, data on R&D give no indication of the amount of subsequent expenditure necessary to translate an innovation fully into production. Neither R&D nor patent data provide information on the speed or extent of diffusion of innovations, which may vary by industry or country. In light of these points, it is clear that the information presented below cannot provide a complete picture of technological competitiveness. It nevertheless provides evidence on one major aspect of technological activity, and so contributes to an understanding of differences between countries and sectors within a country, and their relative development over time.

Brooks (1984, p341) notes that national investment in R&D is frequently used as a proxy for innovative effort as in Clegg (1987) and Magnier and Toujas-Bernate (1994). R&D spending is aggregated and shares of commodity revenue will allocate R&D spending across commodities. Higher output value of a commodity should create more interest in R&D.

Skilled labor is considered as a proxy for human capital (H). The number of workers in agriculture is estimated from the data of the economically active population in agricultural occupations (agriculture, forestry, hunting, and fishing) published in the

Yearbook of Labor Statistics (various issues) by the International Labor Organization (ILO). Forestry and fishery workers (excluding hunters) from the ILO labor population in agricultural occupations is the product of the population and the ratio of the gross output in agriculture to the combined output of agriculture, forestry, and fishing, as in Hayami (1985), assuming the input mix is constant across these industries.

As a proxy variable for the level of advanced technical education, graduates from secondary institutions are used. The data are from UNESCO *Basic Facts and Figures* and *Statistical Yearbook* (various issues). The variables used in the study are summarized in Appendix C:

6.1 Model Estimation

The model is estimated in levels, since we are interested in the long-run determinants of exports and the impact of R&D and human capital which are subject to diffusion lags. This poses some difficulties because the time series component of the panel may not be stationary, and there is the possibility of obtaining spurious relations among the variables.

Several tests have been proposed to check whether or not variables contain a unit root, a necessary condition for establishing cointegration relationship between the variables. We test all variables using the Augmented Dickey Fuller (ADF) test and Phillips-Perron (PP) test.

MacKinnon critical values for the ADF test and PP unit root tests are administered for US and competitors in corn, cotton, soybeans, and wheat exports from 1970-2002. The ADF and PP tests differ mainly in how they treat serial correlation. The ADF test assumes that error terms are uncorrelated and have a constant variance. PP test relaxes these assumptions. It should be noted that if test statistics reject the null hypothesis of a unit root, then the use of a cointegrated test is not necessary. A necessary condition for integration is that all series are integrated in the same order.

Tables 2 (a) in the appendix reports the observed statistics for the ADF and PP unit root test for exports variable. The test for unit roots indicates rejecting the null hypothesis of unit root at 5% and 1% levels of significance for the variables. However, the ADF test for the US, South Africa, and Australian corn are not significant. Results on the other variables are reported in Tables 2(b)-2(g) in the Appendix based on a unit-root null versus a trend stationary alternative. While all PP test results reject the null hypothesis of the unit root, all ADF tests do not show similar results. This indicates that all variables in the series are not integrated in the same order. The problem is that a conventional *t*-test cannot be used as under the null hypothesis.

Since the study uses panel data, one possibility of controlling for this problem is to run separate regressions for each country using the different well-known cointegration techniques. There are two problems with this. First, the limited number of observations in our panel can result in difficulty when making inferences about the presence of unit roots or cointegration relations of the variables. Both due to this shortage and the small sample period, all the tests developed in time series literature suffer from low explanatory power. This could lead us to accept the null hypothesis of a unit root or no cointegration when the alternative is true. Secondly, estimating the model using time series data will leave us with few degrees of freedom to make inference, especially in models like ours in which we can have up to 6 independent variables. We increase the power of the tests and the degrees of freedom by combining cross-section and time series data. This is, of course, at the expense of not allowing for much heterogeneity between the different cross-sections of the panel.

This study relies on Kao and Chiang (1998) who discuss the properties of the OLS and dynamic OLS (DOLS) estimators for the estimation of the long-run cointegration vector. Kao and Chiang (1998) find that the OLS fixed effects estimation of the panel is subject to a non-negligible bias in finite samples. For this reason, they propose alternative estimators. One proposed alternative is the DOLS estimator based on Stock and Watson (1993) obtained running the following regression:

$$y_{it} = \alpha_i + \beta x_{it} + \sum_{j=1}^{p} \eta_j \Delta x_{i,t-j} + \sum_{j=1}^{p} \xi_j \Delta x_{i,t+j} + e_{it} \qquad (32)$$

The DOLS regression adds to the OLS the leads and lags of the differences of the independent variables. This ensures asymptotically unbiased estimates and avoids the estimation of nuisance parameters. Kao and Chiang (1998) also show that the DOLS estimator is preferable to both the OLS and the FM for finite samples. We will report both the OLS and the DOLS estimations for our four specifications of the impact of export demand function with respect to R&D and Human capital. The OLS regression results are included for comparison purposes and only results from the DOLS regression model are included in the discussion.

A multicollinearity matrix for all variables used in the study was evaluated since it would be inappropriate to use explanatory variables that are nearly perfectly collinear. This would create a multicollinearity problem. All variables had a correlation coefficient of less than 0.36. The low value of correlation coefficient may be an indication that multicollinearity is not a problem in our DOLS regression model.

7. Results

We report the DOLS estimations for four specifications of the impact of the export demand function with respect to R&D and human capital. The estimation results are reported in Tables 3-10 in the Appendix. The coefficients measure the percentage change of the dependent variable resulting from a 1% change in the independent variables, keeping all other independent variables constant. All regression equations indicate significant F- statistics that show the overall significance of the estimated equations at the 1% level.

Tables 3 -6 report results of the OLS model estimation. Each OLS table contains outcomes of four OLS regression models as expressed by equations 28 – 31 (page 64-67). Tables 7-10 report outcomes of four DOLS regression models. The adjusted R^2 for the regression models range from 0.59 to 0.96 in OLS model, and 0.63 to 0.99 in DOLS model. This an indication of good predictive power for the two models with DOLS model having a better predictive power.

Comparison between OLS and DOLS estimates indicates that DOLS gives a better fit with lower mean square error and higher reported adjusted R^2. Also, coefficients of variables in the DOLS model have a higher value when compared to their OLS estimates. The OLS regression results are, therefore, included for comparison purposes and only results from the DOLS regression model are included in our discussion.

The estimation results indicate that the sign and size of the income (GDP) parameter are as expected in all four models. The impact of R&D is clearly positive and significant for all specifications except in the wheat sub-sector. Specific results related to different commodity exports from US and its competitors are discussed next.

7.1 Corn

The corn market in this study focuses on the corn export market share. Table 7 of the appendix presents DOLS regression results of corn exports from US and its competitors. Dummy variables are included to obtain country specific effects of R&D, human capital, and Michaely Index measure of competitiveness. The DOLS regression contains indexes for R&D, human capital, and Michaely Index along with related variables, as the independent variables.

Coefficients of GDP and relative prices are statistically significant at the 1% level in all cases, consistent with our expectations. This indicates that the more income a country has the more corn it should be able to import. The coefficient on the relative volatility variable for corn is positive and statistically significant at 1% as shown by Table 7 equation (i). Since the relative volatility is a measure of US exchange rate volatility compared to the volatility of the competitor's exchange rate, one would expect the coefficient on this variable to be negative if exchange rate volatility was a factor that importers were concerned about when they make their import decisions. One explanation could be that since most corn exports go to countries that have diversified financial markets, exchange rates volatility might be lower in these countries.

The R&D coefficient shows a positive relationship with corn exports and is significant at the 1% level. This indicates that corn exports are positively influenced by the level of R&D investment within the exporting country. The elasticity of R&D is substantially higher for the US at 4.4 than for its competitor South Africa at 2.3 while Argentina which has negative coefficient (Table 7 equation (iv)). These coefficients indicate that corn exports from US increase faster for every dollar increase in R&D

expenditure when compared to its competitor's corn exports, given the same level of R&D expenditure increase.

The Michaely Index measure of trade specialization is positive and significant indicating that corn exporting countries become relative net exporters as their exports increase (Appendix Table 7 equation (iii)). Table 7 indicates that Argentina has a Michaely Index coefficient of 7.5 followed by the US with a coefficient of 4.8. Argentina is therefore considered to be more specialized in corn exports when compared to the US.

The human capital index coefficient was significant and negative indicating that corn exports do not benefit from the improvement in human capital of the exporting countries as shown by Table 7 equation (ii). One explanation could be as in Schunh and Angeli-Schuh (1989) who note that the aggregate production function of agriculture in the US and other developed countries show that investments in human capital is a perfect substitute at the aggregate level for labor as input in the production process. Human capital is factor-augmenting as it increases the supply of labor services without the need for increases in physical stock. It is therefore possible to increase production in the corn sector with less labor after investments in human capital.

7.2 Cotton

Exports from the US, Brazil, and Australia are examined. Results of the DOLS regression model are shown in Table 8. The coefficients for income, exchange rate volatility, R&D, human capital, and the Michaely Index of competitiveness are positive and significant at 10% in all cases, consistent with our expectations.

The R&D coefficient shows the expected positive relationship of R&D expenditure with cotton exports and is significant at 1% level. This indicates that cotton exports benefit with increases in R&D expenditure in the exporting countries. R&D expenditure effects on cotton exports are most profound when considered for Brazil which has a positive and significant coefficient as indicated by Table 8 equations (iv).

The human capital coefficient is positive and significant at the 1% level as indicated by Table 8 equation (i) - (iii). This indicates that cotton exports are positively influenced by investments in human capital. The US human capital coefficient has the expected sign. Brazil has a negative but significant human capital coefficient. One explanation for Brazil's negative human capital coefficient could be that as farmers invest more in technology (R&D), less human capital is needed. Also, as in corn, human capital is labor augmenting with ability to increase the supply of labor without increases in its physical stock.

The Michaely Index coefficient of trade specialization has a positive sign and is significant at the 1% level as indicated by Table 8 equation (iii), consistent with our expectations. When compared to its competitors, Australia has a positive and significant Michaely Index coefficient as indicated by Table 8 equation (iv). On the other hand, Brazil has a negative Michaely Index coefficient. This indicates that Australia is more specialized in cotton exports when compared to US and Brazil.

7.3 Soybeans

The study examines soybeans exports from US, Argentina, and Brazil. Results of the DOLS regression equations are presented on Table 9. The coefficients for income, relative price, and R&D have the expected signs and are significant at 1% as indicated by

Table 9 equation (i). Exchange rate volatility has the expected sign but is not significant. It should be noted that soybeans go to the richer countries compared to commodities like wheat. These countries have diversified financial markets which might reduce the volatility of exchange rates and its impact to imports. The income coefficient is significant at 5% level, while both relative price and R&D coefficients are significant at 1% level.

The R&D coefficient for the US has the expected sign but is not significant. However, the R&D coefficient for Brazil has a positive sign and is significant at the 1% level as indicated by Table 9 equation (iv). This indicates that Brazil soybeans exports accrue the highest benefit with an increase in R&D expenditure, followed by the US, as shown in Table 9 equation (iv).

The human capital coefficient for Argentina is significant at the 1% level indicating that Argentinean soybeans exports benefit most with increases in human capital as indicated by Table 9 equation (iv). The Michaely Index coefficient for trade specialization is significant at 1% level as indicated by Table 9 equation (iii). All the country specific Michaely Index coefficients have the expected signs but only Argentina's Michaely Index is significant at 1%.

7.4 Wheat

Wheat exports from the US, Canada, and Australia are examined. Results based on DOLS regression model are summarized in Table 10. The results show that the coefficient of the income variable has the expected sign and is significant at 1% as indicated by Table 10, equation (i). However, the overall results do not lead to the detection of any significant relationship between wheat exports on one hand, and relative prices and R&D on the other hand.

The human capital coefficient is significant at 1% level, but with a negative sign. This indicates that in general, human capital increases will not be associated with increases in the level of wheat exports. However, the human capital coefficient for the US is significant at the 10% level, indicating that US wheat exports benefit most from increases in human capital as indicated in Table 10 equation (iv). Canada and Australia's human capital coefficients are not significant.

The overall Michaely Index coefficient of trade specialization for wheat is positive and significant at the 1% level, as indicated in Table 10 equation (iii). The Michaely Index coefficient for US and Canada are positive and highly significant at 1% as shown in Table 10 equation (iv) with US being the most significant, followed by Argentina and Australia.

8. Discussion and Conclusion

The importance of exports to agriculture makes the competitiveness of US agricultural products an ongoing concern for domestic producers and US policymakers. According to various studies, policies such as R&D and human capital investment affect US competitiveness in agriculture. Domestic market competitiveness of US agriculture is expressed through enhanced trade in the international market.

This study evaluates corn, cotton, soybeans, and wheat export markets for their responsiveness to R&D and human capital variations with the assumption that R&D and human capital will positively influence the volume of trade of these commodities. This study extends the analyses of factors related to export competitiveness as defined in the literature and in Almarwani (2003).

The present study uses volume of exports, commodity prices, nominal exchange rates, GDP of the major importing countries, R&D expenditure of exporting countries, and secondary school enrolment of exporting countries. Exchange rate volatility is calculated using nominal exchange rate data. Michaely Index is calculated to represent a measure of competitiveness.

Appendix Tables 3 to 10 provide summary results for the export model results for the US and its competitors. The results are divided into two sections; the OLS and DOLS regression models. Each table summarizes results of four regression equations. Three regression equations link the pooled data for selected commodity exports to exports, commodity prices, and nominal exchange rates variables. The fourth equation introduces the country specific dummies for R&D, human capital, and Michaely Index.

As far as the robustness of the signs and their conformity to expected values, the results meet some, but not all of the a-prior expectations. Estimation results indicate that, for the agricultural commodities considered, the most important variables that explain variation in the US and competitors' exports include the income of the importing countries, the relative price between the importing and exporting country, R&D expenditure of the exporting country, Human Capital investment in exporting country, and the competitiveness of the commodity as measured by the Michaely Index.

The expected value of the coefficient on the GDP variables is positive and statistically significant for corn, cotton, and soybeans. The GDP coefficient has a negative coefficient for wheat. The GDP variable coefficient should theoretically have a positive sign on most commodities as imports increase with income. One of the reasons that could explain the negative GDP coefficient for wheat is that most wheat exports go to the poorer countries to meet shortfalls in their domestic wheat production. Although the GDP of these countries might be low, they are forced to import wheat to satisfy their domestic food demands.

The exchange rate volatility has a positive value on exports in corn and cotton which are statistically significant. The inconsistency of exchange rate volatility results support the ambiguity of agricultural exports to variations in exchange rate volatility as stated in Chowdhury (1993).

The overall coefficient of relative price is positive and statistically significant as expected in corn and soybeans. This indicates that corn and soybeans exports are the most responsive to differences in commodity prices between the exporting and importing countries. Overall, the R&D coefficient has positive sign and is statistically significant at the 1% level as expected in studied commodities. This indicates that when R&D investments are made in a country, agricultural exports are expected to increase. Country specific values of this variable vary depending on the commodity. The R&D coefficient for US corn is positive and highly significant compared to South Africa and Argentina that are the main competitors.

The R&D coefficient for soybeans in the US has a positive sign but is less significant when compared to the coefficient for Brazil. This indicates that the Brazilian soybeans sector benefits more with increases in R&D expenditure when compared to the US. The R&D coefficient for cotton in the US has a positive sign but is less significant when compared to the coefficient of Brazil. This indicates that the Brazilian cotton sector exports benefit more from increases in R&D expenditures compared to the US and Australia. However, the R&D coefficients for wheat in the US and Canada are negative though significant. This indicates that the US and Canada wheat exports do not directly benefit from increases in R&D investments.

The overall coefficient for the Michaely index of trade specialization is positive and statistically significant at the 1% level, as expected in studied commodities. This indicates that selected countries are relative net exporters of the studied commodities. When considering country specific results, the corn coefficient for the US and Argentina is positive and statistically significant. Since the Argentina has a higher Michaely Index coefficient for corn it is more specialized in corn exports than its competitors.

The Michaely index of trade specialization for US wheat is positive and statistically significant. This indicates that US wheat sector is more specialized in terms of export when compared Canada and Australia that follow in the order. Also, based on the Michaely index, Argentina is most specialized in soybeans exports when compared to the US and Brazil, while Australia is the most specialized in cotton exports.

The overall human capital index is negative and statistically significant at the 1% level for corn and wheat. This indicates these crops do not benefit with increased human capital development. One explanation for this outcome is that investments in human capital raise labor productivity in agriculture which qualifies it for employment in other sectors. This makes human capital more mobile. Since human capital investments are factor-augmenting, increases in the productivity of corn and wheat sectors are possible even as labor moves out to other sectors. However, the overall human capital index for cotton is positive and statistically significant, as expected.

The US human capital index coefficient for wheat has a positive sign and is significant, while the sign for its competitor's are negative and not significant. For Argentina, the soybean sector has a positive and significant human capital coefficient while US and Brazil has negative signs. The positive human capital coefficient for Argentina is an indication that its soybeans sector benefits most from increases human capital investments when compared to the US and Brazil sectors.

It is important to note that the results of the study are based on the assumption that each country's R&D investments outcomes will accrue only within its geographical boundary. However, most agricultural commodity trade is controlled by multinationals that spread across several geographical regions. Therefore, items like patents resulting from R&D expenditure might be registered in one country while their application might spread beyond the registrant country.

The result of this study indicates that R&D investment and competitiveness, as measured by the Michaely Index, are important factors that positively influence agricultural commodity exports. All commodities that were studied had positive relationship between R&D and their exports. Results based on R&D variable show that US is most competitive in corn production while Brazil is most competitive in soybeans production. The results also indicate that the level of commodity competitiveness influences exports. Relative price and Michaely Index of competitiveness were positive and significant. The US is most competitive exporter in wheat based on the Michaely Index results. On the other hand, Argentina is the most competitive in corn and soybeans exports, while Australia is most competitive in cotton.

The overall human capital coefficient is negative. Also, the US wheat sector has the expected sign and the Argentina soybean sector has a positive and significant human capital coefficient. Based on the human capital coefficient, Argentina soybeans sector is the most competitive when compared to other competitors.

Overall, the results of this study indicate that investments in R&D influences agricultural commodity exports while we do not get consistent results to show that human capital has any effects on agricultural commodities export. This shows that R&D measure can be included when evaluating the competitive position of US agriculture. The results of this study could open an avenue for more research on the impact of R&D and human capital on non-bulky agricultural export commodities so as to enhance the empirical findings of the study.

Appendix 1A. Tables for Chapter1

Table 1. Commodities, US Competitors, and Major world importers

Commodities	Competitor	Major world importers
Corn	Argentina, South Africa	Algeria, Egypt, Morocco, Tunisia, South Korea, Malaysia, Mexico, Saudi Arabia, Taiwan, Canada
Cotton	Australia, Brazil	Algeria, Morocco, Tunisia, Indonesia, India, China, Mexico, Thailand, Russia, Turkey
Soybean	Argentina, Brazil	Egypt, Morocco, Indonesia, China, South Korea, Japan, Taiwan, Germany, Netherlands, Spain
Wheat	Australia, Canada	Algeria, Egypt, Morocco, Tunisia, South Korea, Brazil, Indonesia, Iran, Japan, Philippines

Table 2a. Order of Integration: Unit Root Test on Exports Variable

Commodities	Competitors	ADF test (One lag)	Phillips-Perron test
Corn	US	-1.87 *	-35.01***
	South Africa	-1.42	-32.55***
	Argentina	-2.63***	-42.11***
Cotton	US	-3.35***	-43.21***
	Brazil	3.37***	-13.95***
	Australia	0.46	-30.39***
Soybeans	US	-3.21***	-39.35***
	Argentina	-2.43**	-32.74***
	Brazil	-2.64***	-13.02***
Wheat	US	-3.43***	-43.64***
	Canada	-3.27***	-41.07***
	Australia	-2.69***	-40.71***

*, **, and *** denote rejection of the null hypothesis of the unit root at 10%, 5% and 1% significant.

Table 2b. Order of Integration: Unit Root Test on Income Variable

Commodities	Competitors	ADF test (One lag)	Phillips-Perron test
Corn	US	-1.28	-32.34***
	Argentina	-2.71*	-32.664***
	Brazil	-3.11***	-130.04***
Cotton	US	-3.11***	-32.74***
	Australia	0.43	-32.74***
	Brazil	-3.11***	-32.74***
Soybeans	US	-3.11***	-32.74***
	Argentina	-3.11***	-32.74***
	Brazil	-3.11***	-32.74***
Wheat	US	-3.11***	-43.64***
	Argentina	-3.11***	-41.07***
	Brazil	-3.11***	-40.71***

*, **, and *** denote rejection of the null hypothesis of the unit root at 10%, 5% and 1% significant.

Table 2c. Order of Integration: Unit Root Test on Volatility Variable

Commodities	Competitors	ADF test (One lag)	Phillips-Perron test
Corn	US	-2.95***	-49.86***
	Argentina	-2.19**	-43.99***
	South Africa	-2.08**	-32.66***
Cotton	US	-2.95***	-49.86***
	Australia	-2.60***	-46.60***
	Brazil	-3.57***	-37.21***
Soybeans	US	-2.95***	-49.86***
	Argentina	-2.19**	-43.99***
	Brazil	-1.38	-37.24***
Wheat	US	-2.95***	-49.86***
	Australia	-2.60**	-49.26***
	Canada	-2.17**	-40.71***

*, **, and *** denote rejection of the null hypothesis of the unit root at 10%, 5%, and 1% significant.

Table 2d. Order of Integration: Unit Root Test on Relative Price Variable

Commodities	Competitors	ADF test (One lag)	Phillips-Perron test
Corn	US	-0.38	-33.14***
	Argentina	-3.69**	-43.99***
	South Africa	-1.55**	-51.66***
Cotton	US	0.83	-44.09***
	Australia	-3.50***	-48.72***
	Brazil	-2.93***	-50.06***
Soybeans	US	-4.01***	-54.89***
	Argentina	-4.58**	-42.90***
	Brazil	-5.62***	-64.36***
Wheat	US	-3.22***	-50.56***
	Australia	-3.55***	-50.66***
	Canada	-2.93***	-53.90***

*, **, and *** denote rejection of the null hypothesis of the unit root at 10%, 5%, and 1% significant.

Table 2e. Order of Integration: Unit Root Test on R&D Variable

Commodities	Competitors	ADF test (One lag)	Phillips-Perron test
Corn	US	1.201	-31.12***
	Argentina	-1.82*	-39.40***
	South Africa	-1.24	-35.70***
Cotton	US	-3.17**	-34.82***
	Australia	-4.75***	-59.14***
	Brazil	-15.72***	-47.80***
Soybeans	US	-0.83	-34.82***
	Argentina	-1.82*	-39.40***
	Brazil	-2.93***	-47.81***
Wheat	US	-0.83	-34.82***
	Australia	-4.75***	-59.14***
	Canada	0.50	-31.48***

*, **, and *** denote rejection of the null hypothesis of the unit root at 10%, 5%, and 1% significant.

Table 2f. Order of Integration: Unit Root Test on Human Capital Variable

Commodities	Competitors	ADF test (One lag)	Phillips-Perron test
Corn	US	-3.16**	-31.70***
	Argentina	-11.51*	-33.52**
	South Africa	-14.19***	-34.001***
Cotton	US	-3.17***	-34.43***
	Australia	-2.30**	-31.15***
	Brazil	-15.71***	-34.77**
Soybeans	US	-3.17***	-34.43***
	Argentina	-11.51***	-33.59***
	Brazil	-15.71***	-34.77***
Wheat	US	-3.17***	-34.43***
	Australia	-2.30**	-34.78***
	Canada	13.56***	-31.15***

*, **, and *** denote rejection of the null hypothesis of the unit root at 10%, 5%, and 1% significant.

Table 2g. Order of Integration: Unit Root Test on Michaely Index Variable

Commodities	Competitors	ADF test (One lag)	Phillips-Perron test
Corn	US	1.21	-32.00***
	Argentina	-1.82*	-42.84***
	South Africa	-1.24	-44.06***
Cotton	US	-3.91***	-54.09***
	Australia	-1.22	-34.17***
	Brazil	-2.13**	-38.32***
Soybeans	US	-1.66	-37.38***
	Argentina	-2.81**	-44.09***
	Brazil	-2.25**	-42.66***
Wheat	US	-1.43	-36.41***
	Australia	-3.46***	-51.19***
	Canada	-0.89	-33.83***

*, **, and *** denote rejection of the null hypothesis of the unit root at 10%, 5%, and 1% significant.

Table 3. Corn Export Function Estimation using OLS

Variable	Equation (i)	Equation (ii)	Equation (iii)	Equation (iv)
Y_{it}	0.32	0.72	1.37	1.43
	(1.38)	(2.99)***	(7.69)***	(5.91)***
V_{it}	0.85	0.64	0.74	-0.07
	(2.74)***	(2.15)**	(3.64)***	(-0.58)
RP_{it}	1.87	1.20	0.97	0.04
	(2.88)***	(1.88)*	(2.20)**	(0.12)
RD_{it}	0.99	0.81	0.75	-3.91
	(6.62)***	(5.51)***	(7.44)***	(-1.15)
H_{it}		-12.10	-6.91	-0.14
		(-3.64)***	(-2.95)***	(-0.03)
CP_{it}			8.30	8.13
			(10.22)***	(4.21)***
$D2{*}RD_{it}$				3.89
				(1.19)
$D3{*}RD_{it}$				2.15
				(0.92)
$D2{*}H_{it}$				-2.39
				(-0.296)
$D3{*}H_{it}$				-8.748
				(-1.861)*
$D2{*}CP_{it}$				5.085
				(1.914)*
$D3{*}CP_{it}$				-0.743
				(-0.370)
R^2	0.68	0.72	0.87	0.96
F-stat.	(50.90)***	(48.69)***	(103.16)***	(153.34)***

The OLS estimates for US, Argentina, and South Africa for the period 1970-2002. *t*-ratios in parenthesis. ***, **, and * indicates 1%, 5% and 10% level of significance, respectively. *D2* =US, *D3* = South Africa.

Equation (i): $\ln X_{it} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln E_{it} + \beta_3 \ln P_{it} + \beta_4 RD_{it} + \varepsilon$

Equation (ii): $\ln X_{it} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln E_{it} + \beta_3 \ln P_{it} + \beta_4 RD_{it} + \beta_5 H_{it} + \varepsilon$

Equation (iii): $\ln X_{it} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln E_{it} + \beta_3 \ln P_{it} + \beta_4 RD_{it} + \beta_5 H_{it} + \beta_6 Cp_{it} + \varepsilon$

Equation (iv): $\ln X_{it} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln E_{it} + \beta_3 \ln P_{it} + \beta_4 RD_{it} + \beta_5 H_{it} + \beta_6 Cp_{it} + \beta_7 (D_2 RD_{it})$

$$+ \beta_8 (D_3 RD_{it}) + \beta_9 (D_2 H_{it}) + \beta_{10} (D_3 H_{it}) + \beta_{11} (D_2 Cp_{it}) + \beta_{12} (D_3 Cp_{it}) + \varepsilon$$

Table 4. Cotton Export Function Estimation using OLS

Variable	Equation (i)	Equation (ii)	Equation (iii)	Equation (iv)
Y_{it}	0.85	0.84	1.87	2.53
	(2.27)**	(2.25)**	(8.30)***	(6.34)***
V_{it}	0.76	1.26	2.03	1.73
	(1.74)*	(2.18)**	(6.08)***	(4.40)***
RP_{it}	-1.41	-1.54	-0.73	-0.43
	(-1.63)*	(-1.78)*	(-1.48)	(-0.82)
RD_{it}	1.82	1.59	-0.02	0.18
	(5.20)***	(4.06)***	(-0.06)	(0.20)
H_{it}		2.11	0.81	1.00
		(1.32)	(0.88)	(0.13)
CP_{it}			31.05	25.92
			(13.92)***	(6.86)***
$D2*RD_{it}$				-0.73
				(-0.57)
$D3*RD_{it}$				4.36
				(1.06)
$D2*H_{it}$				9.67
				(1.05)
$D3*H_{it}$				-15.01
				(-1.58)
$D2*CP_{it}$				7.12
				(1.73)*
$D3*CP_{it}$				-0.71
				(-0.55)
R^2	0.59	0.60	0.87	0.88
F-stat.	(33.93)***	(27.71)***	(103.25)***	(53.66)***

Notes:

1. The OLS estimates are based on pooling data for US, Brazil, and Australia for the period 1970-2002. *t*-ratios in parenthesis. *D2* =US, *D3* = Brazil.

2. ***, **, and * indicates 1%, 5% and 10% level of significance, respectively.

Table 5 Soybeans Export Function Estimation using OLS

Variable	Equation (i)	Equation (ii)	Equation (iii)	Equation (iv)
Y_{it}	2.00	2.00	2.39	2.34
	(3.88) ***	(3.87) ***	(5.03) ***	(-2.57) **
V_{it}	0.01	0.01	-0.05	0.41
	(0.01)	(0.03)	(-.10)	-0.88
RP_{it}	9.54	9.55	8.34	4.74
	(8.06) ***	(8.01) ***	(7.52) ***	(-4.42) ***
RD_{it}	1.77	1.77	1.22	-1.39
	(6.87) ***	(6.83) ***	(4.65) ***	(-0.29) ***
H_{it}		-0.81	-4.94	60.82
		(-0.19)	(-1.23)	(3.75)
CP_{it}			16.06	15.38
			(4.67) ***	(5.21)
$D2*RD_{it}$				4.17
				(0.92)
$D3*RD_{it}$				15.33
				(3.67) ***
$D2*H_{it}$				-39.69
				(-1.73) *
$D3*H_{it}$				-8.84
				(-0.74)
$D2*CP_{it}$				13.55
				(2.07) **
$D3*CP_{it}$				1.99
				(0.91)
R^2	0.69	0.69	0.75	0.84
F-stat.	(50.98)***	(40.38)***	(44.81)***	(37.65)***

Notes:

1. The OLS estimates are based on pooling data for US, Brazil and Argentina for the period 1970-2002. *t*-ratios in parenthesis. *D2* =US, *D3* = Brazil.

2. ***, **, and * indicates 1%, 5% and 10% level of significance, respectively.

Table 6. Wheat Export Function Estimation using OLS

Variable	Equation (i)	Equation (ii)	Equation (iii)	Equation (iv)
Y_{it}	0.81	0.93	1.30	1.40
	(6.37)***	(8.24)***	(12.47)***	(15.55)***
V_{it}	1.57	1.50	1.68	-0.32
	(6.35)***	(6.98)***	(9.62)***	(-0.37)
RP_{it}	-1.67	-1.14	-0.05	-0.31
	(-5.23)***	(-3.89)***	(-0.18)	(-1.79)
RD_{it}	-0.68	-0.99	-0.11	0.02
	(-3.10)***	(-4.98)***	(-0.57)	(0.12)
H_{it}		-2.73	0.85	-7.91
		(-5.61)***	(1.34)	(-3.42)***
CP_{it}			4.62	5.17
			(7.21)***	(13.50)***
$D2*RD_{it}$				-0.62
				(-2.49)**
$D3*RD_{it}$				-2.73
				(-7.50)***
$D2*H_{it}$				3.46
				(1.14)
$D3*H_{it}$				-0.09
				(-0.04)
$D2*CP_{it}$				6.84
				(8.75)***
$D3*CP_{it}$				0.21
				(0.92)
R^2	0.67	0.75	0.84	0.96
F-stat.	(47.55)***	(56.63)***	(81.74)***	(156.87)***

Notes:

1. The OLS estimates are based on pooling data for US, Australia, and Canada for the period 1970-2002. *t*-ratios in parenthesis. *D2* =US, *D3* = Canada.

2. ***, **, and * indicates 1%, 5% and 10% level of significance, respectively.

Table 7. Corn Export Function Estimation using DOLS

Variable	Equation (i)	Equation (ii)	Equation (iii)	Equation (iv)
Y_{it}	0.06	0.57	1.26	1.38
	(0.25)	(1.96)*	(6.03)***	(5.87)***
V_{it}	0.99	0.80	0.85	-0.17
	(3.01)***	(2.48)**	(3.85)***	(-1.43)
RP_{it}	1.98	1.69	0.98	-0.71
	(3.03)***	(2.68)***	(2.24)**	(-0.23)
RD_{it}	0.95	0.80	0.70	-4.65
	(6.20)***	(4.92)***	(6.68)***	(-2.12)**
H_{it}		-8.66	-8.42	-1.80
		(-2.96)***	-(4.23)***	(-0.40)
CP_{it}			7.93	7.47
			(10.13)***	(4.28)***
$D2*RD_{it}$				4.44
				(2.29)**
$D3*RD_{it}$				2.33
				(1.61)
$D2*H_{it}$				-0.65
				(-0.12)
$D3*H_{it}$				-8.76
				(-2.71)***
$D2*CP_{it}$				4.87
				(2.09)**
$D3*CP_{it}$				-0.19
				(-0.108)
R^2	0.99	0.99	0.99	0.99
F-stat.	(17.84)***	(15.69***	(19.50)***	(21.68)***

Notes:

1. The DOLS estimates are based on pooling data for US, South Africa, and Argentina for the period 1970-2002. One lag and one lead of the differenced independent variables are used to estimate the dynamic model. *D2* = US, *D3* = South Africa. *t*-ratios in parenthesis.

2. ***, **, and * indicates 1%, 5% and 10% level of significance, respectively.

Table 8. Cotton Export Function Estimation using DOLS

Variable	Equation (i)	Equation (ii)	Equation (iii)	Equation (iv)
Y_{it}	0.87	1.03	1.65	1.48
	(1.78)*	(2.25)***	(4.02)***	(2.19)**
V_{it}	0.66	1.56	1.75	1.62
	(1.84)*	(3.79)***	(4.91)***	(4.79)***
RP_{it}	-0.36	-0.35	-0.59	-0.16
	(-0.65)	(-0.68)	(-1.35)	(-0.42)
RD_{it}	2.21	1.87	0.77	-1.38
	(7.40)***	(6.39)***	(2.38)***	(-1.23)
H_{it}		5.287	2.37	1.29
		(3.70)***	(1.77)*	(0.09)
CP_{it}			18.98	47.78
			(5.38)***	(4.23)***
$D2*RD_{it}$				1.06
				(0.58)
$D3*RD_{it}$				13.32
				(3.41)***
$D2*H_{it}$				6.48
				(0.62)
$D3*H_{it}$				-223.76
				(-2.96)***
$D2*CP_{it}$				-33.82
				(-1.56)
$D3*CP_{it}$				-42.79
				(-3.26)***
R^2	0.62	0.67	0.76	0.82
F-stat.	(34.15)***	(34.46)***	(43.83)***	(32.59)***

Notes:

1. The DOLS estimates are based on pooling data for US, Australia, and Brazil for the period 1970-2002. One lag and one lead of the differenced independent variables are used to estimate the dynamic model. *D2* =US, *D3* = Brazil. *t*-ratios in parenthesis.

2. ***, **, and * indicates 1%, 5% and 10% level of significance, respectively.

Table 9. Soybeans Export Function Estimation using DOLS

Variable	Equation (i)	Equation (ii)	Equation (iii)	Equation (iv)
Y_{it}	1.66	1.67	1.98	2.25
	(2.36)**	(2.36)**	(3.10)***	(2.04)**
V_{it}	-0.27	-0.26	-0.38	0.40
	(-0.42)	(-0.39)	(-0.65)	(0.66)
RP_{it}	9.97	10.01	8.22	4.51
	(6.23)***	(6.19)***	(5.45)***	(3.28)**
RD_{it}	1.87	1.87	1.30	-0.78
	(6.35)***	(6.31)***	(4.41)***	(-0.15)
H_{it}		-1.28	-5.71	59.42
		(-0.27)	(-1.31)	(3.19)**
CP_{it}			16.92	16.01
			(4.53)**	(5.12)***
$D2*RD_{it}$				3.34
				(0.69)
$D3*RD_{it}$				16.85
				(3.74)***
$D2*H_{it}$				-29.40
				(-1.15)
$D3*H_{it}$				-15.12
				(-1.03)
$D2*CP_{it}$				9.85
				(1.355)
$D3*CP_{it}$				0.743
				(0.317)
R^2	0.63	0.63	0.70	0.82
F-stat.	(17.84)***	(15.69)***	(19.50)***	(21.68)***

Notes:

1. The DOLS estimates are based on pooling data for US, Argentina, and Brazil for the period 1970-2002. One lag and one lead of the differenced independent variables are used to estimate the dynamic model. *D2* =US, *D3* = Brazil. *t*-ratios in parenthesis.

2. ***, **, and * indicates 1%, 5% and 10% level of significance, respectively.

Table 10. Wheat Export Function Estimation using DOLS

Variable	Equation (i)	Equation (ii)	Equation (iii)	Equation (iv)
Y_{it}	-0.02	0.15	0.36	1.25
	(.861)	(1.17)	(2.48)	(15.07)***
V_{it}	-7.02	1.54	1.11	-2.59
	(-2.52)***	(0.47)	(0.35)	(-2.12)**
RP_{it}	-1.61	-1.08	-0.50	-0.41
	(-4.59)***	(-3.16)***	(-1.28)	(-2.45)**
RD_{it}	0.62	0.30	0.85	-0.00
	(7.70)***	(2.75)***	(3.75)***	(-0.019)
H_{it}		-2.89	-0.93	-7.96
		(-4.21)***	(0.34)	(-4.40)***
CP_{it}			2.47	4.64
			(2.74)***	(11.86)***
$D2{*}RD_{it}$				-0.75
				(-3.04)*
$D3{*}RD_{it}$				-2.47
				(-6.47)***
$D2{*}H_{it}$				3.25
				(1.90)*
$D3{*}H_{it}$				-0.94
				(-1.04)
$D2{*}CP_{it}$				6.46
				(9.42)***
$D3{*}CP_{it}$				0.096
				(0.460)
R^2	0.73	0.81	0.86	0.96
F-stat.	(28.94)***	(39.66)***	(51.63)***	(122.35)***

Notes:

1. The DOLS estimates are based on pooling data for US, Canada, and Australia for the period 1970-2002. One lag and one lead of the differenced independent variables are used to estimate the dynamic model. *D2* =US, *D3* = Canada. *t*-ratios in parenthesis.
2. ***, **, and * indicates 1%, 5% and 10% level of significance, respectively.

Appendix 1B. List of variables used in the study

Volume of Export (X)

Volumes of exports in metric tons for a 31-year period are used to calculate the lag value for quantity variable. All products have the same unit. The variable (*lnX*) which is the natural logarithm of the export quantity values is used in the study.

World Income as aggregate Gross Domestic Product (Y)

Economic theory suggests that income in importing countries is a major determinant of a nation's exports. The importing country's GDP plays a major factor in determining their readiness to cover the payments for imports. World income is selected to represent the income measurement and *ln(Y)* is the natural logarithm of GDP, which is used in the regression equations

Relative Price (RP)

The relative price is a measure that indicates the drive or incentive for trade. Price differences between exporting countries are expected to direct commodities from low price markets to markets that offer higher price. The relative price coefficient (*RP*) is calculated as the weighted average of world importers price (*P*) against the exporters prices (*P**). The variable (*lnRP*) is the natural logarithm of the weighted average of importing countries price to the exporting county price, *P/P**.

Exchange Rate (EX)

Nominal exchange rate (*EX*) and its volatility (*V*) are used in the study. Exchange rate volatility is a measure that intends to capture the uncertainty faced by exporters due to unpredictable fluctuations in the exchange rates. A nominal exchange rate movement is considered as a fundamental determinant of price competitiveness. The natural logarithm (*lnEX*) variable is used in the regression equation. This study follows recent literature the moving average standard deviation as a measure of exchange rate volatility.

The moving sample standard deviation of the growth rate of both nominal and real exchange rate is one of the measures of exchange rate volatility that is employed in this study. The measure has been used by a number of authors such as de Vita and Abbot (2004), Chowdhury (1993), and Arize (2000). This measure is approximated by a time-varying measure defined as follows:

$$V_{t+m} = \left[\frac{1}{m} \sum_{i=1}^{m} (R_{t+i-1} - R_{t+i-2})^2 \right]^{1/2}$$

where R is the natural log of the bilateral real exchange rate (ε) and m is the order of the moving average.

<u>Human Capital (H)</u>

Human capital theory suggests that it is human capital, the knowledge and skills embodied in people, is vital for a country's prosperity. Human capital boosts growth through stimulating technological creation, invention, and innovation, as well as facilitating the uptake and imitation of new technologies thereby enhancing exports as a country becomes more cost competitive. The study uses secondary school graduates and a proxy for skilled labor (*H*). According to Bowlus and Robinson (2005), secondary school graduates are an important contributor to the quantity of human capital. The fraction of secondary school graduates to the population or labor can be used as a proxy for a country's human capital stock in international comparisons. The study develops a skilled labor (*H*) index for agricultural populations by calculating a fraction of secondary school graduates to the agricultural labor force for the US and its competitors. *H* has a quotient of between 0 and 1.

Research and Development (R&D)

According to the literature, it is expected that countries engaging in R&D activities have a more comparative advantage in exporting their products. Furthermore, countries with having (large) R&D expenditure may move to the forefront of the technology boundary when they invent new products or new production processes. They may then obtain competitive advantages compared to other countries producing competing goods. It is therefore expected that the export performance of a country is positively related to its R&D behavior. The R&D variable used in the study is developed as,

$$R\,\&\,D_{i,t} = \alpha_1 + \alpha_2 R\,\&\,D_{i,t-1} + \alpha_3\left(V_{i,t-1}\big/S_{i,t-1}\right) + \alpha_4 S_{i,t} + \mu_{i,t}$$

where $R\,\&\,D_{i,t}$ = *R&D* spending of commodity *i* in year *t* (*t* = 1971-2001), V_{it} = value of output for commodity *i* in year *t* and S_t = sector output in year t.

The Michaely Index (*M*)

The Michaely index is a measure for comparative advantage. The Michaely Index value ranges from zero to unity, with a value closer to one indicating a greater degree of trade specialization.

$$M_{ij} = X_{ij}\Big/\sum_i X_{ij} - M_{ij}\Big/\sum_i M_{ij}$$

where X_{ij} are exports of sector *i* from country *j,* and M_{ij} are imports for sector *i* to country *j*. The degree of specialization in each sector is weighted by its relative importance in the country's total trade. This index also ranges between zero and one, and the value of one implies a complete specialization in trade. The variable *ln*(*M*), natural logarithm of *M* values, was calculated using excel formulas.

CHAPTER 2. COMPETITIVENESS OF GENETICALLY MODIFIED CROPS IN THE SPECIFIC FACTORS MODEL

1. Introduction

The ability for a country to maintain a competitive export position depends on the adoption of improved technology that enables high quality products, efficient production, and capacity to process and market. Many countries are increasing their capacity to develop and adapt efficient technologies, and the US with its strong public and private research should strive to be a leader in technological innovations (Colyer and Jolly, 2000).

Biotechnology crop development is an example of R&D and it is believed that biotechnology innovations affect competitiveness by differentially reducing production costs and increasing productivity. Similar to the accumulation of capital, growth in productivity as a result of biotechnology can bring about an internationally competitive agricultural sector (Gopinath and Kennedy, 2000).

According to Huang *et al.* (2004) the productivity impact of GM technologies in crops is typically factor-biased. The yield increases through GM technology, for example, allow the same volume of output to be produced with less units of land. Similarly, the labor savings obtained from less weeding and pesticide sprayings lead to a drop of labor demand at the same level of output. Also, more output can be produced with the same amount of labor. The combined effects of factor-biased technical change depend on the relative cost shares of production factors and on the substitution elasticities in the production function. Increased demand through lower prices in the wake of cost savings will be an important determinant of the competitiveness of the sector.

This study uses specific factor model of production to predict the effects of projected output and price adjustment on the competitiveness of US genetically modified (GM) crops. We examine the trade-offs in resource use and output prices. The specific factor model is a general equilibrium model of production in which each sector employs one specific factor, and shares common factors with every other sector. The study uses the projected prices as reported in the *ERS, Agricultural Baseline Projections to 2013* (2003).

2. Literature Review

Biotechnology is any technique that uses living organisms or substances derived from these organisms to make or modify a product, improve plants or animals, or develop microorganisms for specific uses (Cohen, 1999). Modern biotechnology refers to the applications of new developments in recombinant DNA technology, advanced cell and tissue culture techniques, and modern immunology. Some of the most important applications of modern biotechnology are genomics, bioinformatics, plant transformation, molecular breeding and diagnostics (Jolly, Jeffeson, and Traxler, 2005).

Biotechnology leads to crop specific factor biased technical change (Huang et al, 2004). Its applications achieve cost savings through reducing the use of specific inputs (e.g. pesticides) or of certain processes (e.g. weeding) thereby increasing farmer profitability, typically by reducing input requirements and hence costs, i.e. an increase in factor productivity. Applications that reduce crop losses are likely to have a similar impact. Although technologies that directly lead to increased yields are not widespread, many of those that achieve reduction in input costs and crop losses also result in enhancing average yields. Biotechnology, therefore, offers a potentially powerful tool to increase competitiveness (Ismael and Bennet, 2005).

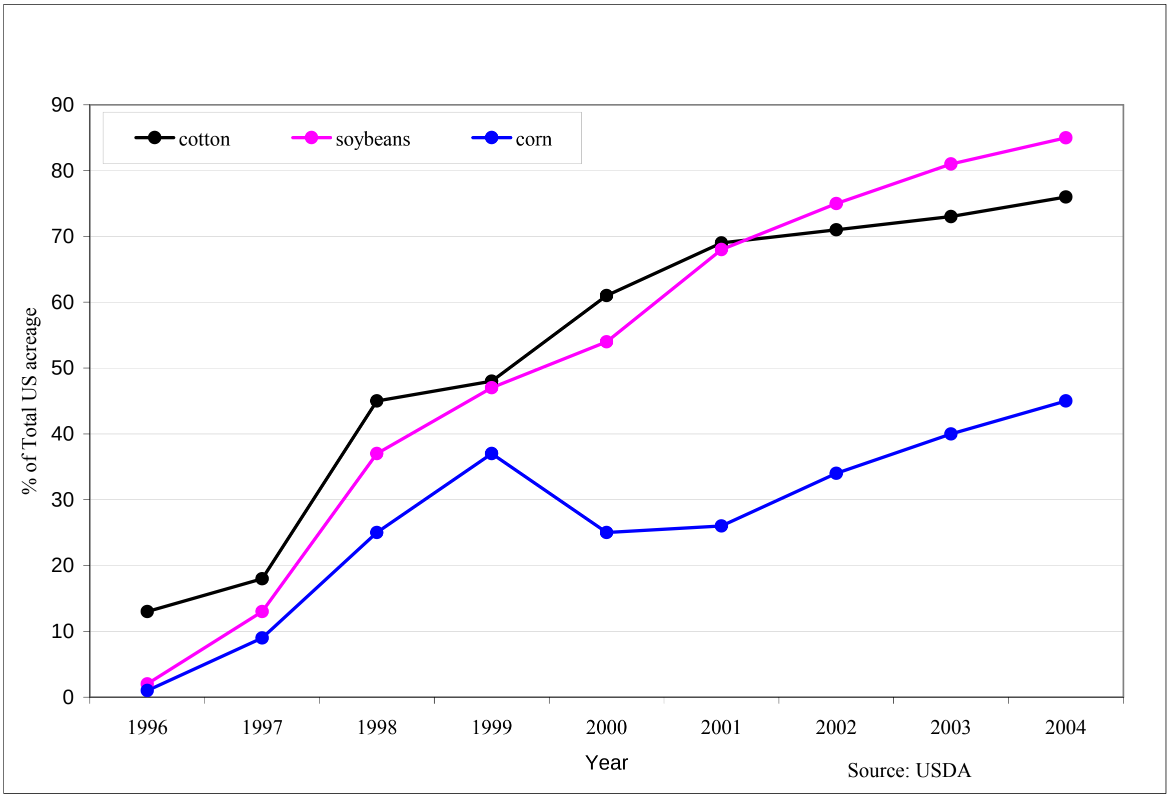
Genetic modification can also be used to improve the final *quality* characteristics of a product for the benefit of the consumer, food processing industry, or livestock producer. Such traits may include enhanced nutritional content, improved durability and better processing characteristics. Crops with modified traits will typically sell at higher market prices since they are better-quality products (Nielsen and Anderson, 2001).

Genetic engineering (GM) techniques and their applications have developed rapidly since the introduction of the first genetically modified plants in the 1980s. In 1996, 4.2 million acres were planted in six countries with GM crops. By 2004, the numbers had grown to 200 million acres in 17 countries on six continents – a 47-fold increase in nine years. The adoption of GM crops has been the most rapid in the US, where the area planted with GM crops has increased from 3.7 million acres in 1996 to 117.6 million acres in 2004 (James, 2004).

In the US, the main GM crops under cultivation are corn, soybeans, and cotton (Appendix A). In 2004, the percentage of US soybeans planted in genetically engineered varieties grew, accounting for 85% of all soybean planted. This reflects an increase of 3.9 million acres and a total of 63.6 million acres of GM soybean. The percentage of GM corn rose to 45% of all US corn planted, with farmers planting 4.9 million acres more than in 2003, giving a total of 36.5 million acres of GM corn. For the first time in three years, total cotton acreage in the US increased. The share of cotton, which is GM, increased 3% from 2003 to 76% in 2004, a total of 10.6 million acres (Figure 1). Wheat producers are yet to commercially adopt biotechnology.

The adoption of GM crops has brought significant gains to those adopting the crops. Falck-Zepeda, Traxler, and Nelson (2000) estimated that an average of more than $200 million per year in benefits was generated by the use of *Bt* cotton. The average benefit shares were 45% to US farmers, 36% to germplasm suppliers, and 19% to cotton consumers. On the other hand, Frisvold, Tronstad, and Mortensen (2000) estimated average total benefits of $181 million, with 20% share going to US farmers and 27% to US consumers.

Figure 1. US Biotech Crop Acreage as a Percent of Total Area Planted (1996-2004)



According to Traxler (2004), Roundup Ready (RR) soybeans created more than $1.2 billion in economic surplus in 2001. Soybean consumers worldwide gained $652 million (53% of total benefits) due to lower prices while seed firms received $421 million (34%). Soybean producers in Argentina and the US received net benefits of more than $300 million and $145 million, respectively. Farmers as a group received net benefits of $158 million, 13% of total economic gains produced by the technology. Huang *et al.* (2004) note that where China commercializes both *Bt* cotton and GM rice, the welfare gains will amount to an additional annual income of about $5 billion in 2010. This amounts to about $3.5 per person.

Continued expansion in the use of GM crops depends in part on the benefits obtained by farmers cultivating transgenic instead of conventional crops relative to the higher cost for transgenic seeds. So far, the improvements have not increased yields per hectare of the crops but rather from a reduction of cost of production (OECD 1999). Empirical data on the economic benefits of GM crops are limited and the effects vary from year to year and depend on a range of factors such as crop type, location, magnitude of pest attacks, disease occurrence and weed intensity. James (2004) mentions some examples of results that have been achieved: leaf yield was 5-7% higher and insecticide-use 2-3% lower for virus tolerant tobacco in China; 70% of the insect resistant *Bt*-cotton in the US in 1996 did not require any insecticide treatment and average yields increased by 7%; cultivation of herbicide tolerant soybeans in the US in 1996 lowered herbicide applications by 10-40%, provided more stable yields and a range of other agronomic and quality improvements.

This study argues that the productivity impact of GM technologies enhances not only one crop competitiveness against another crop, as farmers allocate their resources where they are most efficient, but also the country's competitiveness as lower production costs make it possible for a country to export commodities at a cheaper price.

The study uses a specific factors model, a general equilibrium model, to predict the effects of projected output and factor price adjustments and the competitiveness of soybean, corn, and cotton GM crops. Cotton is an important crop to southern farmers since most of the US production takes place in the southeast and southwest. Soybean is produced mainly in the Midwest, but a few southern states produce significant amounts of soybeans. Corn production has been affected by biotechnology, but low production and yields received from corn in the southern states are indicators that the southeastern states have a slight comparative disadvantage in the production of corn relative to other states, and its competitiveness relative to other crops is weak (Jolly, Jefferson, and Traxler, 2005). Using the specific factor model and based on projected price adjustments, output adjustments, and resource allocation we investigate how the adoption of GM crops may influence the competitiveness of US agriculture by 2010. Specific objectives of the study include:

- analyze adjustments in output and factor prices of select GM crops using a specific factors model of production,
- evaluate the relationship between adoption of GM crops and the projected adjustments in their output and factor prices,
- evaluate the use of specific factors model in determining projected output and prices can be used as a measure of US agricultural competitiveness.

3. The Model

The study uses specific factors model of production in order to evaluate the effects of projected output and price adjustment on the competitiveness of US GM crops. We define GDP as the sum of gross value added (*VA*) by all resident producers in the economy, plus any product taxes minus any subsidies not included in the value of the products (BEA, 2004). *VA* is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. We divided the economy into three disaggregated sectors: agriculture (*A*), manufacturing (*MF*), and services (*SV*) and the sum of their revenue equals economy-wide GDP (Gopinath and Roe, 1997). *VA* in each sector is the net output of a sector after adding up all outputs and subtracting intermediate inputs (BEA, 2004).

The agricultural sector is composed of corn (*Cn*), soybeans (*Sy*), cotton (*Ct*), wheat (*Wt*) and other-agriculture (*Oa*), and other-agriculture includes all other enterprises in the agricultural sector besides the four crops (USDA, 2004). Corn, soybeans, cotton, and wheat crops are the most traded agricultural products in the US. They contributed more than 50% of the total *VA* by crops, and 22% of agricultural sector *VA* to the US economy in 2004 (USDA[1], 2005). The four crops also provided 40% of the total value of US agricultural exports in 2003 (USDA[2], 2005). Soybeans, corn, and cotton are considered GM crops since they have adoption rates greater than 40% of the total area planted (James, 2004). Wheat and other-agriculture are considered non-GM enterprises since they have lower GM adoption.

The model considers seven producing industries: corn, soybeans, cotton, wheat, other-agriculture, manufacturing, and services that sum-up to the GDP (Gopinath and Roe, 1997). The agricultural (*A)* sector utilizes seeds (*S*), fertilizer (*F*), chemicals (*C*), energy (*E*), labor (*L*), and capital (*K*) factors of production (USDA, 2004). The manufacturing (*MF)* and service (*SV)* sectors utilize *E*, *L,* and *K* factors of production. R&D (*R*) is considered an input since it is a factor of production that accounts for technological change (Rodolfo and Sirenia, 2005). The model assumes full employment of all factors of production and that *E*, *L*, and *R* are perfectly mobile across sectors. The amount of factors employed in each industry is constrained by the factor endowments. There is perfect competition in the output market with costs equal to prices.

The specific factors model of production is presented following Thompson and Toledo (2001), and consists of the following steps. First, factor shares θ and industry shares λ are calculated using factor payments. Factor shares represent the share of each factor in the revenue of each sector, and industry shares represent the proportion of each factor employed in each sector. Second, the factor intensity a_{ij} representing the cost minimizing input of factor i in good j is calculated. Third, substitution elasticities are derived using factor shares and industry shares. The substitution elasticities describe the adjustment in the cost minimizing input of one factor due to a change in the price of another as developed by Jones (1965) and Takayama (1982). Following Allen (1938) the cross price elasticity between the input of factor i and the payment to factor k in sector j is

$$E^k{}_{ij} = \hat{a}_{ij}/\hat{w}_k = \theta_{kj}/S^k{}_{ij} \tag{1}$$

where ^ represents percentage change in variables, and $S^k{}_{ij}$ is the Allen partial elasticity of substitution. Cobb-Douglas production implies $S^k{}_{ij} = 1$. With the constant elasticity of substitution (CES) production function, the Allen partial elasticity can assume any positive value. Assuming linear homogeneity, $\Sigma_k E^k_{ij} = 0$, the own price elasticity E^i_{ij} is derived as the negative sum of cross price elasticities. Since the cross price elasticity is a weighted Allen elasticity, with the Cobb-Douglas production functions, it follows that the cross price elasticity is equal to the factor share (Toledo, 2003).

The aggregate substitution elasticities for the economy are the weighted average of the cross-price elasticities for each sector. In other words, elasticities are summed across industries to arrive at the aggregate substitution elasticities, as described by Thompson (1994). The derivation of Cobb-Douglas substitution elasticities σ_{ij}, uses factor and industry shares;

$$\sigma_{ij} \equiv \hat{a}_{\mathrm{ij}} / \hat{w}_{\mathrm{k}} = \sum_j \lambda_{ij} E^k_{ij} = \sum_j \lambda_{ij} \theta_{kj} S^k_{ij} \tag{2}$$

Competitive pricing and full employment are stated

$$\sum_j a_{kj} x_j = \upsilon_k \, , \tag{3}$$

$k = S_{Sy}, S_{Cn}, S_{Ct}, S_{Wt}, S_{Oa}, F, C, E, L, R, K_{Sy}, K_{Cn}, K_{Ct}, K_{Wt}, K_{Oa}, K_{MF}, K_{SV}$

$$\sum_i w_i a_{im} = p_m \, , \tag{4}$$

$m = Sy, Cn, Ct, Wt, Oa, MF, SV$

a_{ij} is the cost minimizing input of factor i in sector j, x_j is the output of good j, v_k is the endowment of factor k, w_i is the price of factor i, and p_m is the price of good m. Differentiating (3) and (4) as in Feenstra (2004) leads to

$$\sum_i \sigma_{ki} \hat{w}_i + \lambda_{kj} \hat{x}_j = \hat{v}_k \, , \tag{5}$$

$$\sum_i \theta_{im} \hat{w}_i = \hat{p}_m \, , \tag{6}$$

Using the cost minimizing assumption, equation (5) and (6) are put into matrix form as

$$\begin{pmatrix} \sigma & \lambda \\ \theta' & 0 \end{pmatrix} \begin{pmatrix} \hat{w} \\ \hat{x} \end{pmatrix} = \begin{pmatrix} \hat{v} \\ \hat{p} \end{pmatrix} \tag{7}$$

where σ is the 17 × 17 substitution elasticities, λ is the 17 × 7 matrix of industry shares, and *θ',* is the 7 × 17 matrix of factor shares. Endowments are held constant and ^ represents percentage changes while *w, x, v,* and *p* represent factor prices, output, factor endowments, and prices, respectively.

The inverse of the 24 × 24 matrix in equation (7) relates the exogenous price changes to endogenous factor prices and output. The inverted equation (7) leads to comparative static elasticities $\hat{w}/\hat{p}$ and $\hat{x}/\hat{p}$ as in equation 8.

$$\begin{pmatrix} \hat{w} \\ \hat{x} \end{pmatrix} = \begin{pmatrix} M & N \\ Q & R \end{pmatrix} \begin{pmatrix} \hat{v} \\ \hat{p} \end{pmatrix} \tag{8}$$

Matrix *M* describes how factor prices are affected by changing endowments holding prices constant. Matrix *Q* captures the effects of changing endowments to outputs, *Rybczynski effect*. An increase in the endowment of a factor utilized intensively in a sector will enhance productivity in that sector therefore make it more competitive. Matrix *N* describes how changing prices affect factor prices, *Stopler-Samuelson effect*. An increase in the relative price of an output from a sector leads to a rise in the return to the factor it uses intensively, making the sector more competitive (Feenstra, 2004). Matrix *R* describes a local surface of production possibilities. Each output should be positively related with its own price, and some other outputs must decline with unchanged factor endowments. Outputs and factor prices adjust to maintain full employment and competitive pricing in the comparative statics of the model as noted by Toledo (2003).

4. The Data

Data on GDP and *VA* on agriculture, manufacturing, and services are obtained from the US Department of Commerce, Bureau of Economic Analysis for 1995 and 2001. Data on value added for the agricultural sectors are calculated based on the gross value of production minus total variable costs for each crop per acre. To obtain the total *VA* for agricultural sectors, *VA* per acre was multiplied by the area harvested for the crop. Data on area harvested, crop expenses, and gross value of production were obtained from the ERS, United States Department of Agriculture for 1995 and 2001. Data on energy consumption by sector were obtained from the Department of Energy. Data for R&D were obtained from the National Science Foundation. Capital was calculated as residue of *VA* after subtracting energy and labor expenses.

The study uses the projected prices for agricultural prices as reported in the *ERS, Agricultural Baseline Projections* (1995, 2003). *ERS* projects price of corn to increase by 21.7% in 2010 from its 2001 base. Wheat and Soybean prices are also projected to increase by 18.7% and 28.7%, respectively. *ERS* does not project cotton prices so we use the US Congressional Budget Office (CBO) projected baseline prices for cotton. CBO projects cotton prices to increase by 4.1% between 2001 and 2010 (Echols, 2001). Since over 50% of total agricultural *VA* is derived from forestry sector, we use projected price increase in softwood as a proxy for other-agriculture. Softwood prices are expected to increase by 10.6% between 2001 and 2010 (Presternon and Abt, 2002).

Data for projected price increases in the manufacturing and services sector are not obtainable. However, the Bureau of Labor services (www.bls.gov) has listed *industry output and employment projections to 2010.* According to the report, between the year

2000 and 2010, labor force and GDP growth will remain constant with rising productivity rates leading the way for output increases. The report notes that industrial and manufacturing sector will grow by 3.0% and 3.4% from 2000 to 2010. We assume that the elasticity between output and prices is 1. We project prices for manufacturing to increase by 34.4% during the same period and those of services to increase by 39.7%.

5. Results and Discussions

Table 1 reports the total factor payment matrix in million dollars for each of the factors of production in 2001. Seeds are specific to individual crop enterprises in the agricultural sector. Fertilizer and chemicals are specific to the agricultural sector. Energy, labor, R&D, and capital are shared among all sectors of the economy.

Table 1. Factor Payment Matrix for all Sectors, 2001 (million dollars)

	Agricultural Sector Industry							
	Soybeans	Corn	Cotton	wheat	Other[1]	Manufacturing	Services	Total
Seed	1674	2451	587	377	3835	0	0	8924
Fertilizer[2]	617	3617	485	1420	3480	0	0	9619
Chemicals[3]	1696	2004	904	428	3284	0	0	8316
Energy[4]	644	1583	573	546	6761	137820	387162	535089
Labor	151	221	467	146	20912	877165	2993222	3892283
R&D	1236	1608	382	561	6019	198505	65900	274211
Capital	5936	8748	1258	1427	7363	1341300	6172200	7538232
Total	11954	20233	4656	4903	51655	2554790	9618484	12266674

[1]other agriculture [2]Fertilizer, lime, and gypsum [3]chemicals & pesticides [4]Fuel, lube, and electricity

Table 2 shows the shares of each factor in the revenue of each sector in 2001, and is derived from Table 1. The largest factor share for all sectors in 2001 was capital. Capital factor share for the soybeans sector is 49.7%. Of the four crops considered, the largest factor share for seeds is in soybeans at 14%, and the lowest is in wheat at 7.7%. While soybeans and corn factor shares for R&D are second and fourth largest at 10% and

8%, they are the two largest in dollar terms \$1.24 billion and \$1.61 billion. Soybeans and cotton have the lowest factor shares for fertilizer at 5% and 10% while wheat has the largest with 29%. The largest labor factor share is in cotton with 10% and the lowest is in corn 1.1%.

Table 2. Factor Shares, $\theta_{ij,}$ of all Sectors in the US GDP (2001)

	Soybeans	Corn	Cotton	Wheat	Other	Manufacturing	Services
Seed	0.1400	0.1212	0.1261	0.0768	0.0742	0.0000	0.0000
Fertilizer	0.0516	0.1788	0.1043	0.2896	0.0674	0.0000	0.0000
Chemicals	0.1419	0.0991	0.1941	0.0872	0.0636	0.0000	0.0000
Energy	0.0539	0.0782	0.1231	0.1113	0.1309	0.0539	0.0403
Labor	0.0126	0.0109	0.1002	0.0297	0.4048	0.3433	0.3112
R&D	0.1034	0.0795	0.0820	0.1144	0.1165	0.0777	0.0069
Capital	0.4966	0.4324	0.2702	0.2910	0.1425	0.5250	0.6417

Table 3 presents industrial shares for the various sectors. The values are derived from Table 1. The largest industry share for seeds was other-agriculture, corn, and soybeans at 43%, 27.5%, and 18.8%. Fertilizer industry share was largest in corn, followed by other-agriculture and wheat at 37.6%, 36.2%, and 14.8%. Manufacturing sector had the largest share of R&D at 74.4%.

Table 4 shows the factor intensities, the relative importance of one factor versus others in sector production when compared across sectors. For instance, corn and soybeans use seeds relative to labor most intensively at 2.2 and 11.1. Changes in factor intensities shift comparative advantage over time.

Table 3. Industry Shares, λ_{ij}, of all Sectors in the US GDP (2001)

	Soybeans	Corn	Cotton	Wheat	Other	Manufacturing	Services
Seed	0.18757	0.27469	0.06581	0.04220	0.42973	0.00000	0.00000
Fertilizer	0.06409	0.37603	0.05047	0.14758	0.36182	0.00000	0.00000
Chemicals	0.20395	0.24099	0.10870	0.05143	0.39493	0.00000	0.00000
Energy	0.00120	0.00296	0.00107	0.00102	0.01264	0.25756	0.72355
Labor	0.00004	0.00006	0.00012	0.00004	0.00537	0.22536	0.76901
R&D	0.00451	0.00586	0.00139	0.00204	0.02195	0.72391	0.24033
Capital	0.00079	0.00116	0.00017	0.00019	0.00098	0.17793	0.81879

Appendix Table 5 shows the Cobb-Douglas substitution elasticities matrix. The largest own substitution elasticity was for chemicals and fertilizer while the smallest was for capital in the services sector. A 10% increase in the price of chemicals and fertilizer would cause a 20% decrease in the chemicals and fertilizer use. Capital in other-agriculture had the largest own substitution within the shared sectors. Also, own R&D substitution elasticities were larger than own labor elasticities. A 10% increase in the cost of R&D decreases its unit input by 8.7%.

Appendix Table 6 shows elasticities of factor prices with respect to prices of goods in the general equilibrium comparative statics. Price changes effects on factor payments are uneven since with any price change some factors benefit while others lose. The most elastic effects occur for capital in other agriculture (*OA*). A 10% decrease in prices would lower payments to capital in *OA* by 30%. Of the four crops considered, the most elastic effects occur for capital in cotton and for seeds in wheat. A 10% increase in the prices of wheat, and cotton would raise payments to seeds by 24%, and 22%, and would lower the payments to labor 0.5% and raise payments to labor in cotton by 0.3%. Cotton is the most labor intensive crop of the four crops considered.

Appendix Table 6 also captures the Stolper-Samuelson effects of a price change on the sector specific inputs. Seeds and capital are sector specific. The effects of a price increase are magnified and the return on seeds and capital is more than proportional. Higher prices in a sector increases its capital returns but lowers the returns in other sectors. While some sectors benefit, other sectors lose with any price change (For an example, see Thompson and Toledo, 2001). For instance, a 10% increase in the price of cotton would raise the return on cotton seeds by 22% and the return on capital by 24%. Also, a 10% increase in the price of soybeans would raise returns to fertilizer and chemicals by 3 and 20%, respectively.

Appendix Table 7 indicates that the largest own output effects occur in other agriculture, followed by wheat and cotton. A 10% drop in output prices would reduce output of other agriculture, wheat and cotton by 19, 14 and 12%, respectively. A 10% drop in output prices would reduce output for soybeans and corn by 5.2 and 6.7%, respectively. The low elasticities of output with respect to prices is an indication that US soybeans and corn sectors are more competitive because they can offer lower prices without reducing their production significantly, when compared to other agriculture, wheat and cotton. This implies that the US production of soybeans and corn can increase due to expansion of acreage in the wake of high demand resulting from their ability to accept lower prices without significantly hurting their output.

6. Discussion

6.1 Projected Price Changes and Adjustments

To obtain vector price adjustments, the vector of projected price changes is multiplied by the matrix of factor price elasticities in Appendix Tables 6, and to obtain Output projections the output elasticities matrix also in Appendix Table 6 is multiplied by the projected vector price changes. The results are presented in Appendix Table 8.

Appendix Table 8 shows that by the year 2010, the payments to soybeans, corn, wheat, and other-agriculture seeds are expected to rise by 33%, 23%, 13%, and 4.5%, while the payments to cotton seeds are expected to fall by 14%. Payments to fertilizer, chemicals, and R&D are projected to rise by 14%, 13%, and 30%. Energy payments are expected to increase by 29% and payments to labor wages are also projected to increase by 29%.

As stated by *Stopler-Samuelson theorem*, an increase in the relative price of a good will increase the real return to the factor used intensively in that good, and reduce the real return to the other factor. Seeds, fertilizers, energy, and chemicals are the most intensively used factors of production in crops that have adopted biotechnology. With soybeans, corn, and wheat prices projected to increase by 2010, real return on these factors are also projected to rise.

Soybeans and corn outputs are expected to increase by 4% and 2%, while cotton, wheat, and other-agriculture outputs are expected to fall by 21%, 4%, and 17%. Manufacturing and services output is expected to increase by 5% and 6%.

The effects of price changes on factor payments are uneven in that when price changes some factors benefit and others lose. The study shows that with higher positive prices changes projected in soybeans and corn sectors, farmers are going to re-allocate their resources accordingly. Farmers will re-adjust their production by taking resources from wheat, cotton, and other-agriculture and using these resources to produce more soybeans and corn. These will lead to increased soybeans and corn production, and reduction in the production of cotton, wheat and other-agriculture. The process will continue as long as the marginal returns on soybeans and corn production is greater than for the other crops.

6.2 GM Crop Adoption, Projected Price, and Output Changes

Appendix Table 9 compares the projected price and output changes in 2010 with the GM crops adoption in 1995 and 2001. The table shows that soybeans had the highest GM adoption at 75%, followed by cotton and corn at 71 and 34% in 2001, respectively. The four crops considered in the study did not have any GM adoption in 1995 while wheat is considered to have no GM adoption by 2001. Appendix Table 9 shows that based on 1995 predicted price change, when there was no GM adoption, output for the four crops was expected to fall by 2010 with the largest output drop expected in the cotton and wheat sectors at 70 and 27%, respectively. Output in the manufacturing and services sector was projected to increase by 3.2 and 5.5%, respectively.

Appendix Table 9 also shows that the largest gain in prices using the 2001 projections will be in the soybean sector that also has the highest GM adoption. This is followed by the corn sector which was third in GM adoption in 2001. Wheat and cotton prices are expected to increase by 19 and 4%, respectively. This makes soybeans the most competitive crop followed by corn, based on the projected price changes. Wheat and cotton crops are projected to be least competitive crops by 2010.

Results based on 2001 projected output changes in Appendix Table 9 show a similar trend. Soybean output, with most GM adoption, will increase by 4%, followed by corn at 2%. Wheat and cotton are projected to have their output fall by 5% and 27%, respectively.

The results in Appendix Table 9 indicates that although there may be other factors that might may influence increases in projected output for soybeans and corn, adoption of technology (biotechnology) should be among them. Biotechnology adoption leads to a parallel shift of the production function resulting in higher output at same level of input use. Biotechnology adoption has, therefore, increased tremendously driven by farmers' expectations of lower production costs, higher yields, and reduced pesticide use. This has lead to farmers planting more of crops that few years ago would not have been profitable.

Although the study was conducted using data for 1995 and 2001, the study acknowledges that in recent years, large government payments have boosted corn returns, providing incentives to plant corn to meet the increasing demand for ethanol production. However, corn production costs have risen due to higher fuel, fertilizer and drying costs.

7. Conclusion

The projected price and output change, as shown in Appendix Table 9, indicates that all crops were expected to have reduced output and lower prices by 2010, based on 1995 projections, when there was no GM adoption. On the other hand, the results for 2001 projections indicate that crops that had successfully adopted GM technology, and reduced production costs as reflected by low price elasticity to output, will have increased output and higher prices by 2010.

When making decisions to adopt GM crops, agricultural producers rearrange their production matrices and select the least-cost resource combination. Eckert and Leftwich (1998) define the least-cost resource combination as a combination of resources for a firm at which the marginal physical product per dollar's worth of one resource is equal to the marginal physical product per dollar's worth of every other. To capture the cost savings brought about by biotechnology innovations, producers adjust their inputs allocation according to their marginal rate of technical substitution.

In 2001, the least-cost resource combination in the sectors that have adopted biotechnology changed considerably relative to 1995. For instance, the factor share of seeds in the soybean sector increased from 6.5% to 14%, more than 100% increase, while the factor share of labor fell from 4.5% to 1.3%, and the factor share of capital fell by 15.7% from 65.4% to 49.7%. The magnitude of the decrease in factor share of capital in soybean is extraordinary when considering the intensity of capital used in US agriculture.

The study, therefore, demonstrates a positive relationship between adoption of GM technology and the projected adjustments in output and prices. Crops that were predicted to have negative output growth based on 1995 projections are expected to have positive output growth using 2001 predictions after they were able to adopt GM technology successfully.

The study also shows soybeans and corn sectors which have successfully adopted GM technology have low elasticities of output with respect to prices. These are necessary conditions for agricultural commodities competitiveness and are an indication that both sectors are price competitive because they can afford to lower their prices without significant reduction in output. Ability for the US to produce soybeans and corn at a lower cost, and therefore, market them at lower price by 2010 will ensure that it will retain or even improve its market share in the world export market. Since costs in producing a commodity are indicators of competitiveness of that commodity, the US is competitive in soybean and corn production, and therefore, exports.

The study, therefore, concludes that public and private policies towards investments in GM technologies should be encouraged since they enhance US agricultural export commodities competitiveness. Further studies can estimate the changes in the marginal rate of technical substitution between inputs with the advent of biotechnology, and can also estimate the rate of return of every dollar invested in GM technology R&D and the effect this R&D on the terms of trade.

Appendix 2A. Tables for Chapter 2

Table 4. Factor Intensities (2001)

	Sy	Cn	Ct	Wt	Oa
S/F	2.72	0.68	1.21	0.27	1.10
S/C	0.99	1.22	0.65	0.88	1.17
S/E	2.60	1.55	1.02	0.69	0.57
S/L	11.1	11.1	1.26	2.59	0.18
S/R	1.35	1.52	1.54	0.67	0.64
S/K	0.28	0.28	0.47	0.26	0.52
F/C	0.36	1.80	0.54	3.32	1.06
F/E	0.96	2.29	0.85	2.60	0.51
F/L	4.08	16.3	1.04	9.76	0.17
F/R	0.50	2.25	1.27	2.53	0.58
F/K	0.10	0.41	0.39	1.00	0.47
C/E	2.63	1.27	1.58	0.78	0.49
C/L	11.2	9.05	1.94	2.94	0.16
C/R	1.37	1.25	2.37	0.76	0.55
C/K	0.29	0.23	0.72	0.30	0.45
E/L	4.26	7.15	1.23	3.75	0.32
E/R	0.52	0.98	1.50	0.97	1.12
E/K	0.11	0.18	0.46	0.38	0.92
L/R	0.12	0.14	1.22	0.26	3.47
L/K	0.03	0.03	0.37	0.10	2.84
R/K	0.21	0.18	0.30	0.39	0.82

Notes:

S = seed	M = manufacturing	KSy = Soybean capital
C = chemicals	S = services	KCn = Corn capital
E = energy	Sy = soybeans	KCt = Cotton capital
L = labor	Cn = corn	KWt = wheat capital
R = R&D	Ct = cotton	KOa = Other Agriculture capital
K = capital	Wt = wheat	MF = Manufacturing capital
F = fertilizer	Oa = other agriculture	SV = Services capital

Table 5. Cobb-Douglas Substitution Elasticities, σ_{ij} (2001)

		$\hat{w}_{Sy}$	$\hat{w}_{Cn}$	$\hat{w}_{Ct}$	$\hat{w}_{Wt}$	$\hat{w}_{Oa}$	$\hat{w}_{F}$	$\hat{w}_{C}$	$\hat{w}_{E}$	$\hat{w}_{L}$	$\hat{w}_{R}$	$\hat{w}_{KSy}$	$\hat{w}_{KCn}$	$\hat{w}_{KCt}$	$\hat{w}_{KWt}$	$\hat{w}_{KOa}$	$\hat{w}_{MF}$	$\hat{w}_{SV}$
Seed	$\hat{a}_{Sy}$	**-0.86**	0.00	0.00	0.00	0.00	0.05	0.14	0.05	0.01	0.10	0.50	0.00	0.00	0.00	0.00	0.00	0.00
	$\hat{a}_{Cn}$	0.00	**-0.88**	0.00	0.00	0.00	0.18	0.10	0.08	0.01	0.08	0.00	0.43	0.00	0.00	0.00	0.00	0.00
	$\hat{a}_{Ct}$	0.00	0.00	**-0.87**	0.00	0.00	0.10	0.19	0.12	0.10	0.08	0.00	0.00	0.27	0.00	0.00	0.00	0.00
	$\hat{a}_{Wt}$	0.00	0.00	0.00	**-0.92**	0.00	0.29	0.09	0.11	0.03	0.11	0.00	0.00	0.00	0.29	0.00	0.00	0.00
	$\hat{a}_{Oa}$	0.00	0.00	0.00	0.00	**-0.93**	0.07	0.06	0.13	0.41	0.12	0.00	0.00	0.00	0.00	0.14	0.00	0.00
Fertilizer	$\hat{a}_{F}$	0.06	0.33	0.04	0.14	0.34	**-2.05**	0.09	0.10	0.16	0.10	0.03	0.21	0.04	0.11	0.31	0.00	0.00
Chemicals	$\hat{a}_{C}$	0.18	0.21	0.10	0.05	0.37	0.11	**-2.08**	0.10	0.18	0.10	0.10	0.14	0.08	0.04	0.34	0.00	0.00
Energy	$\hat{a}_{E}$	0.00	0.00	0.00	0.00	0.01	0.00	0.00	**-0.76**	0.32	0.03	0.00	0.00	0.00	0.00	0.01	0.12	0.26
Labor	$\hat{a}_{L}$	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	**-0.43**	0.02	0.00	0.00	0.00	0.00	0.01	0.11	0.28
R&D	$\hat{a}_{R}$	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.04	0.33	**-0.87**	0.00	0.00	0.00	0.00	0.02	0.34	0.09
Capital	$\hat{a}_{KSy}$	0.14	0.00	0.00	0.00	0.00	0.05	0.14	0.05	0.01	0.10	**-0.50**	0.00	0.00	0.00	0.00	0.00	0.00
	$\hat{a}_{KCn}$	0.00	0.12	0.00	0.00	0.00	0.18	0.10	0.08	0.01	0.08	0.00	**-0.57**	0.00	0.00	0.00	0.00	0.00
	$\hat{a}_{KCt}$	0.00	0.00	0.13	0.00	0.00	0.10	0.19	0.12	0.11	0.00	0.00	0.00	**-0.66**	0.00	0.00	0.00	0.00
	$\hat{a}_{KWt}$	0.00	0.00	0.00	0.08	0.00	0.29	0.09	0.15	0.03	0.11	0.00	0.00	0.00	**-0.75**	0.00	0.00	0.00
	$\hat{a}_{KOa}$	0.00	0.00	0.00	0.00	0.07	0.07	0.06	0.13	0.41	0.12	0.00	0.00	0.00	0.00	**-0.86**	0.00	0.00
	$\hat{a}_{MF}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.34	0.08	0.00	0.00	0.00	0.00	0.00	**-0.48**	0.00
	$\hat{a}_{SV}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.31	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**-0.36**

Table 6. Elasticities of Factor Prices with Respect to Prices [*dw/dp*] (2001).

		$\hat{p}_{Sy}$	$\hat{p}_{Cn}$	$\hat{p}_{Ct}$	$\hat{p}_{Wt}$	$\hat{p}_{Oa}$	$\hat{p}_{MF}$	$\hat{p}_{SV}$
Seed	$\hat{w}_{Sy}$	1.52	-0.08	-0.07	-0.07	-0.28	-0.06	0.02
	$\hat{w}_{Cn}$	-0.06	1.67	-0.09	-0.16	-0.45	-0.00	0.05
	$\hat{w}_{Ct}$	-0.09	-0.18	2.25	-0.13	-0.74	0.09	-0.05
	$\hat{w}_{Wt}$	-0.08	-0.35	-0.16	2.40	-0.86	-0.08	-0.01
	$\hat{w}_{Oa}$	-0.02	-0.04	-0.18	-0.15	2.90	-0.71	-0.69
Fertilizer	$\hat{w}_{F}$	0.03	0.37	0.04	0.36	0.62	-0.22	-0.19
Chemicals	$\hat{w}_{C}$	0.20	0.23	0.21	0.05	0.80	-0.23	-0.22
Energy	$\hat{w}_{E}$	0.00	-0.02	0.13	0.12	0.14	0.22	0.42
Labor	$\hat{w}_{L}$	-0.02	-0.04	0.03	-0.05	0.66	0.18	0.28
R&D	$\hat{w}_{R}$	0.04	-0.01	0.05	0.12	0.12	0.65	0.03
Capital	$\hat{w}_{KSy}$	1.52	-0.08	-0.07	-0.07	-0.28	-0.06	0.02
	$\hat{w}_{KCn}$	-0.06	1.63	-0.08	-0.16	-0.42	-0.01	0.04
	$\hat{w}_{KCt}$	-0.10	-0.20	2.42	-0.15	-0.80	0.04	-0.05
	$\hat{w}_{KWt}$	-0.08	-0.33	-0.15	2.32	-0.82	-0.07	0.01
	$\hat{w}_{KOa}$	-0.02	-0.05	-0.20	-0.16	2.98	-0.72	-0.71
	$\hat{w}_{MF}$	0.01	0.03	-0.04	0.00	-0.46	1.67	-0.23
	$\hat{w}_{SV}$	0.01	0.02	-0.02	0.02	-0.33	-0.11	1.39

Table 7. Elasticities of Output with Respect to Prices [*dx/dp*] (2001)

	$\hat{p}_{Sy}$	$\hat{p}_{Cn}$	$\hat{p}_{Ct}$	$\hat{p}_{Wt}$	$\hat{p}_{Oa}$	$\hat{p}_{MF}$	$\hat{p}_{SV}$
$\hat{x}_{Sy}$	0.52	-0.08	-0.07	-0.07	-0.28	-0.06	0.02
$\hat{x}_{Cn}$	-0.06	0.67	-0.08	-0.16	-0.43	-0.07	0.04
$\hat{x}_{Ct}$	-0.10	-0.18	1.24	-0.14	-0.74	0.03	-0.05
$\hat{x}_{Wt}$	-0.08	-0.35	-0.15	1.41	-0.85	-0.08	0.01
$\hat{x}_{Oa}$	-0.02	-0.05	-0.19	-0.15	1.86	-0.70	-0.68
$\hat{x}_{MF}$	0.01	0.03	-0.04	0.00	-0.46	0.67	-0.23
$\hat{x}_{SV}$	0.01	0.02	-0.02	0.02	-0.33	-0.11	0.39

Table 8. Simulating Project Output Changes with Cobb-Douglas Production Function (2001)

Predicted % Δ Price By 2010		Effects on Factor Prices		Output Adjustments	
$\hat{p}_{Sy}$	28.7	$\hat{w}_{Sy}$	33.2	$\hat{x}_{Sy}$	4.49%
$\hat{p}_{Cn}$	21.8	$\hat{w}_{Cn}$	23.4	$\hat{x}_{Cn}$	1.89%
$\hat{p}_{Ct}$	4.10	$\hat{w}_{Ct}$	-14.3	$\hat{x}_{Ct}$	-20.5%
$\hat{p}_{Wt}$	18.7	$\hat{w}_{Wt}$	13.1	$\hat{x}_{Wt}$	-4.47%
$\hat{p}_{Oa}$	21.1	$\hat{w}_{Oa}$	4.46	$\hat{x}_{Oa}$	-17.2%
$\hat{p}_{MF}$	34.4	$\hat{w}_{F}$	13.7	$\hat{x}_{MF}$	4.91%
$\hat{p}_{SV}$	39.7	$\hat{w}_{C}$	12.9	$\hat{x}_{SV}$	5.95%
		$\hat{w}_{E}$	29.4		
		$\hat{w}_{L}$	28.7		
		$\hat{w}_{R}$	29.9		
		$\hat{w}_{KSy}$	33.2		
		$\hat{w}_{KCn}$	23.2		
		$\hat{w}_{KCt}$	-17.7		
		$\hat{w}_{KWt}$	13.7		
		$\hat{w}_{KOa}$	4.04		
		$\hat{w}_{MF}$	39.3		
		$\hat{w}_{SV}$	45.5		

Table 9. GM adoption, Projected Output and Factor Prices Adjustments by 2010

	GM adoption (%)[+]		Prices Changes (%)[++]		Output Changes (%)[++]	
Sector	1995	2001	1995	2001	1995	2001
Soybeans	0	75	-16.7	28.7	-8.30	3.95
Corn	0	34	-25.9	21.8	-15.2	1.70
Cotton	0	69	-40.5	4.10	-70.0	-27.0
Wheat	0	0	-27.5	18.7	-27.2	-5.10
Manufacturing	N/A	N/A	69.1	34.4	3.21	4.91
Services	N/A	N/A	75.0	39.7	5.53	5.95

[+]2004 [++]2010

Appendix 2B. Dominant Biotech Crops in 2004

	Million Hectares	% Biotech
Herbicide tolerant Soybean	48.4	60
Bt Maize	11.2	14
Bt Cotton	4.5	6
Herbicide tolerant Maize	4.3	5
Herbicide tolerant Canola	4.3	5
Bt/Herbicide tolerant Maize	3.8	4
Bt/Herbicide tolerant Cotton	3	4
Herbicide tolerant Cotton	1.5	2
Total	81	100

Source: James, 2004

CHAPTER 3: ANALYZING THE USE OF AIDS MODEL IN EVALUATING THE COMPETITIVENESS OF US WHEAT

1. Introduction

Product differentiation and technological advantages have been widely recognized as crucial factors determining the export performance of countries and sectors. Indeed, the quality of the product and the capacity to produce different varieties of goods are the crucial factors that explain why countries are able to export more than others, or why some countries gain more export market share at the expense of others (León-Ledesma, 2002).

According to the *law of one price*, if there is no transportation or other transaction costs, competitive markets will equalize the price of a homogenous good in two countries as long as prices are expressed in the same currency. Also, as stated by the *Bertrand Paradox*, price is the only variable of interest to consumers for such a homogenous good. Consequently, no country can raise its price above marginal cost without losing its entire market share. In contrast, product differentiation establishes market niches that allow countries to enjoy some market power over these clienteles (Bertrand, 1987).

The primary aim of differentiating a product is to reduce price competition. By differentiating the product, a seller attempts to reduce the influence of price on demand by creating a distinctive good or service via promotion, packaging, delivery, customer service, availability and other marketing factors. Successful product differentiation creates value to both customer and producer using a non-price-based strategy (Evans and Berman, 1997). Product differentiation has been suggested to boost farmer profits (Barkema, 1993; Antle, 1999; Levins, 2000; Schweikhardt, 2000; Babcock, 2002).

Product differentiation refers not only to offering products that consumers need and want, but more specifically, to offering goods that are close but not perfect, substitutes for one another. Even though it may result in higher costs, product differentiation is expected to increase market power and profits for the firm. Differentiation may be vertical when it satisfies the demand for quality and consumers are clear as to which product is superior to another. Higher prices for that product are the appropriate indicator of higher quality (Pagoulatos, 2003).

The other form of product differentiation is known as horizontal, and it satisfies consumers' demand for variety. The products are of the same quality but differ in their (real or presumed) characteristics. Furthermore, the various characteristics are valued differently by different consumers (Pagoulatos, 2003).

This study argues that although agricultural economists have generally treated wheat as undifferentiated from an analytical perspective, class differences should be recognized. According to the study, wheat differentiation enhances competitiveness of the exporting country. Using product differentiation as a non-price strategy, a country can sustain its market share and increase revenue by increasing sales at current prices or increasing the commodity price when maintaining the quantity constant as depicted by Figure 1.

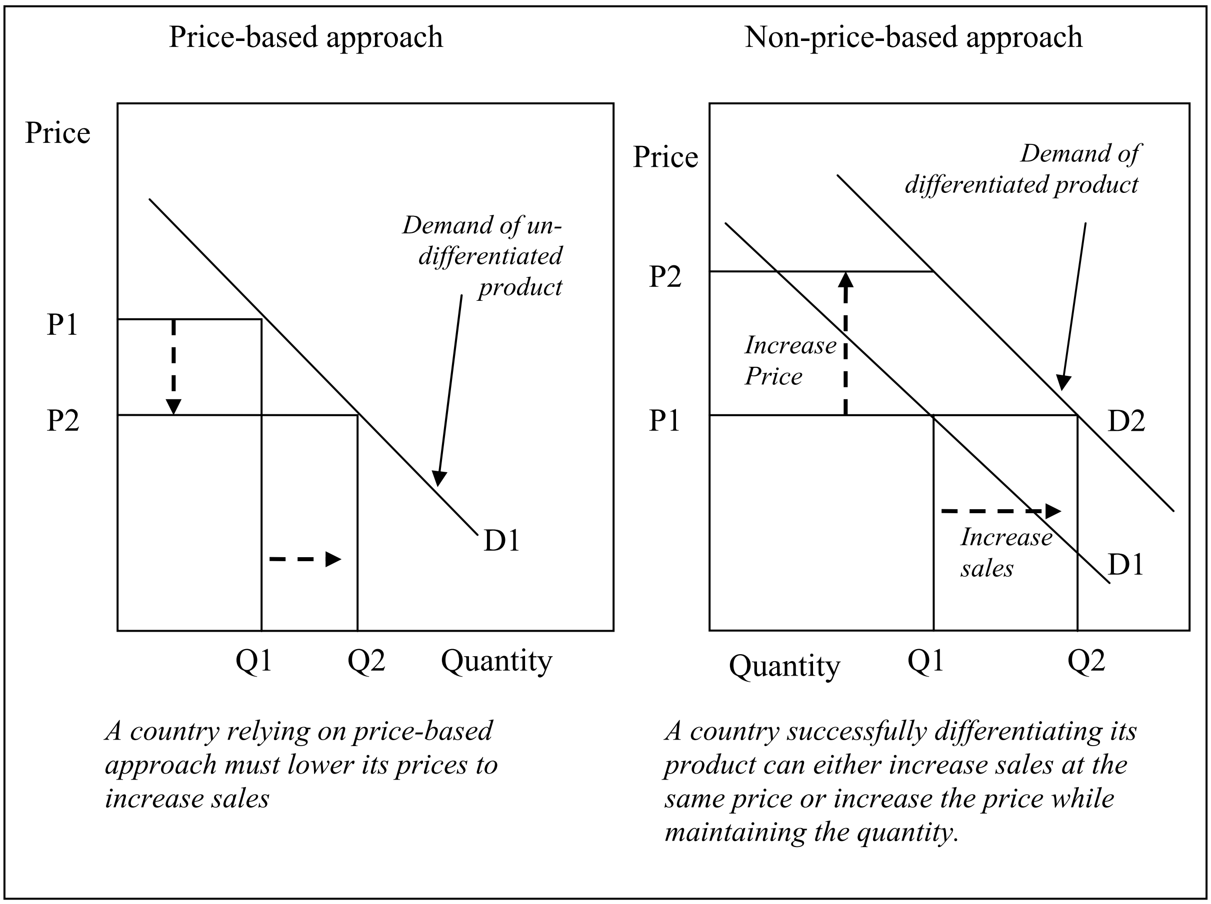
Expenditure elasticity of import demand for wheat denotes the percentage change in demand for wheat imports from the given country to the percent change in total expenditure on wheat imports from all countries. If the expenditure elasticity is greater than one, it is a good indication for an exporting country that its wheat exports can expand more than others and its market share increases as Egypt wheat market grows (Larson and Akiyama, 2004). The ability of a country to have higher prices or positive expenditure elasticity, in a competitive market when offering an almost homogenous commodity, is an indication of product differentiation. The study, therefore, uses price and expenditure elasticity as an indicator of product differentiation for Egyptian wheat imports.

Using the Almost Ideal Demand System (AIDS) model approach to generate price and income elasticities as indicators of product differentiation, the study evaluates US wheat competitiveness against Australian wheat in the Egyptian market. The study also evaluates whether the AIDS model can be used as a measure of agricultural export commodities competitiveness especially for commodities with perceived quality differences.

The specific objectives of the study are to: (1) use the AIDS model to estimate wheat import demand elasticities for the major suppliers in Egyptian market; (2) determine whether demand and income elasticities can be used as measures of product differentiation to explain the competitive position of US wheat, relative to Australian wheat in Egyptian market; and (3) discuss policy issues related to the marketing US wheat in Egypt. The results will provide useful information for US government policy makers and wheat industry organizations that assist the US wheat industry as it adapts to a highly competitive and changing wheat market.

This study has four sections, plus an introduction and a conclusion. These include a discussion on US and Australia wheat market positions in the Egyptian market, methodology employed in the construction of linear approximate almost idea demand system (LA/AIDS) model, descriptions of the database used in the empirical analysis, and estimation of the model. The main findings of the study, including estimated results and policy implications, are also discussed.

Figure 1. Export Commodities Differentiation and Increased Sales



2. Literature Review

2.1 The wheat market

The major wheat producing countries in 2004/2005 were EU, China, India, US, Russia, Canada, Australia, Pakistan, Ukraine and Turkey, contributing more than three quarters of the world's total wheat output (ERS/USDA, 2006). The total quantity of wheat traded was approximately 110 million metric tons for the 2004/2005 period. Most of the countries that import wheat are located in North Africa, Middle East, or Eastern Asia and accounted for more than 60% of net wheat trade in 2004/2005 period. They included Egypt, Brazil, Algeria, Japan, South Korea, Indonesia, Philippines, Mexico, Nigeria, Morocco, and Iraq (USDA, 2006).

Many different varieties of wheat are produced commercially around the world (Appendix 1). The principal criterion used for classifying wheat is ‘hardness’ which is a milling characteristic that is determined by protein content. ‘Hard’ wheat is characterized by high protein content whereas softer varieties have low protein content. ‘Hard’ varieties produce elastic dough suitable for the making of bread while those of medium hardness are used to make unleavened breads, Arabic and Indian-style flat breads and steamed breads. Soft wheat, with low protein content is milled into flour for cakes, cookies, pastries and crackers (Ghoshray, Lloyd, and Rayner, 2000).

Wheat is far from a homogenous commodity. Variation according to location and numerous dimensions of quality may affect the pattern of trade and the end-uses to which the particular form of wheat may be put. Such differences demarcate markets and are likely to impact upon the linkages for what may often be imperfect substitutes. In principle, the differences that exist between internationally traded wheat may be sufficient to divorce one market from another with the result that prices may evolve independently from one another. Alternatively, various types of wheat may be sufficiently differentiated to ensure that they have distinct behaviors, but sufficiently substitutable to ensure that their prices are tied together over the long term (Ghoshray, Lloyd, and Rayner, 2000).

Asia has been the leading buyer of US wheat for many years, with Japan, China, South Korea, Philippines, and Taiwan as the major export markets. However, this study focuses on the Egyptian market as the US has been a major supplier of wheat to Egypt, through commercial sales and under the PL 480 (Food for Peace) program, for more than forty years. The long-term trade relationship makes it possible to examine US market position in the Egyptian market. It also makes it possible to obtain data required for such an analysis (USDA, 2004).

The other major wheat suppliers to the Egyptian market are Russia, Argentina, France, and Australia. Together with the US they accounted for almost 91% of the total imports in 2003/2004. The balance 9% came from Germany, Sweden, Brazil, Syria, Spain, and others, each with a small share of the market. Wheat exports to Egypt accounted for about 33% of total US wheat exports in 2003/2004 (USDA, 2005).

The US continues to lose market share in the Egyptian wheat market. From the beginning of 2005/06 through the end of February 2006, US exports accounted for 15% (820,000 MT) of Egyptian wheat imports. This compared with 26% (1,417,460 MT) during the same period in 2004/05. The decline is due to the differential between US wheat prices and prices from other sources like Russia, Argentina, and France (Giles, Seifarth, and Ibrahim, 2006).

Wheat is Australia's most important grain crop. By world standards, Australia is a relatively small producer of wheat, accounting for only 3% of annual world production. However, about 80% of Australia wheat is exported. This means that Australia contributes around 15% of world trade, making it the fourth largest exporter after the US, Canada and the European Union. Australia's main wheat export markets are concentrated in Asia and the Middle East with Indonesia, Egypt, Iraq and Japan leading the importers over the past three years. In recent years the market for Australian wheat exports to China has grown steadily (ABARE, 2006).

All Australian wheat is marketed overseas by the Australian Wheat Board (AWB). Australian wheat is recognized in Egypt for its consistently high quality because it is white, clean, dry, and insect-free. These marketing features have been fundamental to the success of Australian wheat market in Egypt. It is used to make noodles, steamed buns, flat breads, loaf breads, cakes and pastries (Parker and Shapouri, 1993). Egypt is seen as an important part of AWB export focus with an import requirement of 6.5 million tons. In 2003/04, Australia's export of wheat to Egypt was 2.3 million tons, making it Australia's third largest market. According to USDA (2004) Australian wheat is a major competitor of US wheat exports in Egypt.

2.2 Egypt Wheat Market

Wheat is considered a strategic commodity in Egypt because of its importance in the Egyptian diet. It provides more than one-third of the daily caloric intake of Egyptian consumers and 45 percent of their total daily protein consumption. Wheat is mainly consumed in the form of bread. It is also the major staple crop produced in Egypt, occupying about 32.6 percent of the total winter crop area (Rosen, 1993).

Egypt has become the largest market for US wheat exports which amounted to 4 million tons in 2004. US wheat exports to Egypt have also benefited from US credit especially since foreign exchange has been especially tight in Egypt. Egypt is also a major recipient of US export assistance under programs such as P.L. 480, Export Credit Guarantee Program (GSM-102), the Export Enhancement Program (EEP) (Parker and Shapouri, 1993; USDA, 2004).

Quality, along with price, has an important impact on Egypt's choice of suppliers. Egyptians do not include cleanliness in their quality list. The main concern is live insects and insect damage. This is followed by moisture levels; weed seed, shrunken and broken kernels, and falling number. In terms of color, white wheat is preferred (Parker and Shapouri, 1993).

Australia's white wheat is the most preferred in Egypt followed by US wheat. Since the US can supply a wide assortment of wheat, Egypt can shift from a type with quality flaws, real or perceived (like soft red winter to white), to satisfy its consumers. Since the US has large supplies of most major types of wheat, the decision to stop importing a particular type of wheat may not cause total purchases from US to decline (Parker and Shapouri, 1993).

2.3 Previous Studies

Grain trading firms and agencies have long recognized the importance of quality differences among wheat from different origins and their variability through time. The extent and effect of differentiation in the world grain (wheat) trade has, therefore, been of interest to grain market analysts. However, agricultural economists have generally treated wheat as undifferentiated from an analytical perspective. In more recent years, class differences have been recognized (Dahl and Wilson, 2000).

Several studies have indicated that wheat has numerous end uses and indigenous characteristics should, therefore, be treated as heterogeneous. Wilson (1989) demonstrated that over time, differentiation (using the Hufbauer index) has increased. Wilson and Gallagher (1990), and Wilson (1989) indicated that through time, there has been a growing diversity of demands for end-use characteristics. In other words, demands have never been homogenous, and the degree of differences in preferences appears to be growing.

Other studies that have looked at the demand for wheat classes include on one hand Agriculture Canada (1987) that analyzed regional import demands for aggregated classes. On the other hand, Benirschka and Koo (1996) analyzed demand for wheat classes using loosely specified models with respect to functional form, relationships among elasticities, and, in some cases, included variables.

Wilson (1994) did a study on wheat class demands for Pacific Rim countries using a translog function. The results of the study indicated substantial differences among underlying demand parameters for different wheat classes as well as across countries. In addition, the expenditure level has important impacts on the distribution of imported wheat classes; and preferences have shifted significantly through time, generally toward higher protein wheat (Dahl and Wilson, 2000).

3. The empirical model

The Almost Ideal Demand System (AIDS) (Deaton and Muellbauer 1980a) was selected to see if its results can be an appropriate way of looking at agricultural commodities competitiveness when considering commodities from different origin. The study wishes to evaluate if the AIDS model results can give a better perspective of competitiveness especially considering substitute agricultural export goods from different sources with perceived quality differences.

AIDS model was selected because it has a flexible functional form, allowing testing of theoretical restrictions on demand equations as exemplified in extensive use in applied demand analysis especially in recent years. AIDS model satisfies the axioms of choice exactly and allows exact aggregation over consumers. Its flexibility provides an arbitrary first-order approximation to any demand system and enables the testing of the homogeneity and symmetry conditions through linear restrictions on fixed parameters. The AIDS model was, therefore, considered appropriate for empirical estimation of demand parameters as defined in this study.

The AIDS model is as proposed by Deaton and Muelbauer (1980b) as follows:

$$w_i = \alpha_i + \sum \gamma_{ij} \ln p_j + \beta_i \ln\left[\frac{M}{P}\right] \tag{1}$$

where w_i is the budget share of the i^{th} good, M is the total expenditure, p_j is the price of i^{th} good, P is a properly defined price aggregator. The price aggregator form is given by:

$$\ln P = \sum_i \alpha_i \ln(p_i) + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln(p_i)\ln(p_j) \tag{2}$$

Some restrictions are imposed to enable identification of the parameters. The following parameter restrictions adding-up, homogeneity and symmetry are derived from the standard demand theory:

$$\sum_i \alpha_i = 1; \sum_i \beta_i = 0; \sum_i \gamma_{ij} = 0; \sum_j \gamma_{ji} = 0 \text{ and } \gamma_{ji} = \gamma_{ij} \tag{3}$$

The most usual form of linearization for the systems was proposed by Deaton and Muellbauer (1980b), and consists in substituting *lnP* for Stone Price Index $\ln P^* = \sum_{i=1}^{n} w_i \ln p_i$, into equation (1), the resulting model is called LAIDS (Linear Almost Idea Demand System). Both the first and second-stage equation systems are based on equation (1), and are subject to the restrictions of adding-up, homogeneity, and symmetry as described in equation (3).

Marshallian and Hicksian measures of elasticities were computed from the estimated coefficients of the AIDS model using derivation by Chalfant* as follows:

$$\varepsilon_{ii} = -1 + \frac{\gamma_{ii}}{w_i} - \beta_i \,;\; \varepsilon_{ij} = \frac{\gamma_{ij} - \beta_i w_j}{w_i} \,;\; \delta_{ii} = -1 + \frac{\gamma_{ii}}{w_i + w_j} \,;\; \delta_{ij} = \frac{\gamma_{ij}}{w_i + w_j} \tag{4}$$

where ε and δ denote Marshallian and Hicksian elasticities, respectively. The expenditure elasticities can be obtained from the estimated coefficients as well:

$$\eta_i = 1 + \frac{\beta_i}{w_i} \tag{5}$$

Several formulas for calculating elasticities associated with the LA/AIDS model have been discussed (Green and Alston 1990, 1991; Hahn 1994). While some treat LA/AIDS model as a model on its own and calculate elasticities accordingly, others estimate the parameters from the LA/AIDS model and the calculate elasticities based on the formulae obtained from the original AIDS model. Each approach has had criticisms as being internally inconsistent or lacking in approximation property (Hahn 1994; Moschini 1995). Hahn (1994) advises that for good results only the original AIDS model should be estimated, and any of its linear approximations. This study, therefore, obtains its empirical results by estimating the original complete non-linear version of the AIDS model. The empirical AIDS model for wheat imports to Egypt is specified in equations (6) – (8) as follows:

$$W_{USA} = \alpha_1 + \gamma_{11} \log P_{USA} + \gamma_{12} \log P_{AUS} + \gamma_{13} \log P_{ROW} + \beta_1 \log(\frac{x}{p}) + \varepsilon_{1t} \tag{6}$$

$$W_{AUS} = \alpha_2 + \gamma_{21} \log P_{USA} + \gamma_{22} \log P_{AUS} + \gamma_{23} \log P_{ROW} + \beta_2 \log\left(\frac{x}{p}\right) + \varepsilon_{2t} \tag{7}$$

and

$$W_{ROW} = \alpha_3 + \gamma_{31} \log P_{USA} + \gamma_{32} \log P_{AUS} + \gamma_{33} \log P_{ROW} + \beta_3 \log\left(\frac{x}{p}\right) + \varepsilon_{3t} \qquad (8)$$

where the W_{USA}, W_{AUS} and W_{ROW} are market shares (in value terms) of the US, Australia and rest of the world (ROW), respectively; P_{USA}, P_{AUS} and P_{ROW} are import values of wheat from the US, Australia, and ROW, respectively; x is the value of total wheat imports in Egypt; P is the Translog price index; and e_{1t}, e_{2t}, and e_{3t} are the error terms, which are assumed to be normally distributed with constant means and variances, and may be contemporaneously correlated.

The AIDS model assumes that wheat is weakly separable from other goods; that its consumption depends only on group expenditures, wheat prices, and other demand shifters. Wheat from different origins is differentiated by quality and price. According to a study by Wilson (1994) on import demand for wheat in the Pacific Rim countries, substantial difference existed in import demand parameters for wheat of different classes as well as across countries. Wheat from different origins is believed to be of different classes and so they are not perfect substitutes.

The AIDS model is developed under the assumption that decisions to import wheat by the Egyptian milling industry are made using a two-stage budgeting procedure as explained by Deaton and Muellbauer (1983b, pp. 122-126). In the first stage, total expenditure is allocated over broad groups of food commodities such as wheat, corn, and rice. In the second stage, group expenditure on wheat, which is now assumed to be exogenous, is allocated to wheat products from different countries, such as wheat from the US, Australia, and ROW. The Durbin-Watson (DW) Tables were used to test the hypothesis of zero autocorrelation. For models whose DW *d*-statistics showed evidence of autocorrelation, the Cochran iterative method was used as a corrective measure for first order autocorrelation.

The estimation method employed is the Interactive Seemingly Unrelated Regression (ISUR). When ISUR is employed to estimate a LAIDS model, the property of additivity of the demand function renders the variance and covariance matrix singular. To solve for this, one of the equations is excluded from the system during the estimation. The coefficients of the excluded equation are later recovered given the additivity property. All prices are normalized by the average price in order to keep the homogeneity property. Symmetry is imposed in the estimation process.

4. The Data

The study uses annual data, from 1972 to 2002, on wheat import prices and quantities into Egypt from the US, Australia, and ROW. The US, Australia, and ROW wheat exports to Egypt data were obtained from the Food and Agricultural Organization (FAO) exports of cereals by source and destination available online at www.fao.org. Wheat export prices for US were obtained from ERS/USDA, while Australia's and ROW wheat export price data were obtained from the Australian Bureau of Agricultural and Resource Economics (ABARE) available online at www.abareconomics.com.

Consumer price index for Egypt was obtained from International Monetary Fund (IMF) International Financial Statistics available online at www.econstats.com. The FAO exports of cereals by source and destination data run from 1980 to 2002. However, FAO has data of total wheat imports from 1972 to 2002. Data for US and Australia wheat exports to Egypt from 1972 to 1979 were calculated by multiplying the total Egypt wheat imports by the US and Australia share of imports as in Parker and Shapouri (1993).

5. Results and Discussions

Table 1 reports summary statistics for the values of import and market shares. The Table shows that between 1972 and 2002, prices varied more than market shares, as summarized by coefficients of variation (COV) results.

Figures 2 and 3 report the import prices and market share for US and Australian wheat in Egyptian market. It is evident that US and Australia wheat prices have similar time trend, with Australia prices generally higher than the US prices. The higher price for Australia wheat when compared to US wheat in the Egypt market may be a reflection of the difference in perceived quality of wheat from the two countries.

That Australia has been able to retain and sometimes increase its market share while still enjoying higher prices for its wheat compared to the US is an indication that Australia has been able to differentiate its wheat from that of the US in the Egyptian market. According to Parker and Shapouri (1993) Egyptians are willing to pay a premium of $18 to $20 per ton for Australian wheat, which they perceive to have higher quality, although US wheat appears to have a cost advantage.

Figure 3 shows that the US dominates in wheat supplies to the Egyptian market and there is a big difference is market share between the US and Australia. However, this gap is not a guarantee as US wheat exports to Egypt have declined in some years. The gap is expected to be sustained according to USDA (2004) as Egypt has returned to buy US wheat. Quoting *US Export Sales*, commitments to Egypt, USDA reports that 2004 wheat sales were more than 3.5 times as much compared to the previous year's level. Egypt is once again the largest market for US wheat exports due to tight foreign exchange and US credit arrangements for agricultural commodities exports.

Figure 2. Egypt Import Prices for the US and Australia Wheat (1972-2002)

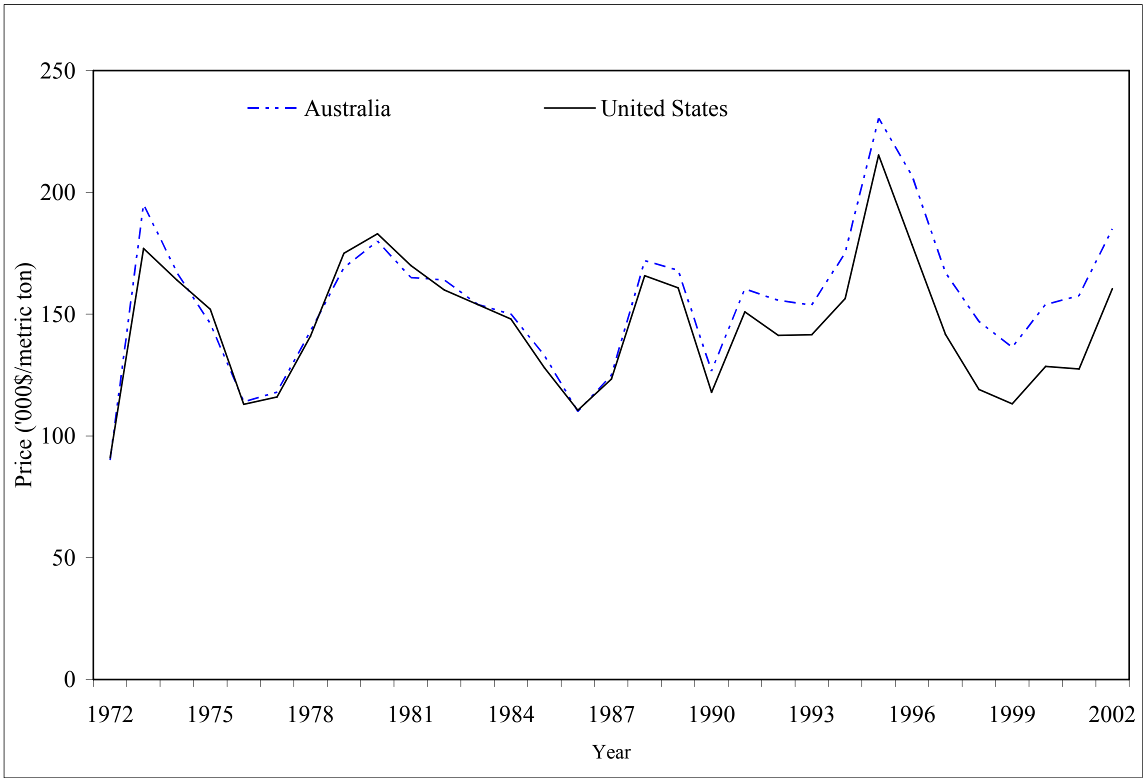
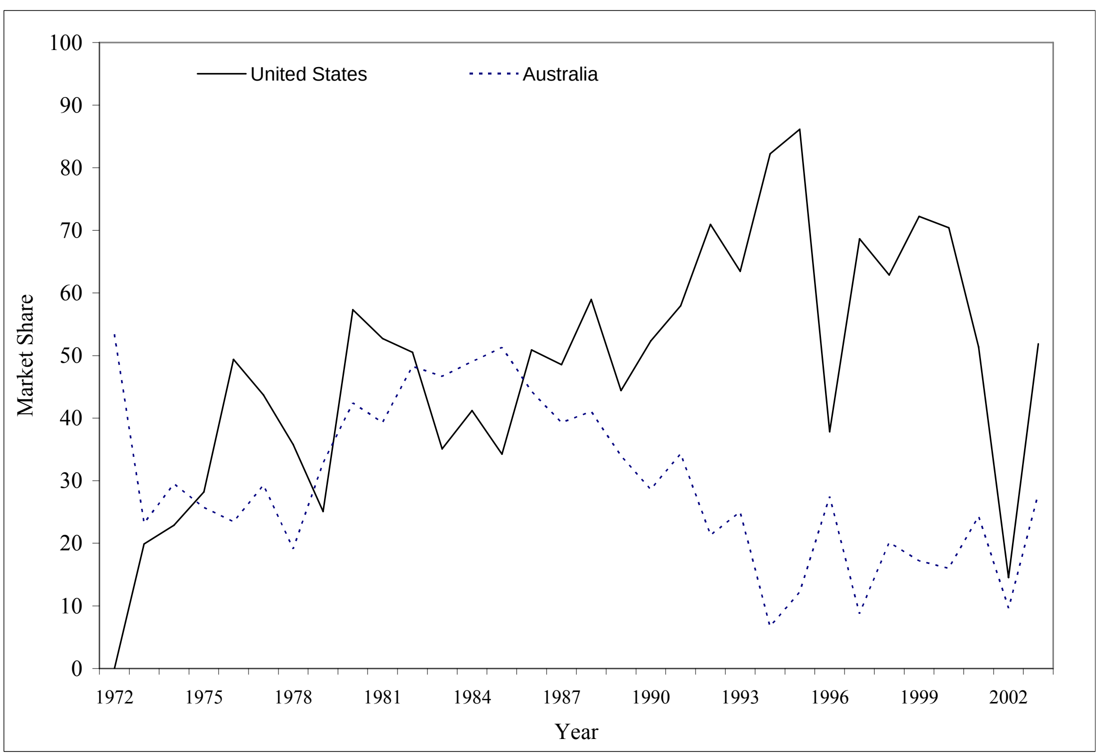


Figure 3. US and Australia Wheat Market shares in Egypt Market (1972-2002)



5.1 Estimated demand elasticities

Since the primary objective of this analysis is to investigate the impact of wheat differentiation on competitiveness of US wheat relative to Australian wheat in the Egyptian market, only results that are directly relevant to US and Australia are discussed in detail. Results that are related to ROW suppliers are only discussed where appropriate.

As shown by Table 4, the estimated price coefficients are statistically significant at the 10% level, except for cross-price coefficients in the US equation with respect to own price, Australia, and the ROW price. The coefficients associated with total expenditure are statistically significant when compared to estimated price coefficients. According to Deaton and Muellbauer (1980b, p. 78), demand response to total expenditure is relatively easy to measure with precision while price responses are more difficult to obtain.

Demand elasticities for wheat imports in the Egyptian market are presented in Table 5. They are calculated based on the mean values of the prices. The estimated expenditure elasticities for the US, Australia and ROW are 1.64, 2.11, and -0.5, respectively. The results indicate that both US and Australian wheat are normal goods while ROW wheat is an inferior good. The results also indicate that when total expenditure on wheat imports in Egypt increases by one percent, *ceteris paribus*, the quantity demanded of US wheat will increase by 1.64% and that of Australian wheat will increase by 2.11%. Meanwhile, the quantity demanded of ROW wheat will decrease by 0.5%.

Table 5 results show that US and Australia wheat are perceived to be of better quality than ROW wheat. On the other hand, Australia’s wheat with higher expenditure elasticity may be perceived to be of even better quality than US wheat since income (expenditure) elasticities are believed to be larger for the best or preferred grade and smaller for lower grades (Tomek and Robinson, 1990). The results indicate that although the US is better positioned than ROW in the Egyptian market in being preferred as wheat supplier, it still lags behind Australia. These results are further confirmation that Australia has successfully differentiated its wheat exports to Egypt from the US wheat exports.

Although the US wheat might be cheaper or inferior product relative to Australia wheat, this may be to US advantage. This is particular true in this period when Egypt has tight foreign exchange and US credit is coming to its rescue (USDA, 2004). As a result, cheaper US wheat is preferred to Australia wheat, which has the perceived higher quality but is more expensive. US wheat will, therefore, continue to enjoy an advantage over Australian wheat. However, as the Egyptian economy grows so will be the demand for higher quality wheat and the US will need to improve its wheat quality and image in order to sustain or improve its market share in Egypt (Kherallah, Löfgren, Gruhn, and Reeder, 2000).

The estimates for own-price elasticities for the US and Australia are –1.12 and –2.47, respectively. These results suggest that both demand for US and Australia wheat are own-price elastic. The own-price elasticity for the demand of US and Australian wheat indicate that wheat exports to Egypt would be affected negatively with increases in its own price, *ceteris paribus*. The results also show that US wheat demand and the revenue from exporting wheat can be enhanced if prices for US wheat are reduced. However, because the US own-price elasticity is not statistically significant at 10% level, we may have to interpret these results cautiously. These results also indicate that Australia would increase its wheat exports to the Egypt market by reducing its price.

The results in Table 5 show that US and Australian wheat may be substitutes for one another as indicated by values of significant cross-price elasticities that have positive sign. The calculated estimate for cross-price elasticity of 1.8 indicates that a 1% increase in the price of the Australian wheat, *ceteris paribus*, leads to 1.8% increase on the demand for US wheat. By comparison, a 1% increase on US wheat price, *ceteris paribus*, will lead to 0. 96% decrease on the quantity demanded for Australia wheat. The cross-price elasticities for the US wheat with respect to the Australian wheat are not statistically significant at 10% level. The results show that US wheat is considered to be stronger substitute for Australian wheat; while the reverse may not be said to be true. These results show that Egyptians tend to buy more US wheat when Australian wheat is considered to relatively expensive. However, a price increase for US wheat relative to the Australian wheat, *ceteris paribus*, does not lead to Egyptians buying more Australian wheat to substitute for the now expensive US wheat.

The results also indicate that the demand for US wheat is not as sensitive to its own price change when compared to Australia wheat, and that US wheat is seen as a strong substitute for Australia wheat. The demand for US wheat can, therefore, be improved by lowering the price. Thus, increasing production efficiency coupled with quality improvements may be one way of improving the performance of US wheat export in the Egyptian market.

The results from this study show that while US wheat is perceived as a normal good, Australia wheat may be differentiated in the Egyptian market. That is why Australia's wheat has higher expenditure elasticity and the ability to sustain higher prices without loss in market share. This is an indication that Australia may be considered a strong competitor for US in the Egyptian wheat market. The opportunity, however, exists for the US wheat industry to enhance its market position through improved marketing strategy. The marketing strategy might include improved efficiency during production that will lead to lower costs therefore ability to price US wheat cheaply. Also, enhanced product promotion will lead to improved perceived quality image for US wheat. This way, the US wheat can be differentiated from Australian and ROW wheat.

The results of this study are consistent with earlier studies (see also Parker and Shapouri, 1993). This is an indication that the AIDS model can be used as a measure of agricultural export commodities competitiveness especially for commodities, from different sources with perceived quality differences.

6. Conclusions

US and Australia are the largest wheat suppliers to Egypt, sometimes supplying nearly 90 percent of total wheat demand for the Egyptian market. The US had a dominant position in the Egyptian wheat market until the 1990s; while Australia has continued to defend its market share in Egypt and improved it in recent years. This study makes contribution to the literature by explaining the US wheat market position in Egypt using demand and expenditure elasticities. This information is important to the US agricultural policy makers if they want US to be competitive in the North African market.

The study finds that Australia has defended its market share and maintained higher prices, probably by differentiating its wheat through creating a perception that its wheat is of better quality. We can therefore say that the US wheat market share in Egypt can be improved and defended by continued investment on the production side that will lead to lower production costs and appropriate marketing strategies. Lower prices and improvement in perceived quality for the US wheat will certainly make it more competitive in the Egypt market.

Demand elasticities for wheat imports in the Egyptian market show that Australian wheat is perceived to be better quality than US wheat. This means that although the US may have a stronger market position than ROW in the Egyptian market for being the preferred supplier with better wheat, it still lags behind Australia.

The study also finds that demand for US wheat is less own-price elastic when compared to the demand for Australian wheat. Moreover, US wheat is found a strong substitute for Australian wheat, while the reverse may not be necessarily true. The US lower own-price elasticity can be said to be advantageous in at this time when the Egyptian economy is weak with foreign exchange been especially tight. The export US credit for agricultural commodities has been of great help. However, for US wheat to be competitive in the future, it is important that the wheat sector maintain the current low prices through lower production costs and at the same time differentiate US wheat from other wheat's through enhanced quality and improvement in perceived quality image through effective marketing campaigns.

Appendix 3A. Tables for Chapter 3

Table 1. Wheat Prices and Market Shares in the Egyptian market (1972-2002)[a]

	Mean	St deviation	COV[b]	Minimum	Maximum
MS_{USA}	48.00	20.00	2.41	0.00	0.86
MS_{AUS}	30.00	13.00	2.26	0.07	0.53
MS_{ROW}	22.00	19.00	1.18	0.00	0.76
P_{USA}	138.29	25.05	5.52	69.00	185.00
P_{AUS}	155.43	28.98	5.36	90.00	230.42
P_{ROW}	145.97	26.84	5.44	91.00	215.33

[a]Market shares measured in percentages and prices are measured in US dollars/metric ton.
[b]COV = Coefficient of Variation = Mean / St. deviation.

Table 2. Theoretical Restrictions Imposed on the AIDS model

Adding-up restrictions	Homogeneity restrictions	Symmetry restrictions
$\alpha_1 + \alpha_2 + \alpha_3 = 1$,	$\gamma_{11} + \gamma_{12} + \gamma_{13} = 0$,	$\gamma_{12} = \gamma_{21}$,
$\beta_1 + \beta_2 + \beta_3 = 0$,	$\gamma_{21} + \gamma_{22} + \gamma_{23} = 0$, and	$\gamma_{13} = \gamma_{31}$, and
$\gamma_{11} + \gamma_{21} + \gamma_{31} = 0$,	$\gamma_{31} + \gamma_{32} + \gamma_{33} = 0$.	$\gamma_{23} = \gamma_{32}$.
$\gamma_{12} + \gamma_{22} + \gamma_{32} = 0$, and		
$\gamma_{13} + \gamma_{23} + \gamma_{33} = 0$.		

Table 3. Likelihood Ratio Test for Various Combinations of Theoretical Restrictions

Sub-models	Calculated χ^2 for R_1	Calculated χ^2 for R_2
Sub-model 1: Adding-up restrictions	--	
Sub-model 2: Adding-up + Homogeneity restrictions	χ^2 (2) = 2.03*	χ^2 (2) = 2.09*
Sub-model 3: Adding-up + Homogeneity + Symmetry restrictions	χ^2 (3) = 2.10*	χ^2 (1) = 2.10*

* indicates that the differences in log likelihood values are statistically significantly different at the five percent level. At the 95% level of confidence, the critical χ^2 values are: χ^2 (2) = 5.99; and χ^2 (3) = 7.81.

Table 4. Estimated Coefficients of the Unrestricted AIDS Model (without symmetry or homogeneity restrictions), 1972-2002

	USA	Australia	ROW[b]
US price	0.19 (0.92)	-0.13 (-0.89)	-0.06 (-0.28)
AUS price	0.96 (0.21)	-1.13 (-3.58)**	1.03 (2.13)**
ROW price	-0.25 (-0.53)	1.1 (3.28)**	-0.84 (-1.63)*
Total expenditure	0.29 (3.18)**	0.34 (0.53)	-0.32 (-3.31)**
Constant	-2.13 (-2.42)*	0.88 (1.43)	2.25 (2.38)**

The numbers in parentheses are t-ratios. Single (*) and double asterisks (**) denote significance at the 10% and 5% level, respectively.

Table 5. Estimated Elasticities for the Unrestricted AIDS Model (with symmetry or homogeneity restrictions), 1972-2002

	Price elasticities, E_{ij}			Expenditure Elasticities
	US	Australia	ROW	
US	-1.12	1.80	-0.66	1.64
Australia	-0.96	-2.47	3.36	2.11
ROW	-2.23	5.29	-1.52	-0.50

$$E_{11} = \frac{\gamma_{11}}{R_1} - \beta_1 - 1 \qquad \frac{\delta R_1}{\delta \ln P_1} = \gamma_{11} \qquad E_{12} = \frac{\gamma_{12} - \beta_1 R_2}{R_1}$$

Appendix 3B. Estimated AIDS Model Selection

Three versions of the AIDS Model are developed and estimated for testing validity of general restrictions as implied by economics theory. The first sub-model estimates the original AIDS without imposing constraints on parameters except for the adding-up restrictions that are automatically satisfied. The second sub-model imposes the adding-up and homogeneity restrictions. The third sub-model imposes the adding-up, homogeneity and symmetry restrictions jointly. The restrictions imposed on the sub-models are listed in Table 3.

Finally, since budget shares add up and the variance-co-variance matrix of the error terms is singular, the models are estimated twice first by removing the ROW equation, and secondly by excluding the Australia equation. The equations are estimated using the non-linear seemingly unrelated regression (SUR) system, to accommodate parameter restrictions, using LIMDEP. The iterative procedure is equivalent to the maximum likelihood estimation. The test results based on likelihood ratios are presented in Table 4.

As seen in Table 4, the calculated Chi-squared values are less when compared to the corresponding critical values. This implies that homogeneity and symmetry conditions cannot be rejected by the data. Although we do not reject homogeneity or symmetry restrictions, the study estimates both the restricted and unrestricted models. However, only the results for the unrestricted model are discussed fully since the econometric properties results for both models look qualitatively similar, with a few exceptions. Also, the results from unrestricted model are more consistent with the existing theory concerning US and Australia wheat exports to the Egyptian market. Results from the restricted model are also included for comparison purposes.

The estimated equations have good explanatory power with R_1^2 = 0.45, R_2^2 = 0.38, and R_3^2 = 0.31. Thus, between 31 and 45 percent of the observed year-to-year changes in wheat demand in Egypt can be "explained" by the equations. The Durbin-Watson (*DW*) statistic [k=4, n=31] has a value of d_L = 1.16 and d_U=1.75 at 0.05 level of significance. The no correlation region is *DW* value of 1.75 to 2.25. Based on the results from the equations for R_1, $R_{2,}$ and R_3 the *DW* falls on the non-decision region [DW between 1.16 and 1.75]. All the three models were re-run using Cochran iterative method as a corrective measure for first order autocorrelation. The results were, however, not significantly different than the ones where no corrective measure was done. The results presented on this study are from the original model.

Appendix 3C. Estimated Coefficients for Restricted AIDS Model (with symmetry or homogeneity restrictions), 1972-2002

	USA	Australia	ROW[b]
US price	0.17 (0.89)[a]	-0.04 (-0.30)	-0.13 (-0.65)
AUS price	-0.38 (-0.29)	-1.0 (-3.36)**	1.03 (3.28)**
ROW price	-0.13 (-0.65)	1.0 (3.28)**	-0.90 (-2.24)*
Total expenditure	0.31 (4.36)**	0.001 (-0.20)	-0.31 (-3.64)**
Constant	-2.12 (-3.54)**	0.38 (0.80)	2.74 (3.87)**

The numbers in parentheses are t-ratios.
Single (*) and double asterisks (**) denote significance at the 10% and 5% level, respectively.

Appendix 3D. Estimated Elasticities the Restricted AIDS Model (with symmetry or homogeneity restrictions), 1972-2002

	Price elasticities			Expenditure Elasticities
	US	Australia	ROW	
US	-1.14	-0.99	-0.41	1.64
Australia	-0.13	-2.00	3.27	1.00
ROW	0.09	5.28	-1.59	-0.45

Appendix 3E. Classes of Wheat

Types of wheat	Characteristics	Products	Consumers
Argentinean Trigo Pan wheat. (ATP)	Semi-hard wheat Protein (10%) Moisture content (14%)	Bread	FSU, China, Peru, Bolivia and Iran.
Australian Standard wheat. (ASW)	White wheat Medium protein (10%)	Middle Eastern style flat bread and noodles	Mid and Far East
Canadian Western Red Spring wheat No1. (Cl)	Hard wheat Hi protein *12.5%*	Bread	Latin America and China
Canadian Western Red Spring wheat No3. C3	High protein No prescribed minimum	Feed wheat	*
US Dark Northern Spring wheat. (USD)	Hard wheat Hi protein 14%	Pasta products	Central America, Japan, Philippines and Russia
US Hard Red winter wheat. (USH)	Hard wheat Hi protein (12.5%).	Bread rolls. To a lesser extent sweet goods and all purpose flour	FSU, China, Japan, Morocco and Poland
US Soft Red Winter wheat. (USS)	Weak wheat Low protein (10%)	Biscuits, crackers, cakes and pastries	China, Egypt and Morocco.
US Western White wheat, (USW)	Blend of soft white club and common wheat Low protein (9%)	Biscuits, crackers cakes and pastries.	Far East Asian region.
European wheat (USSW)	Soft winter wheat Moderate protein content	Steam bread, flat bread and oriental noodles.	FSU, North and Sub-Saharan Africa

Source: Ghoshray, Lloyd, and Rayner, 2000

CONCLUSIONS

The study presented here is divided into three essays that focus on three statistical analyses commonly used in the field of international trade and economics. The essays fall under one theme of US competitiveness. The study focuses on competitiveness of US agricultural commodities and tries to answer the questions (a) how R&D and human capital influence US agricultural commodity exports competitiveness, (b) how does adoption of genetically modified crops technology affect US agricultural crops (therefore exports) competitiveness, and (c) how does product differentiation affect competitiveness of US agricultural market commodities. The study uses production and marketing approach and tries to demonstrate that technology based measurements (R&D) should be included when discussing competitiveness and evaluates AIDS model approach as a way of measuring agricultural commodities competitiveness.

The first essay estimates dynamic ordinary least squares (DOLS) export model including the developed agricultural R&D index, human capital index, and Mickey Index of competitiveness for US corn, cotton, wheat, and soybeans; as well as for US competitors. Using time series panel data for US and its competitors in different agricultural export markets, the study results show that R&D investment and competitiveness, as measured by the Michaely Index, are important factors that positively influence agricultural commodity exports. The study result shows that agricultural R&D index measure can be included when evaluating the competitive position of US agriculture.

The second essay uses specific factor model of production to predict the effects of GM technology adoption on the competitiveness of US agricultural crops. The study argues that biotechnology leads to crop specific factor biased technical change, offering a potentially powerful tool to increase competitiveness. The study disaggregates the US agricultural sectors into five sub-sectors and based on projected price adjustments, output adjustments, and resource allocation it investigates how the adoption of GM crops may influence the competitiveness of US agricultural crops. The study results demonstrate a positive relationship between successful adoption of GM technology and agricultural crops competitiveness by linking adoption of GM technology with projected positive returns in the sectors.

In the third chapter, an Almost Ideal Demand System (AIDS) model approach is used to assess the competitiveness of US wheat. The study argues that although agricultural economists have generally treated wheat as an undifferentiated product from an analytical perspective, class differences should be recognized. Using the AIDS model approach to generate price and income elasticities as indicators of product differentiation, the study results show that Australia wheat may be differentiated in the Egyptian market because of higher expenditure elasticity, and Australia's ability to sustain higher wheat prices than the US in Egypt without significant loss in its wheat market share. This makes Australia wheat more competitive than the US wheat in the Egyptian wheat market.

The results for this study can be summarized in two-fold. One, for US agricultural sector to remain competitive, the sector must continue to invest in technology. This will ensure that US agricultural sector continues to enjoy lower production costs which translate to lower export prices. Two, lower prices alone will not guarantee US agricultural export competitiveness unless they are accompanied by improvement in perceived quality.

In terms of policy, the study therefore concludes that public and private policies towards investments in R&D and other technologies should be encouraged since they enhance US agricultural export commodities competitiveness. Also, while US agricultural export commodities producers should be encouraged to improve quality of produce, US agricultural commodities marketing policies should also be geared towards improvement of quality image through effective promotional campaigns.

BIBLIOGRAPHY

ABARE (Australian Bureau of Agricultural and Resource Economics) (2006). "*Australian Commodity Statistics 2006*," Canberra.

Agénor, P. (1997). "*Competitiveness and External Trade Performance of the French Manufacturing Industry,*" Weltwirtschaftliches Archiv. Review of World Economics. N° 133 (1).

Agriculture Canada (1987). "*Analysis of Strategic Mixes for Canadian Wheat Exports," Guelph*, Ontario.

Ahearn, M., J. Yee, E. Ball, and R. Nehring (1998). "*Agricultural Productivity in the U.S,"* AIB-740, ERS, USDA, January 1998.

Allen, R.G.D. (1938). "*Mathematical Analysis for Economists*," London: Macmillan.

Almarwani, A. A. (2003). " *The Exchange Rate and the Competitiveness of Selected US Agricultural Products,"* A Dissertation submitted for fulfillment of Doctor of Philosophy, Auburn University, May 2003.

Antle, J. (1999). "*The New Economics of Agriculture,*" American Journal of Agricultural Economics, 81(5): 993-1010.

Antle, J.M., and V.H. Smith (1999). "*The Economics of World Wheat Markets*," CABI.

Arize, A. C, Osang, T. and D. J. Slottje (2000). "*Exchange-Rate Volatility and Foreign Trade: Evidence From Thirteen LDC's*," Journal of Business and Economic Statistics 18, 10-17.

Ash, M. and E. Dohlman (2006). "*Oil Crops Situation and Outlook Yearbook*," Market and Trade Economics Division, Economic Research Service, USDA, May 2006, OCS-2006.

Assery, A. and D. A. Peel (1991). "*The Effect of Exchange Rate Volatility on Exports: Some new Estimates,*" Economic Letters 37, 173--177.

Babcock, B. A. (2002). "*Rural America and Modern Agriculture: What Kind of Future?" Iowa Ag Review,* 8(2):1-3.

Baffes, J. (2004). “*Cotton Market Setting, Trade Policies, and Issues*,” World Bank Policy Research Working Paper 3218, February 2004.

Bahmani-Oskooee, M. and N. Ltaifa.(1992). *“Effects of Exchange Rate Risk on Exports: Cross-country Analysis,*” World Development. 20:1173-81.

Banse, M., Gorton, M., Hartell, J., Hughes, G, Köckler, J. Möllman, T. and W. Munch (1999*). “The Evolution of Competitiveness in Hungarian Agriculture: from Transition to Accession,”* paper presented the IXth European congress of Agricultural Economists, Warsaw, Poland, 24th-28th August.

Barkema, A. (1993). *“Reaching Consumers in the Twenty First Century: The Short Way Around the Barn,”* American Journal of Agricultural Economics, 75(5).

Batten, D.S., and M. T. Belongia (1986)*.” Monetary Policy, Real Exchange Rates, and US Agricultural Exports,”* American Journal of Agricultural Economics. 68:422-27.

Batten, D.S., and M. T. Belongia (1984). *“The Recent Decline in Agricultural Exports: Is the Exchange Rate the Culprit?,”* Fed. Res. Bank St. Louis. Rev. 66:5-14.

Benirschka, M. and W.W. Koo (1996). “*World Wheat Policy Simulation Model: Preliminary Baseline*,” Agricultural Economics Report No. 344, Department of Agricultural Economics, North Dakota State University, Fargo, February 1996.

Bertrand, K. (1987). “*Marketers discover what "quality" really means*,” Business Marketing, 72 (April): 58-70.

Bowlus, A. J. and C. Robinson (2005). "*The Contribution of Post-Secondary Education to Human Capital Stocks in Canada and the United States*," CIBC Human Capital and Productivity Project Working Papers 2005.

Brooks, H. (1984). ”*Technology as a Factor in US Competitiveness; US Competitiveness in the World Economy,”* Scott, Bruce R. and Lodge, George C., ed.; Harvard Business School Press, 1984.

Bureau of Economic Analysis (BEA), United States Department of Commerce. *National Account Data,* http://www.bea.gov/bea/dn1.htm. Updated regularly.

Burfisher, M.. E.and E. A. Jones (1998). *"Regional Trade Agreements and US Agriculture,"* Agricultural Economics Report No. 771. 156 pp, November 1998 http://www.ers.usda.gov/publications/aer771/

CAST (1995). “*Competitiveness of US Agriculture and the Balance of Payments*,” Council for Agricultural Science and Technology, http,//www.cast-science.org/cast-science.lh/valu_is.htm

Chambers, R.G., and R.E. Just (1982). "*An Investigation of the Effects of Monetary Factors on U.S. Agriculture*." Journal of Monetary Economics, 9 (1982):235-247.

Clegg, J. (1987). "*Multinational enterprise and world competition.*" New York: St. Martin's Press.

Cockburn, J. (1998). "*Measuring Competitiveness and its Sources, the case of Mali's Manufacturing Sector,*" African Economic Policy Research Report Washington DC.

Cohen, J. I. (ed) (1999). "*Managing Agricultural Biotechnology: Addressing Research Program Needs and Policy Implications," Biotechnology in Agriculture Series*, Nº 23. Oxon, UK: CABI, Publishing in association with The International Service for National Agricultural Research (ISNAR) 1999.

Colyer, D. and C. M. Jolly (2000).*"Findings and Implications."* In Competition in Agriculture, The United States in the World Market, edited by dale Colyer, P. Lynn Kennedy, William A. Amponash, StanleyM. Fletcher, and Curtis Jolly. Howorth Press, New York, 2000.

Colyer, D. and P. L. Kennedy (2000). *Introduction*. In Colyer, D, Kennedy P. L, Amponsah W.A., Fletcher S.M. and Jolly, C.M. (eds), Competition in agriculture: The United States in the world market. Food Products Press, New York: 1-9.

Craig, B. J., P. G. Pardey, and J. Roseboom (1997). "*International Productivity Patterns: Accounting for Input Quality, Infrastructure, and Research*." American Journal of Agricultural Economics79:1064 -1076.

Dahl, B. L. and W. William (2000). *"Grades/Classes of Hard Wheats Exported from North America: Analysis of Growth and Market Segments."* Review of Agricultural Economics 22 (1), 172-191.

Darr, T and G Gribbons (1985). "*How US Exports Are Faring in the World Wheat Market*." Monthly Labor Review.

de Vita, G. and A. Abbott (2004). "*The impact of exchange rate volatility on UK exports to EU countries*," *Scottish* Journal of Political Economy, Vol. 51, No. 1, Department of Agriculture website. ERS Briefing Room, www.ers.usda. gov/briefing /cotton/, accessed June 17, 2006.

Deaton, A. and J. Muellbauer (1980a). "*An almost ideal demand system*," *American Economic Review*, vol 70, no.3, pp.312-25.

Deaton, A. and J. Muellbauer (1983b). "*Economics and Consumer Behaviour*," Vail-Ballou Press, New York.

Dohlman, E., O. Schnepf, and L. Bolling (2003). *"Dynamics of Agricultural Competitiveness: Policy Lessons From Abroad."* USDA/ERS, April 2003.

Dosi, G., K. Pavitt and L. Soete (1990). "*The Economics of Technical Change and International Trade*," Harvester Wheatsheaf, London.

Echols, J. (2001). "*Statement before the U.S. Senate Agriculture Committee*," July 17, 2001. http://agriculture.senate.gov/Hearings/Hearings_2001/July_17__2001/717ech.htm

Eckert, R. D. and R. H. Leftwich (1987). "*The Price System and Resource Allocation*," Tenth edition, The Dryden Press, New York.

Ellis, F. (1998). "*Peasant Economics – Farm Household and agrarian development*," 2nd edition Cambridge: Cambridge University Press.

Enright, M ., A. Francés, and E. S. Saavedra (1996). "*Venezuela: The Challenge of Competitiveness,"* New York: St. Martin's Press, 1996.

ERS (2003). "Agricultural *baseline projections, summary of projections, 2003-2012*." http,//www.ers.usda.gov/Briefing/Baseline/sum03.htm

ERS, USDA[2] (2005). Foreign Agricultural Trade of the United States (FATUS). www.ers.usda.gov/Data/FATUS/ Updated regularly.

ERS, USDA[1] (2005). Farm Income and Costs: Farm Income Forecasts. http://www.ers.usda.gov/briefing/farmincome/data/va_t1.htm Updated regularly.

ERS (2003). "*Agricultural baseline projections: summary of projections, 2003-2012*." http://www.ers.usda.gov/Briefing/Baseline/sum03.htm

Evans, J.and R. Berman (1997). "*Marketing, the seventh edition*," Prentice Hall Inc., New Jersey.

Fagerberg, J. (1988). *"International Competitiveness,"* Economic Journal 98, 355-374.

Fagerberg, J. (1997). *"Competitiveness, scale and R&D,"* in Fagerberg, J., Hansson, P., Lundberg, L. and Melchior, A. (eds.), Technology and International Trade, Edward Elgar, Cheltenham, pp. 38-54.

Falck-Zepeda, J.B., G. Traxler and R.G. Nelson (2000). "*Surplus Distribution from the Introduction of a Biotechnology Innovation*," American Journal of Agricultural Economics, 82(2), 360-69.

FAS, USDA (2003). “*Trade Is Important to US Agriculture*,” US Proposal for Global Agricultural Trade Reform. FAS online, http,//www.fas.usda.gov

Feenstra, R. (2004). “*Advanced International Trade: Theory and Evidence*,” Princeton University Press.

Food and Agriculture Organization (FAO) (1999). “*Biotechnology developments and their potential impact on trade in cereals,”* Joint Session of the 28th session of the Intergovernmental Group on Grains and the 39th session of the Intergovernmental Group on Rice. FAO - Committee on Commodity Problems, Rome, 22 - 24 September 1999.

Food and Agriculture Organization (FAO) (2003). “*Financing Normal Levels of Commercial Imports of Basic Foodstuffs in the context of the Marrakesh Decision on least-developed and net food-importing developing countries*,” Commodity Policy and Projections Service Commodities and Trade Division, The United Nations, Rome, 2003.

Frisvold, G., R. Tronstad, and J. Mortensen (2000). “*Effects of Bt Cotton Adoption: Regional Differences and Commodity Program Effects*,” Western Agricultural Economics Association Meeting. Vancouver, Canada.

Gallacher, M. (1999). "*Human Capital and Production Efficiency: Argentine Agriculture*," CEMA Working Papers 158, Universidad del CEMA.

Ghoshray, A., T.A. Lloyd, and A.J. Rayner (2000). “*EU Wheat Prices and Its Relation with Other Major Wheat Export Prices*,” School of Economic Discussion Paper, University of Nottingham no.00/8.

Giles, F., K. Seifarth, and S. Ibrahim (2006). "*Egypt Grain and Feed*", USDA Foreign Agricultural Service, Global Agriculture Information Network (GAIN) Report EG6007, 3/8/2006. http://www.fas.usda.gov/gainfiles/200603/146187048.pdf

Gopinath, M. and P.L. Kennedy (2000). “*Agricultural trade and productivity growth: a state-level analysis*,” American Journal of Agricultural Economics, Vol. 82, No. 5, pp.1213–1218.

Gopinath, M. and T.L. Roe (1997). “*Sources of Sectoral Growth in an Economy Wide Context: The Case of U.S. Agriculture*,” Journal of Productivity Analysis 8(3):293-310

Gopinath, M. and T. L. Roe (2000). *“The competitiveness of US Agriculture,”* In Competition in Agriculture, The United States in the World Market, edited by dale Colyer, P. Lynn Kennedy, William A. Amponash, StanleyM. Fletcher, and Curtis Jolly. Howorth Press, New York, 2000.

Gopinath, M., T. L. Roe, and M.D. Shane (1996). *“Competitiveness of US food Processing: Benefits from primary agriculture,”* American Journal of agricultural Economics 78(4); 1044-1055.

Gorton, M. and S. Davidova (2001). *"The International Competitiveness of CEEC agriculture,"* Paper presented to the British Association of Slavonic and East European Studies (BASESS) Conference, Cambridge, 7th-9th April 2001.

Green, R. and J.M. Alston (1990). "*Elasticities in AIDS models*," American Journal of Agricultural Economics, 72: 442-445.

Grigsby, S.E., and C.A. Arnade (1986). "*The Effect of Exchange Rate Distortions on Grain Export Markets, The Case of Argentina*." American Journal of Agricultural Economics 68(May 1986):434-440.

Grossman, G. and E. Helpman (1991). "*Innovation and Growth in the Global Economy*, " Cambridge: MIT Press, chapters 6-10.

Hahn, W. F. (1994). "*Elasticities in AIDS Models: Comment*," American Journal of Agricultural Economics, Vol. 76, No. 4 (Nov., 1994), pp. 972-977.

Harrigan, J. (1995). "*Factor Endowments & The International Location of Production: Econometric Evidence for the OECD, 1970-1985*," The Journal of International Economics, v. 39 no. 1/2 (August): 123-141.

Harrison, R. W. and P. L. Kennedy (1999). *"Trade, Technology, and Competitiveness: A Comparison of the European Union and United States Sugar Sectors,"* Paper presented June 13, 1999 at the IAMA Agribusiness Forum in Florence, Italy.

Hayami, Y. and V.W. Ruttan (1985). "*Agricultutal development, an international persepective*," Baltimore, USA. The John Hopkins University Press.

Heboyan, V. and V. W. House (2003). "*Biotechnology for Competitive and Sustainable Agriculture for Economies in Transition: The Case of Armenia,"* 7th International ICABR Conference Ravello, Italy, June 29, 30 - July 1, 2 and 3, 2003.

Huang, J., R. H. H. Meijl, and F. Tongeren (2004). "*Biotechnology boosts to crop productivity in China: trade and welfare implications*," Journal of Development Economics 75:27–54.

Hughes, K.S. (1992). *"Technology and International Competitiveness,"* International Review of Applied Economics 6(2): 166-183.

Ismael, Y. and R. Bennett (2005). *"The Potential Benefits of Agricultural Biotechnology and the Problems of European Attitudes to Biotechnology for the Economies of Small Island Developing States,"* The World Forum on Small Island Developing States held at the University of Mauritius in Reduit.

James, C. (2004). "*Preview: Global Status of Commercialized Biotech/GM Crops: 2004,"* ISAAA Briefs No. 32. ISAAA: Ithaca, NY.

Jolly, C. M., S. Fletcher, L. Kennedy, and W. Amponsah (2000). *"International Market Forces and Southern Agriculture,"* In Competition in Agriculture, The United States in the World Market, edited by dale Colyer, P. Lynn Kennedy, William A. Amponash, StanleyM. Fletcher, and Curtis Jolly. Howorth Press, New York, 2000.

Jolly, C., K. Jefferson-Moore, and G. Traxler (2005). "*Consequences of Biotechnology Policy for Competitiveness and Trade of Southern U.S. Agriculture,"* Journal of Agricultural and Applied Economics, 37, 393-407.

Jones, R. (1965). "*The structure of simple general equilibrium models*," *Journal of Political Economy*, vol. 73, no. 6, pp. 557-572.

Kalaitzandonakes, N. (2000). "*Agrobiotechnology and competitiveness,"* American Agricultural Economics Association 82(5): 1224-1233.

Kannapiran, C. A. and E. M. Fleming (1999). *"Competitiveness and Comparative Advantage of Tree Crop Smallholdings in Papua New Guine,"* Working Paper Series in Agricultural and Resource Economics, 1999.

Kao, C. and M-H. Chiang (1998). "*On the Estimation and Inference of a Cointegrated Regression in Panel Data,"* Working Paper, Center for Policy Research, Syracuse University.

Kherallah, M. , H. Lofgren, P. Gruhn, and M.M. Reeder (2000). "*Wheat Policy Reform in Egypt*," IFPRI Research Report 115, IFPRI, Washington D.C.

Klitgaard, T. and J. Orr (1998). "Evaluating Price Competitiveness of US Exports," *Current Issues in Economics ad Finance.* 4: 1-6.

Kol, J. and L.B.M. Mennes (1985). "*Intra-industry specialization: Some observations on concepts and measurement*", International Journal of Economics, Vol. 21, pp. 173-181.

Krueger, A.O. (1970). "*Technological factors in the composition and Direction of Israel's Industrial Exports,"* Comment. In The technology factor in international trade. A conference of the Universities-National Bureau of Economic Research (1970).

Krugman, P. (1994).*" Competitiveness: A Dangerous Obsession,"* Foreign Affairs, 73 (1994).

Larson, D.F. and T. Akiyama (2004). "*Rural Development and Agricultural Growth in Indonesia, the Philippines and Thailand*," Asia Pacific Press.

Laursen, K. (1998). *"Revealed Comparative Advantage and the Alternatives as Measures of International Specialisation,"* Danish Research Unit for Industrial Dynamics (DRUID)Working Paper No. 98-30.

Laursen, K. (1999*). "The Impact of Technological Opportunity on the Dynamics of Trade Performance."* Structural Change and Economic Dynamics, Vol 10 (3-4).

Leon-Ledesma, M. (2002). "*R&D Spillovers and export performance: evidence from the OECD Countries*," in J.R. Faria and A. Levi (eds.), Economic Growth, Inequality and Migration, Edward Elgar, 2002.

Levins, R. A. (2000). "*A New Generation of Power*," Choices, Second Quarter: 43-46.

Magnier, A. and J. Toujas-Bernate (1994). " *Technology and Trade: Empirical Evidence for the Major Five Industrialized Countries*," Weltwirtshaftliches Archiv 131, 494-520.

Masters, W.A. and A. Winter-Nelson (1995). *"Measuring Comparative Advantage of Agricultural Activities: Domestic Resource Costs and the Social Cost-Benefit Ratio,"* American Journal of Agricultural Economics, Vol. 77, pp. 243-250.

Meyer, L. and S. MacDonald (2006). *Cotton*. US Department of Agriculture website. ERS Briefing Room, www.ers.usda. gov/briefing /cotton/, accessed June 17, 2006.

Michaely, M. (1962/67). "*Concentration in International Trade*, *Contributions to EconomicAnalysis*," Amsterdam, North-Holland Publishing Company.

Mitcher, E. (1968). "*Explaining the international patterns of labor productivity and wages: A production model with two labor inputs*," Review of Economics and Statistics, 50, 461-469.

Montobbio, F. (2003). *"Sectoral patterns of technological activity and export market share dynamics,"* Cambridge Journal of Economics, 27 (4)523-545.

Moreno, L. (1997). "*The Determinants of Spanish Industrial Exports to the European Union*," Applied Economics, 29: 723-32.

Moschini, G. (1995). "*Units of measurement and the Stone index in demand system*," American Journal of Agricultural Economics*,* 77: 63-68.

Nielsen, C. P. and K. Anderson (2001). "*Genetically Modified Foods, Trade, and Developing Countries: Is Golden Rice Special?"* Paper prepared for, Evaluating the Impact of Genetically Engineered Food on the Health and Economy of Rural Populations, University of Michigan, November 12, 2001.

OECD (1999). "*Modern Biotechnology and Agricultural Markets: A Discussion of Selected Issues and the Impact on Supply and Markets," Directorate* for Food, Agriculture and Fisheries. Committee for Agriculture. AGR/CA/APM/CFS/MD (2000)2, Paris: OECD.

Pagoulatos, E. (2003). *"A consumer-oriented agriculture for the 21st century,"* Paper Presented at the Global Markets for High-Value Food Workshop, United States Department of Agriculture, Washington, DC, February 14, 2003.

Parker, J. and S. Shapori (1993). "*Determinants of Wheat Import Demand: Egypt,"* U.S. Department of Agriculture, Economic Research Service, Agriculture Economic Staff Report No. 9321.

Pick, D.H. (1990). *"Exchange Rate Risk and US Agricultural Trade Flows,"* American Journal of Agricultural Economics. 72:694-700.

Porter, E.M. (1990). *" The Competitive Advantage of Nations," New* York 1990.

Posner, M. (1961). "*International Trade and Technical Change," Oxford Economic Papers*, 13, pp. 323-341.

Prestemon, J.P. and R.C. Abt (2002). "*Timber Products Supply and Demand*," Ch. 13 in Southern Forest Resource Assessment, eds. D.N Wear and J.G. Greis. USDA/Forest Service, Southern Forest Research Station, Asheville, NC, Sept. 2002, pp. 299-325.

Regmi, A. and G. Pompelli (2002). "U.S. Food Sector Linked to Global Consumers." *Food Review: The Magazine of Food Economics*, U.S. Department of Agriculture, Economic Research Service, 25(1): 39-44.

Roe, T. L. (2000). "Competitiveness of U.S. Agriculture: Concepts, Issues, and Policy: Discussion." *American Journal of Agricultural Economics*, Vol. 82, No. 5, Proceedings Issue (Dec., 2000), pp. 1234-1237

Rosen, S., ed. (1993). "*Agricultural policy reform: Issues and implications for Africa*," Foreign Agricultural Economic, Report No. 250. Washington, D.C.: United States Department of Agriculture.

Rosson, P., F. Adcock, and A. Hobbs (2001). *"Exchange Rate Impacts on US Agriculture and the Potential Role of Dollarization,"* A Study Provided for the American Farm Bureau Federation, July 16, 2001.

Scherer, F.M. (1992). "*International High-Technology Competition,"* Cambridge, MA: Harvard University Press.

Schimmelpfennig, D., J. Lewandrowski, J. Reilly, M. Tsigas, I. Parry, R. Darwin, Z. Li, R. Mendelsohn, and T. Mount (1994), *"Agricultural Biotechnology: An Economic Perspective,"* Agricultural Economic Report No. 687. 64 pp

Schott, K. (1978). "*'The Relation Between Industrial Research and Development and Factor Demands,*" Economic Journal, Vol. 88 No. 349.

Schuh, G.E. and M. I. Angeli-Schuh (1989). "*Human capital for agricultural development in Latin America.*" San José. 1989. Technology Generation and Transfer. Program papers series, no.11. 39p.

Schweikhardt, D. B. (2000). *"Reconsidering the Farm Problem under An Industrialization Agricultural Sector,"* Department of Agricultural Economics, Michigan State University, Staff Paper #00-15.

Shane, M.D. (1990). *"Exchange Rates and U. S. Agricultural Trade," USDA/ERS,* Agriculture Information Bulletin No 585.

Soete, L. (1987). "The Impact of Technological Innovation on International Trade Patterns: the Evidence Reconsidered," *Research Policy*, 16, pp. 101-130.

Stanovnik P. (2000). "*Measuring the competitiveness of national economies with an emphasis on Slovenia,*" Working paper, No. 6, Institute for Economic Research, 2000.

Stock, J.H. and M.W. Watson (1993). 'A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems.' *Econometrica*, 61, pp. 783-820.

Swann, P. and M. Taghavi (1992). *"Measuring Price and Quality Competitiveness: A Study of 18 British Product Markets,"* Avebury Press, Aldershot.

Takayama, A (1982). On theorems of general competitive equilibrium of production and trade – A survey of some recent developments in the theory of international trade. *Keio Economic Studies* 19, 1-38.

Thompson, H. L. (1994). "*An Investigation into the Quantitative properties of the Specific Factors Model of International Trade*," Japan and the World Economy, pp. 375-388.

Thompson, H. (2000). *"International Economics:Global Markets and International Competition."* World Scientific Publishing, November 2000.

Thompson, H. L and H. Toledo (2001). "*Bolivia with South American Free Trade*," The International Trade Journal, pp. 113-126.

Toledo, H. (2003). "*Workers and Trade Liberalization: Simulating the Potential Impact of the Free Trade Agreement of the Americas on Venezuela's Output and Wages,*" European Trade Study Group ETSG2003 Programme Madrid, 11-13 September 2003.

Traxler, G. (2004). "*Economic impacts of biotechnology-based technological innovations*," ESA Working Paper, forthcoming. Rome, FAO.

Trefler, D. (1993). "*International Factor Price Differences: Leontief Was Right!*," Journal of Political Economy 101, 961-987.

Trefler, D. (1995). "The *Case of the Missing Trade and Other Mysteries*," American Economic Review 85, 1029-1046

Tsakok, I. (1990). *Agricultural Price Policy: A Practitioner's Guide to Partial-Equilibrium Analysis* (Ithaca: Cornell University Press).

Tweeten, L. (1992). *"Agricultural Trade."* Boulder.

U.S. Department of Agriculture, Economic Research Service, Wheat Situation and Outlook Yearbook Summary, March 28, 2006.

U.S. Department of Agriculture, Economic Research Service. Wheat Situation and Outlook Yearbook, March, 2004.

U.S. Wheat Associates (2006). What happened to Egypt? USwheat.org accessed October 10th, 2006. http://www.uswheat.org

UNCTAD (2006). "*Cotton - Market information in the commodities area*," United Nations Conference on Trade and Development (UNCTAD), June 2006.

UNCTD (2002). *"Transfer of technology for successful integration in the global economy: A note on methodology for case studies,"* April, 2002

US Department of Agriculture, Economic Research Service (2006), "*Wheat Situation and Outlook Yearbook Summary*," March 28, 2006.

USDA (2006). "*Cotton World Markets and Trade*," USDA/FAS, June 2006.

USDA (2006). "*Outlook for US Agricultural Trade*," AES-50 May 24, 2006.

Vollrath, T.L. (1987). "*Revealed Competitive Advantage for Wheat,"* Economic Research Service Staff Report No.AGES861030 (US Department of Agriculture: Washington DC.

Vollrath, T.L. (1989). "*Competitiveness and Protection in World Agriculture,*" Agricultural Information Bulletin No. 567, Economic Research Service (US Department of Agriculture: Washington DC).

Webster, A. and M. Gilroy (1995). "*Labour Skills and the UK's Comparative Advantage with its European Union Partners*," Applied Economics, Vol. 27, pp. 327-342.

Wiebe, K. D., M. J. Soule and D. E. Schimmelpfennig (1998). "*Agricultural Productivity for Sustainable Food Security in Sub-Saharan Africa*." In Food Security Assessment GFA-10, Economic Research Service, Washington DC.

Wilson, W. (1989). "Differentiation and Implicit Prices in Export Wheat Markets," *Western Journal of Agricultural Economics* 14:67-77.

Wilson, W. (1994). "Demand for Wheat Classes by Pacific Rim Countries," *Journal of Agricultural and Resource Economics*, July 1994.

Wilson, W. and P. Gallagher (1990). "Quality Differences and Price Responsiveness of Wheat Class Demands," *Western Journal of Agricultural Economics* 15(2):254-264.

Wisner, R.N and C. P. Baumel (2004). "*Ethanol, exports and livestock: will there be enough corn to supply future needs?*" Feedstuffs 76:30, 1, 20-22, Miller Publishing Co, 2004.

Wolff, E. (1997). *"Productivity Growth and Shifting Comparative Advantage on the industry level,"* in Fagerberg, J. et al. Technology and International Trade, Edward Elgar, Cheltenham.

Yee, J., W.E. Huffman, M. Ahearn, and D. Newton (2002). "*Sources of Agricultural Productivity Growth at the State Level, 1960-1993*," in V.E. Ball and G.W. Norton, Eds., *Agricultural Productivity: Measurement and Sources of Growth*. Boston, MA: Kluwer Academic Publication, 2002, pp. 185-210.