Product Differentiation and Trade in Agri-Food Products: Taking Stock and Looking Forward

by

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INTRODUCTION:

In determining comparative advantage and gains from trade, traditional trade models focused primarily on the production side of the economy. While the oversimplification of the consumption side allowed trade theorists to derive a set of simple but powerful predictions about why countries engage in specialization and trade, the consequences of overly simplified trade models have been brought to the forefront since the 1970s.

The theory of comparative advantage developed by David Ricardo at the beginning of the 19th Century has played an important role in shaping modern thinking about trade. Ricardian trade model assumes that labor is the only input used in a fixed proportion to produce an output in each country. It predicts that a country will export products in which it has higher labor productivity relative to its labor productivity in other products (i.e., it has a comparative advantage). Except for a few early attempts such McDougall (1952) and Stern (1962), there is hardly any empirical study of trade flows that rely exclusively on the Ricardian trade model. This is perhaps due to its exclusive focus on labor productivity and neglect of the contributions of other factors of production as well as its inability to explain what causes labor productivity to vary across countries. However, despite its empirical weaknesses, the Ricardian model remains useful for thinking about the effects of technological changes on specialization, patterns of trade and the distribution of trade benefits (Davis 1995, Eaton and Kortum 1997).

The framework of trade proposed by Heckscher (1919) and Ohlin (1924) departs from the Ricardian model in that it emphasizes the roles of land, labor and capital in both agricultural and industrial production and attempts to explain how variations in the availability of these factors of production determine a country's nature of specialization and patterns of trade. Paul Samuelson added elegance to this framework by developing a two-factor, two-sector and two-country version of the Heckscher-Ohlin model that became the cornerstone of modern theory of international trade. According to the Heckscher-Ohlin-Samuelson theory of trade, a country should specialize in and export a product that uses more intensively the factor of production with which the country is well endowed. Therefore, a capital-rich country like the United States should export the capital-intensive products while a labor-rich country like Bangladesh should export various labor-intensive products. While this theory offers a more logical way to think about trade among nations than the Ricardian approach, it too exclusively focuses on the supply side of the economy and suggests that differences in factor endowments can explain specialization patterns and the volume of trade between countries. The demand side is muted through the assumptions of *identical and homothetic preferences* of consumers and that countries trade in *homogeneous products*. The refinement of the H-O-S trade model continues along with the development of empirical implications of the factor content of net trade flows (Helpman 1999).

While the assumption that international trade takes place in *homogeneous* goods is an important element of the H-O-S trade model, it is quite restrictive in view of the fact that as countries progress economically wide varieties of new products emerge on the market and old products disappear over time. While some countries produce the new products first, other countries end up producing them after a time lag and in some cases, with minor modifications. As a result, many countries, particularly, in the developed world engage in trade of mostly differentiated products and less so in homogeneous products. A casual observation would reveal that many products traded among countries today are differentiated by brand such as computers, medical equipments, breakfast cereals, baby formulas, toothpaste, clothing etc. Moreover, it was observed during the 1960s and 1970s in the European Economic Community that large volumes of trade flow between members of the EEC with similar factor endowments and that within some industries, trade overlap exists. The latter, in fact, has grown significantly over time in the EU. According to the H-O-S model of trade, such overlaps should not exist. The existence and growth of trade overlaps in certain industries suggest that a considerable share of trade among developed countries may not be driven by differences in factor endowments as predicted by the H-O-S model. Note that trade among developed OECD countries account for more that 50% of total merchandise trade flows while about 30% of total trade flows between developed and developing countries. The bulk of trade between developed and developing countries consists of inter-industry trade while trade among developed countries consists mostly of intra-industry trade (IIT). The first comprehensive measurement of the extent of trade overlap by Grubel and Lloyed (1975) attracted considerable research interests in this area (Greenway et a. 1995). The results from these studies cast serious doubt on the relevance of the H-O-S model of trade and may have provided impetus for the development of the "New Trade Theory" by Helpman and Krugman in the 1980s. Product differentiation is at the centre of the "New Trade Theory" which attempts to explain the prevalence of intra-industry trade that currently dominates bulk of commodity trade among the OECD countries.

While the treatment of an agricultural commodity such as wheat, rice, beef, wool, cheese, maize and wine as a homogeneous good appears to be reasonable in theory, in practice differences in production practices, seeds, geographical locations of production, sanitary and phyto-sanitary measures and food safety requirements make the quality of these commodities (at least, as they are perceived by consumers) different. Moreover, the processed agri-food commodities have become the most important type of agricultural commodities traded internationally, particularly among developed OECD countries. The processed agri-food commodities vary considerably in terms of their factor contents, quality attributes and marketing features. Thus, differences in brand, quality and other aspects of heterogeneity make these products differentiated in international trade. Since the pioneering attempt by Armington (1969) to model trade in agricultural products differentiated by the country of origin, a number of researchers used this model to explain trade in major agri-food commodities (Thursby et al. 1986, Goddard 1988, Alston et al. 1990). While the Armington's approach to model trade in agricultural product differentiated by country of origin is the first attempt to relax the assumption of homogeneous good in international trade, it implicitly imposes a set of rather untenable restrictions such as: (i) import shares respond only to changes in relative prices and not to changes in income, and (ii) that the income elasticities of demand for imports of the good from all sources are equal to one. It has also been demonstrated that empirical data do not support either the homotheticity or the separability assumptions often maintained in Armington's framework (Slesnick 1998, Alston et al. 1990). Furthermore, the nature of product differentiation entertained in an Armington model is not related to variations in product quality and hence can be considered exogenous to consumers' decision calculus related to their *'love for variety'* or quality as argued by Lancaster (1979). Nevertheless, this approach has been quite popular among agricultural economists for last three decades.

The most prominent forms of product differentiation in international trade in recent years have been horizontal and vertical product differentiations which are related to differences in product attributes and quality not just perceived by consumers but also due to differences in factor contents in each product. While significant progress has been made during the 1980s in terms of developing the theoretical framework to guide empirical research aimed at explaining intra-industry trade, the progress in applying these models in international trade in agri-food products has been slow. The purpose of this paper is to provide a survey of the literature on product differentiation and international trade in agricultural products, critically assess what has been done, how and why. It is hoped that such a synthesis will open up new avenues for stimulating analytical and empirical research in this area.

The paper proceeds as follows. Section two deals with the theoretical framework relevant for intra-industry trade and highlight major developments since the 1990s. Section three concentrates on how intra-industry trade is classified and measured. This section also highlights some of the challenges researchers face in measuring intra-industry trade in agri-food products. Section four is devoted to gain a better understanding of the determinants of intra-industry trade in agri-food products. This section focuses on econometric studies and highlights some of the modeling challenges faced by empirical researchers in this area. Section five concentrates on how various product differentiation models have been applied to agri-food trade during last fifteen years. Despite the dominance of national product differentiation models during this period, other types of product differentiation models emerged since the 1980s and have been employed to analyze various agricultural trade policies. Due emphasis is given to the new type of product differentiation models in this section. Issues to be considered for future modeling endeavors in this area are discussed in Section six. The final section concludes the paper.

TRADE THEORY AND INTRA-INDUSTRY TRADE

As indicated earlier, neither the Ricardian model nor the H-O-S model of trade is adequate to explain extensive intra-industry trade. Indeed, the development of various indices to measure the extent of intra-industry trade predates the development of a relevant trade theory and many early attempts tried to identify some patterns of trade overlaps. For example, Loertscher and Wolton (1980) found that the share of intra-industry is high when the trading partners are highly developed and at comparable level of development. They also noted that the share of intra-industry is high when the trading partners are large and their sizes are similar. Also during the late 1970s, several IO theorists, particularly, Dixit and Stiglitz (1977) and Lancaster (1975) developed microeconomic foundations for the traditional Chamberlinian monopolistic competition and successfully embedded monopolistic competition in differentiated products in general equilibrium models. While these models relied on restrictive assumptions about tastes and technology, they offered fresh and innovative ways to think about trade based on economies of scale rather than on comparative advantage, factor endowments and factor intensity (Krugman 1995). Thanks to the contributions of Dixit and Stiglitz (1977) and

Lancaster (1975), the theoretical literature on product differentiation, imperfect competition and intra-industry trade grew rapidly in the early 1980s through the works of Krugman (1979, 1980), Helpman (1981), Lancaster (1980), Shaked and Sutton (1984), Brander (1981) and Brander and Krugman (1983). At the early stage of development, various trade models with monopolistic competition appeared to be inconsistent with the H-O-S model of trade and also with each other. However, by thinking in terms of an integrated-economy approach, it is possible to embed trade in differentiated products within a factor proportions model. Thus, the H-O-S trade model and the "New Trade Theory" are complementary in nature; inter-industry trade results from factor endowments and specialization while the intra-industry trade can be explained by product differentiation and scale economies. This is the essence of the remarkable synthesis advanced in Helpman and Krugman (1985). It is no surprise that even after two decades, Helpman and Krugman (1985) remains the most influential text for the "New Trade Theory". What follows next is a non-technical elaboration of this theory and the testable predictions it generates.

The integrative view of international trade developed by Helpman and Krugman (1985) relaxes the neoclassical assumptions of homogeneous products, constant returns to scale and perfect competition and allows for an interplay among economies of scale, product differentiation and factor proportions by embracing Chamberlinian monopolistic competition in trade. Since many intermediate and final consumer goods are differentiated by brand or by other means, to explain extensive intra-industry trade, Helpman and Krugman (1985) introduced sectors with differentiated products into the trade theory and argued that product differentiation typically involves economies of scale. The prevalence of scale economies motivates firms in a country to produce differentiated products that enhance foreign trade. Furthermore, the existence of economies of scale motivates countries to invest in research and development so that new techniques of production can be developed and employed to exploit the benefits scale economies over time. Due to the benefits of learning-by-doing or of prudent investments in R&D, some companies in some countries will have access to certain technologies (note such technological races in the electronics and pharmaceutical industries which are not available to their rivals. As a result, a company developing a differentiated product gains some monopoly power because there is no perfect substitute for its unique brand in the market. Finally, the economies of scale limit the range of differentiated products that can be supported by the market. The smaller the economies of scale, the larger the number of profitable brands that become available on the market. This results in each country specializing in the production of some differentiated products and trading them with other countries. On the demand side, due to variations in income, tastes and preferences among its people, each country demands a wide variety of differentiated products. When trade takes place among these countries, brand-specific economies of scale lead to *intra-industry* trade. Helpman and Krugman (1985) also demonstrated that economies of scale, product differentiation and various forms of competition are compatible with factor price equalization and with the factor content of trade.

Since, the vast majority of empirical research in intra-industry trade, either in agri-food or in manufacturing sectors, is based on this theory, it is important to bring out the key predictions of this theory. The key predictions generated by Helpman and Krugman (1985) trade theory are as follows:

• The share of *intra-industry* trade is larger between two countries that are similar in composition of factor endowments and in size. In a generalized framework with multi-country trade, this theory suggests that relatively more intra-industry trade will take place between a pair of countries with similar factor compositions than between a pair of countries with dissimilar factor compositions. The difference in factor composition across countries can be measured by cross-country differences in income per capita. Therefore, the most important testable hypothesis in this case is that "*the share of intra-industry trade in bilateral trade flows is larger for countries with similar per capita income*". It is also possible to develop another hypothesis related to relative sizes of trading partners and the share of intra-industry trade in bilateral trade flows. These hypotheses are related to the composition of bilateral trade flows.

• Economies of scale and product differentiation drive firms and countries to specialize and specialization encourages larger volumes of international trade. Assuming that consumers in all countries have identical homothetic preferences for traded goods and trade is balanced, spending levels on each good are proportional to GDP levels. Thus, it implies that *a given percentage increase in the GDP of a country will expand its trade volume with another country by the same amount*. This idea is also at the heart of a "Gravity Equation" which has a long and rich history in empirical analysis of trade flows between countries and has been a workhorse in empirical trade studies for almost half a century (see Timbergen 1962; Linnemann 1966; Anderson 1979; Bergstrand 1985 & 1989; Deardorff 1998; Baier and Bergstrand 2001; Anderson and Wincoop 2003; Feenstra 2002 & 2004).

• Finally, for a group of countries, the share of intra-industry trade in the within-group trade volume should be larger when within-group dispersion of per capita income (proxy for factor composition) is smaller. This hypothesis deals with the composition of within-group trade flows.

Although there has been no major development in trade theory during the last two decades following the publication of Helpman and Krugman (1985), a number of authors made attempts to test the hypotheses from the new trade theory using different data sets. In addition to examining the consistency of the above hypotheses with data, these studies also develop insightful empirical implications of the new trade theory. It is useful to recap the findings in this literature before examining how the theory has been applied to explain trade flows in agri-food commodities.

Since empirical measurement of the extent of intra-industry trade predates formal articulation of the new trade theory by Helpman and Krugman (1985), many early attempts deal with elaboration and explanation of trade-overlaps rather than rigorous testing of any theoretical prediction. Of many attempts to empirically examine intra-industry trade since 1985, Helpman (1987) is particularly noteworthy. Drawing on Helpman and Krugman (1985), Helpman (1987) developed two simple models of monopolistic competition, which yield three testable hypotheses. He used data on trade flows for 14 OECD countries from 1956 to 1981 to investigate the consistency of theoretical predictions with data. Helpman used the absolute difference in GDP per capita to capture the differences in the composition of factor endowments and the level of each country's GDP to measure the size variable. Using graphs and simple regression analysis, Helpman found that the extent of intra-industry trade was larger the more similar were the income per capita in trading nations. He also found that the size of a smaller country had a positive effect while that of a larger country had a negative effect on the share of intra-industry trade among the OECD countries in his sample. Finally, he used the ratio of the standard deviation of income per capita to its mean (dispersion index) to examine the relationship between the within-group share of intra-industry trade and the degree on dispersion in per capita income. Based on a scattered plot of 26 data points (and not a standard hypothesis test), he observed that they are negatively correlated. Based on these results, Helpman (1987) argued that empirical results are more consistent with the predictions of the new trade theory in which scale economies and product differentiation drive specialization in production and trade than they are with factor endowments based explanations.

Hummels and Levinsohn (1995) reexamined Helpman's (1987) evidence employing different data sets and rigorous econometric analysis. Starting with a simple model in which all trade take place in differentiated products produced by countries employing increasing returns to scale technologies and consumers in all trading nations have identical homothetic preference, Hummels and Levinsohn were able reproduce Helpman's (1987) result. They used OECD data from 1962-83 and treated each country-pair in each year as an observation to generate a sample of 2002 observations and estimated a gravity equation with fixed and random effects (with and without detrending). They found that even after controlling for deterministic trends in data and country-pair fixed effects, about 98 percent of the variation in trade volume is explained by the model and Helpman's size dispersion index was highly significant. Therefore, the results strongly support one of the predictions of the new trade theory and corroborate the findings of Helpman (1987). To test the robustness of these results, Hummels and Levinsohn then set out to develop a counter factual, arguing that if product differentiation is the main reason for the remarkable fit, the equation should not perform well in a mixed sample of developed and developing countries since trade between these countries are based more on differences in factor endowments (i.e., inter-industry) and less on similar but differentiated products (i.e., intra-industry). While the model did not fit as well when they applied it to a group of developed and developing countries, as it did in the OECD sample (the goodness-of-fit declined from 0.98 to 0.67), it was nevertheless significant. Hummels and Levinsohn also demonstrated that Helpman's (1987) results continue to hold if one uses income per worker or absolute differences in capital-labor ratios or land-labor ratios instead of using differences in per capita income to capture differences in factor endowments. However, when they introduced country-pair dummy variables into the equation, these dummies could explain most of the variation in the share of intra-industry trade. This finding implies that unspecified characteristics of country-pairs explain intra-industry trade more than the variables emphasized by the new trade theory. They conclude that the evidence does not support the view that product differentiation with scale economies is the main reason why intra-industry trade flows have grown among countries with similar sizes and that the theory needs refinement to better fit the data.

Durkin and Krygier (2000) employed the method developed by Greenway et al. (1994) to examine the relationship between differences in per capita income and the share of intra-industry trade in bilateral trade flows. They used 5-digit SITC data on bilateral trade flows for 20 OECD countries from 1989 to 1992. They distinguished between horizontally and vertically differentiated trade and found that about 70% of the US intra-industry trade with other OECD countries is vertically differentiated and that variation in income distribution has a significant effect on vertically differentiated products trade but not on trade of horizontally differentiated goods. Thus, for vertically differentiated goods, difference in per capita income has a positive effect on the share of intra-industry trade while for horizontally differentiated goods the relationship is negative. This finding calls into question some of the results from studies not differentiating trade in vertically and horizontally differentiated products.

While it is well known that the gravity equation performs well in explaining variation in bilateral trade flows, there is little agreement in the literature about which theory or theories, the H-O-S trade model or the new trade theory can account for its empirical success. Evenett and Keller (2002) made an attempt to address this issue. Since both theories can predict the gravity equation, Evenett and Keller developed an estimation procedure to discriminate between two models and determine in a transparent manner whether product differentiation with increasing returns to scale or differences in factor endowments can explain the relationships between trade volumes and the size distributions of trading countries. They used a data set consisting of 58 countries that include almost all developed countries and a few developing countries with GDPs above $1.0 billion US in 1985. They divided 2,870 observations of country-pairs with positive amounts of trade into two sub-samples; one group that have less than 5 percent of intra-industry trade measured by the Grubel-Lloyd index (a total of 2240 observations) and the other group having more than 5 percent intra-industry trade (a total of 630 observations). They assumed that countries in the first group trade homogeneous goods while those in the second group trade in differentiated products. The results of their empirical investigation show that the size of the differentiated goods sector and the share of intra-industry trade move together which implies that scale economies and product differentiation are important in explaining the volume of bilateral trade among developed countries. For the first group of countries they did not find evidence to support the hypothesis that differences in factor endowments between countries drive specialization and trade among them. While these findings support the view that product differentiation and increasing returns to scale are empirically relevant factors in helping to explain changes in trade volumes, they do not represent full endorsement of the new trade theory for two reasons. First, data for the first group of countries appear to contain noise that might have tainted the results. Second, there is little support for trade models that predicts perfect specialization. Moreover, trade between developing and developed countries are well explained by an imperfect specialization H-O-S model of trade in homogeneous goods. Taken together, these results highlight the importance of both relative factor endowments and increasing returns to scale as determinants of the extent of specialization and trade. Of course, the relative importance of the traditional and new trade theories depend on the particular sample in question.

The above finding resonates well with the results of Antweiler and Trefler (1997) who developed a methodology for estimating the size of returns to scale (very important for addressing a wide variety of welfare related questions) at the sectoral level from international data. They assembled a data set for 71 countries with 37 industries and 11 factors from 1972 to 1992. They looked at the factor content of exports and imports separately for each trade partner that essentially allows all countries to have different techniques of production. Then they compared these results to difference between total factors in an economy and factors used in domestic consumption. Based on their estimation, Antweiler and Trefler (1997) find that while a majority of the industries appear to be characterized by constant returns to scale, there is evidence for increasing returns to scale in a number of sectors. These results suggest the empirical relevance of both the H-O-S model of trade and trade based on increasing returns to scale and product differentiation.

Since specialization and trade can occur due to an Armington structure of demand (Anderson 1979; Bergstrand 1985), economies of scale and product differentiation (Helpman and Krugman 1985; Helpman 1987), technological differences (Davis 1995), and differences in factor endowments (Deardorf 1998), the gravity equation can be consistent with a wide range of trade theories. Grossman (1998) argued that specialization drives the gravity type model rather than the traditional or the new trade theory and Evenett, and Keller (2002) argued that specialization needed to not be complete to derive a gravity model of bilateral trade flows. Feenstra *et al.* (2001) show that a gravity model to explain intra-industry trade can be generated by a trade model with homogeneous goods if there is imperfect competition and the markets are segmented due to restricted entry (also known as the reciprocal dumping model of trade following Brander (1981); Brander and Krugman (1983); and Venables (1985)). Feenstra *et al.* (2001) used bilateral trade flows among 110 countries for five different years: 1970, 1975, 1980, 1985, and 1990 and a set of covariates such as GDP, distance, geographical contiguity, language, free trade agreement and remoteness to estimate their model. Following Rauch (1999), they divided their sample of 5-digit SITC products into three groups: homogeneous goods, differentiated goods and an in-between category and then estimated gravity equations for bilateral exports in each of the three groups. The results suggest that the elasticity of exports is significantly higher for differentiated products than for homogeneous goods. This is consistent with the predictions of the new trade theory. They also show that a *home market effect* whereby an increase in exporter's income has a more than proportionate effect on exports shows up in the results for differentiated goods. However, for the homogeneous goods, the home market effect is nonexistent and the empirical results are consistent with a reciprocal dumping model with entry barriers. Despite the differences in methodology, these results are broadly consistent with those of Evenett and Keller (2002) in that a gravity model is consistent with both increasing returns to scale and product differentiation and with a conventional H-O-S trade model and that empirical results are consistent with the predictions of both models when care is taken to classify trade flows before econometric estimation.

Debaere (2005) makes an attempt to test predictions from the new trade theory employing aggregate data on bilateral trade flows for 14 OECD and 14 non-OECD countries from 1970 to 1992 compiled by Feenstra *et al.* (1997). Using some of the recent developments in the gravity literature and panel estimation, he finds that for the 14 OECD countries, increased trade to GDP ratios are positively and statistically significantly related to their share in the world trade and to a similarity in size index. However, for the group of non-OECD countries, while trade to GDP ratios were positively related to the world economy, these were not related to their similarity in size index. Finally, contrary to the prediction of the new trade theory, all the estimated parameters were less than one. Thus, while the results for OECD countries lend empirical support to some of the predictions of the new trade theory, the non-OECD results are clearly at odds with the theoretical predictions and call into question the general applicability of the new trade theory.

The 25th anniversary issue of the *Brookings Papers on Economic Activity* has been devoted to international economic issues. In an influential article, *Growing World Trade: Causes and Consequences*, published in this issue, Krugman (1995) asked two fundamental questions: why has world trade grown and what are the consequences of that growth. Regarding the first question, he noted that while the journalistic discussions view the growth in world trade being driven by ever declining costs of transportation and communication due to improvements in technology, economists argue that much of the growth in world trade since World War II can be attributed to policy induced progress in tariff reductions which enhanced bilateral and multilateral trade liberalization. Therefore, the question remains disputed. In the spirit of Krugman's article, Feenstra (1998) suggest four possible factors contributing to the growth in world trade: (i) trade liberalization, (ii) falling transportation costs, (iii) convergence in economic sizes, increasing returns to scale and product differentiation, and (iv) increased outsourcing due to vertical specialization of multinational firms and disintegration of national production process both of which can cause intermediate goods to cross national borders multiple times. Baier and Bergstrand (2001) measure the relative contributions of reductions in transportation cost, trade liberalization, income convergence and income growth to the expansion of world trade in the post WWII period. Assuming that a consumer in each country maximizes a constant-elasticity-of-substitution (CES) utility function subject to a budget constraint where the prices of the imported products reflect "iceberg" transportation costs and *ad valorem* tariffs and a firm in each country maximizes profits subject to two technological constraints, Baier and Bergstrand developed a generalized gravity equation which incorporates tariff barriers, transportation costs and distribution costs explicitly and highlight the importance of output-expenditure constraints emphasized by Anderson (1979), market structure emphasized by Helpman and Krugman (1985) and distribution costs emphasized by Bergstrand (1985). It also incorporates the notion that larger markets will have relatively higher price and wage levels than smaller markets (Krugman 1980) explicitly into the gravity model. Using bilateral trade flow data for 16 OECD countries for 1958-60 and 1986-88 periods, they estimated a generalized gravity model and measured the relative contributions of income growth, income convergence, tariff reductions and declines in transportation cost. The results suggest that trade grew by about 148 percents between the 1960s and the 1980s and that about 67-69% of this growth could be attributed to growth in real GDP, 23-26% to tariff-rate reductions, 8-9% to transport cost declines and none to real GDP convergence. The results also suggest that exports are imperfectly substitutable across national markets, which are consistent with the findings of Engel and Rogers (1998) who noted that consumers markets are essentially national markets and that distribution efforts are organized nationally.

To recap, the developments since the 1990s suggest that there is limited empirical evidence to support all predictions of the new trade theory and that the theory needs to be broadened to explain trade flows among developing countries and between developed and developing countries. What follows next is a brief description of alternative indices used to measure intra-industry trade flows between countries.

INTRA-INDUSTRY TRADE: DEFINITION AND MEASUREMENT

The large volume of intra-industry trade particularly (IIT) among developed countries in the post WWII period is often cited as one of the key empirical reasons for developing the new trade theory based on increasing returns to scale, product differentiation and imperfect competition (Helpman and Krugman (1985,1989). Similarly, in a recent survey article, Leamer (1995) argued that the importance of intra-industry trade highlighted by Grubel and Lloyd (1975) is the most important finding since the Leontief Paradox that had a profound impact on the way economists think about international trade. It has been argued repeatedly by various authors that traditional trade theories neglect the role of economies of scale in trade and hence, cannot explain the large volume of trade in differentiated products between countries which are similar in factor endowments and technology (Lancaster 1980; Balassa and Bauwens 1988; Helpman and Krugman 1985). This section focuses on how intra-industry trade is defined and measured. It also deals with some of the challenging aspects of measuring IIT with available data.

According to Grubel and Lloyd (1975) intra-industry trade can be defined as the value of exports of an 'industry' which can be matched exactly by the value of imports of the same 'industry'. Clearly, the definition of an industry is very important in deriving intra-industry measure of trade. If there are 'n' industries in an economy so that i=1,2,…..,n and X_i is the aggregate value of exports of the ith industry and M_i is the aggregate value of imports of that industry, then intra-industry trade can be expressed as:

$$R_i = (X_i + M_i) - \left| X_i - M_i \right|$$

Note that the measure of inter-industry trade is $\left| X_i - M_i \right|$ which has been widely used in empirical studies of international trade prior to the recognition of intra-industry trade. Thus, intra-industry trade is simply the complement of inter-industry trade as specified in the above equation. The value of intra-industry trade can be normalized by dividing R_i by the total industry trade so that:

$$B_i = R_i / (X_i + M_i) = \{(X_i + M_i) - \left| X_i - M_i \right| \}/ (X_i + M_i) = 1 - \left| X_i - M_i \right| / (X_i + M_i)$$

This is the proportion of total trade that is intra-industry in nature. This is also known as the Grubel-Lloyd index of intra-industry trade which has been used by Helpman (1987), Helpman and Krugman (1989), Hummels and Levinsohn (1995) and many others studying international trade in differentiated products. The economy wide measure of intra-industry trade can be obtained as a weighted average of B_i for all n industries using the relative shares of total trade for each industry as weights.

Instead of matching the values of exports and imports in a particular industry, one could match the proportions of exports and imports in an industry. This would lead to an alternative measure of intra-industry trade. When it is weighted by the average share of the exports and imports of the industry in the total trade (exports plus imports), an alternative measure of economy wide intra-industry trade can be obtained (see Lloyd 2002 for details).

Note that this alternative is essentially a measure of the extent to which industry exports as a share of total exports match industry imports as a proportion of total imports. When the proportions of the volume of imports and export in this measure are replaced by their values, it becomes the Grubel-Lloyd index. This measure was developed and popularized by Finger and Kreinen (1979) and Kol and Mennes (1986). This index has been used to measure the similarity of distributions of exports by commodity and imports by commodity by Finger and Kreinen (1979). More recently, Glick and Rose (1998) used this index to measure the similarity of distribution of exports of two countries to a third country. Which measure is more appropriate for an empirical study? This depends on the purpose of the study. If, for example, the purpose of a study is to explain the nature of specialization and comparative advantage, the Grubel-Lloyd index is more suitable than others. If, however, the main purpose of a study is to measure the similarity between two industries, one needs to match the proportions of exports and imports and not the values.

While the Grubel-Lloyd index became the standard to measure intra-industry trade in empirical trade studies, the question of whether it should be adjusted to reflect persistent trade imbalance has perplexed empirical researchers. In the presence of trade imbalance, the Grubel-Lloyd index would be downward biased and it would capture both intra-industry trade and trade imbalance. Aquino (1978) demonstrated that the adjustment suggested by Grubel and Lloyd (1975) applies to aggregate trade and not to an industry or commodity level trade and he suggested an alternative equiproportionate adjustment in each industry. The adjustment proposed by Aquino was applied by Helpman (1987) and Hummels and Levinsohn (1995) but they could not find any perceptable differences in the results. Greenway and Milner (1981) argued that the Aquino adjustment is inappropriate because it focuses only on manufacturing trade and suggested that it may be best not to make an adjustment to the Grubel-Lloyd index. Similar view has also been expressed by Kol (1988). It should also be noted that all empirical trade studies so far deal with trade in goods only but not trade in services because comparable data for trade in services are not available. If comparable data for trade in services become available in the near future and trade in services is included in the analysis, it would reduce aggregate trade imbalance in goods and hence the importance of adjusting the Grubel-Lloyd index (Lloyd 2002). However, in an increasingly interdependent world of nations characterized by inter-country borrowing and lending trade imbalances may persist over many years even after accounting for trade in services. The literature is yet to focus on how such persistent national trade imbalance can be treated in the intra-industry trade analysis.

To enhance the usefulness of the G-L index for analyzing adjustment issues following a trade agreement, Hamilton and Kniest (1991) introduced a concept called 'marginal intra-industry trade' (MIIT) in which the proportion of the increase in imports and exports are matched rather than the share of exports and imports of total trade. This index will be equal to one when all additional trade is matched and zero when there is no matching at all. The view implicit in this formulation is that one needs to focus on changes in IIT rather than the level of IIT to evaluate the relationship between IIT and structural adjustment. However, as shown by Greenway et al. (1994), the MIIT suggested by Hamilton and Kniest (1991) can be defined only for non-negative values of changes in exports and imports. Moreover, the index is not scaled and it cannot tell us anything about the initial level of trade or the amount of new trade or even the value of production in the industry under investigation. These issues are very important for evaluating the consequences of structural adjustments originating from a free trade agreement.

The empirical anomaly reported by Hummels and Levinsohn (1995) questioned the adequacy of the Helpman and Krugman (1985) model to guide empirical analysis of IIT. This inspired researchers to further investigate the issues paying closer attention to identification, definition and choice of measurement indicators of relevant variables. Among other things, this led to the recognition of horizontal and vertical product differentiation and measurement and brought to the forefront some key issues relevant for modeling of vertical IIT and horizontal IIT. The contributions to the theoretical literature by Falvey (1981), Falvey and Kierzkowski (1987) and Falm and Helpman (1987) suggest that vertical IIT is determined by differences in relative factor endowments between trading partners. Note that this prediction is different than the predictions of the Helpman and Krugman (1985) trade model which focuses on horizontal IIT. More recent studies attempt to breakdown total IIT into horizontal IIT (HITT) and vertical IIT (VITT) and use different explanatory variables to investigate the extent of HITT and VITT and their determinants. The separation of total IIT is based on the assumption that quality is reflected in a product's price and that unit value of export or import can be used for assessing product quality in trade data (Abdel-Rahman 1991, Greenway et al. 1995, Stiglitz 1987). [1] In general, trade flows are considered horizontally differentiated if the spread in unit value of exports relative to the unit value of imports is less than 15% at the five-digit SITC level. When relative unit values are outside this range, the products are considered to be vertically differentiated. Since the determinants of vertical and horizontal IIT differ, empirical models using total IIT as the dependent variable are likely to misspecified. Therefore, disentangling vertical and horizontal IIT and use of appropriate econometric methods remain a fruitful area of research in IIT (Greenway and Tortensson 1997).

There are also some other unresolved issues related to the measurement of intra-industry trade. The first issue is called the categorical aggregation problem. Based on the Standard International Trade Classification (SITC), exports and imports are reported at different levels of aggregation (3 digits, four digits etc.). What is the most appropriate level of aggregation in the SITC classification of commodities traded? How to determine which industries are the sequential Dixit and Grossman type and how to aggregate different commodities into exports and imports of the same industry? It becomes even more complex when there is jointness in production and the products produced jointly are used to satisfy very different consumer demand. This phenomenon is particularly relevant for the agri-food sector. Finally, what are the effects of seasonality on trade and their implications for the measurement of intra-industry trade? While seasonality does not influence trade in manufacturing, it is likely to have a significant effect on trade in agri-food products. Notwithstanding these unresolved issues related to the measurement of intra-industry trade, the Grubel-Lloyd index has been routinely employed by trade researchers to study the existence, growing importance and drivers of intra-indutry trade involving agri-food products. The following section is devoted to this literature.

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[1] Note that the unit value approach has some limitations. First, the unit values of two bundles which differ in terms of the mix of goods can have different unit values which do not reflect differences in quality. Second, consumers can buy a more expensive product in the short run because of availability or other factors and not because of quality considerations. Despite these inadequacies, the unit values are widely used in empirical trade literature, particularly in IIT studies.

DETERMINANTS OF INTRA-INDUSTRY TRADE IN AGRI-FOOD PRODUCTS

Despite the growing importance of intra-industry trade, only a few attempts have been made to investigate the nature and extent of intra-industry trade involving agri-food products. Unlike IIT studies dealing with manufacturing trade, all studies dealing with intra-industry agri-food trade took place after the advancement of the new trade theory based on the economies of scale and product differentiation in the mid 1980s. While the first few initiatives focused on the determination of the extent of intra-industry trade in agri-food products, more recent studies have also concentrated on identifying the determinants of intra-industry trade through testing relevant hypothesis with both time series and cross sectional data. An attempt is made in this section to provide a brief overview of these studies and a synthesis of the progress made so far in this area.

One of the early studies on IIT in agri-food products is McCorriston and Sheldon (1991) who examined trade in processed meat, various cheese products, cereals, processed fruits, processed vegetables, sugar products, alcoholic and non-alcoholic beverages and tobacco products to determine the extent of IIT in the EC and in the United States. They used an adjusted version of the Grubel-Lloyd index to measure the IIT and found that except for exports to Canada, the US trade in selected processed agri-food products was characterized by inter-industry trade while the bulk of EC trade in processed agri-food products was dominated by IIT. They emphasized the role of proximity to market, distance from foreign markets and economic ties with former colonies as the main factors for explaining differences in specialization and trade in processed agri-food products in the EC and in the United States. Note that these factors are not consistent with those predicted by the new trade theory and may have been chosen arbitrarily.

Christodoulou (1992) used the unadjusted Grubel-Lloyd index to measure IIT in meat and processed meat products (pork and beef) industry in the EC countries in 1988. To identify the factors responsible for cross country variations in IIT in the EC, he used market size, taste overlap, market proximity, stage of processing, scale economies, product differentiation and market structure variables. The results suggest that taste overlap and imperfect competition were the most important variables for explaining variations in IIT in the EC meat trade. He also noted that IIT was more significant for both raw and highly processed meats relative to lightly processed meat.

Hirschberg, Sheldon and Dayton (1994) appears to be the first empirical study to analyze IIT in processed food products which closely followed the new trade theory advanced by Helpman and Krugman to specify relevant variables and the empirical model. They used a panel data set of 30 countries for the period from 1964-1985 and employed a fixed effect tobit model in their investigation. They used both adjusted and unadjusted versions of the Grubel-Lloyd index and used size differences of GDPs, GDP per capita, bilateral inequality between GDP per capita, exchange rate and distance as explanatory variables. They have also used a set of dummy variables to account for common borders, language, and culture among trade partners. The results suggest that IIT incraeses with increase in GDP per capita and more similar the GDP per capita between two countries. The results also suggest that common border helps the IIT while distance and fluctuating exchange rates do not.

Pieri *et al.* (1997) examined IIT in dairy products among 10 EU countries from 1988 to 1992 to assess the importance of country-specific and industry-specific factors in dairy products trade. They used EUROSTAT data to compute unadjusted Grubel-Lloyd index to measure IIT in dairy products and used a set of theoretically relevant country-specific (reflecting demand conditions such as trade overlaps, market size, proximity to market and trade imbalance etc.) and industry-specific (reflecting supply conditions such product differentiation, scale economies, market concentration etc.) characteristics to assess the importance of these factors in intra-industry trade in dairy products among the EU countries. The results suggest that IIT in dairy products is higher the more similar the countries are. The results also suggest that the presence of large farms enhanced IIT in dairy products. However, concentration in the retail sector was found to have a detrimental effect on IIT flows in dairy products among the EU countries during the study period.

Henry de Frahan and Tharakan (1998) examined the importance of horizontal and vertical IIT in the processed food sector in the EU between 1080 and 1990. They used EUROSTAT data for 18 NACE food sub-sectors for 8 and 11 EU countries and 39 trade partners in 1980 and 1990. They estimated horizontal and vertical IIT in the selected commodities and used a set of theoretically relevant variables reflecting country-specific and industry-specific characteristics to explain variations in VIIT and HIIT in processed food products. The results from the Tobit regression analysis suggest that average market size and level of economic development of trade partners and their trade preference and geographical proximity have significant positive impact on the level of horizontal IIT. However, differences in factor endowments, market size and scale economies between pairs of countries have significant negative impacts on horizontal IIT. These results are broadly consistent with the predictions of the new trade theory. The results for the vertical IIT model were not very encouraging as some of the key variables such as factor endowment differences had the wrong sign. Similar results have also been obtained by van Berkum and van Meijl (1999) in an attempt to explain horizontal and vertical IIT in the EU agri-food sector. In addition to country-specific and industry specific variables, they also included technology variables and a set of product categories in their analysis. The used EUROSTAT data for 57 product categories or industries in 197 and estimated non-linear regressions to explain horizontal and vertical IIT in the EU agri-food sector. While the empirical results for HIIT were consistent with the theory of product differentiation, the results for the VIIT were mixed. The obtained a significant negative coefficient for differences in endowments which is contrary to the theory. However, differences in technology yielded a significantly positive coefficient only in the vertical IIT model which is consistent with the theory of the vertical IIT.

Qasmi and Fausti (2001) made an attempt to evaluate the impact of NAFTA on inter- and intra-industry trade in agri-food products in North America and in the rest of the world. They used OECD's SITC Rev. 3 data for 23 agricultural products that include meat, meat products, dairy products, grains and cereal products, processed fruits and vegetables and other related products for 1990 and 1995. They computed adjusted G-L index to determine the extent of intra-industry trade in selected agri-food commodities and how did the IIT change between the two periods. The results show that the proportion of IIT was higher for commodities involving a greater degree of processing while trade in bulk commodities with little or no processing was dominated by inter-industry trade. The results also revealed that the US-Canada bilateral trade is dominated by IIT, while Mexican bilateral trade with either Canada or the United States is dominated by inter-industry trade. The authors also note that the proportion of IIT in agri-food commodities in the US with the rest of the world declined between 1990 and 1995. Note that these authors did not make any attempt to explain the IIT using new trade theory nor did they provide any explanation to why the US IIT in agri-food products with the rest of the world declined during the study period. In an attempt to evaluate the IIT in the US food processing industry, Sun and Koo (2002) used the G-L index to measure the degree of IIT from 1989 to 2001 with particular emphasis on 1997. The used USDA data for 24 sub-industries at the 5-digit NAICS level and trade with 24 trading partners and classified total IIT into vertical and horizontal IIT using 6-digit HTS code levels to minimize aggregation problem. The results show that the degree of IIT varies across sub-industries and across different trading partners. Canada is the most important trade partner in processed food products and in 1997 forty one percent of processed food traded between Canada and the US was IIT in nature. Japan, Mexico, France and the United Kingdom are the other important trade partners in this area. While most of the IIT in the US food processing industry is vertical in nature, since 1989 horizontal IIT has been growing faster than the vertical IIT. They do not provide a satisfactory explanation of why this is happening. Sun and Koo (2002) used an identical set of variables to explain HIIT and VIIT in the US food processing sector. The results from their regression analysis suggest that the HIIT model fits data better than the VIIT model and that industry characteristics explain IIT better than the country characteristics included in the analysis.

Fertö (2005) investigated the relationship between factor endowment and vertical IIT in agri-food products between Hungary and the EU. He used OECD data on agri-food trade between Hungary and 14 EU countries from 1992 to 1998 and employed three alternative approaches (the G-L index, the approach suggested by Fontagne and Freundenberg (1997) and that suggested by Nilsson 1997) to measure the IIT. On the basis of unit value differences, he divided the total IIT into vertical IIT and horizontal IIT. Using Falm and Helpman (1987) model of trade in vertically differentiated product, Fertö (2005) specified a set of proxy variables and employed panel regression analysis to explain vertical IIT. The results suggest that there is a positive relationship between VIIT and differences in factor endowment, which is consistent with the theory. Note that the author used differences in the endowments of different types of factors such as land, human capital and physical capital in this study, which may have generated theoretically consistent result. The results also suggest that they way IITs are measured may have significant implications for estimates from regression analysis.

To recap, except one all studies used cross-sectional data to measure IIT and the G-L index has been the most popular measure of IIT in agri-food products. While the separation of total IIT into vertical and horizontal IIT has been a useful exercise in agri-food trade, the results from various studies suggest that they are not very encouraging for the vertical IIT model relative to those for the horizontal IIT model. Clearly, much need to be done in refining the empirical analysis of vertical IIT in agri-food products. Following relevant trade theories closely to develop testable hypothesis and focusing alternative specification of proxy variables could help in this regard. Theoretical predictions are often considered to be relevant in the long run but most of the empirical studies conducted so far appear (dealing with both agri-food products and manufacturing) to have produced results that are more relevant in the short run. The issue related to short-run versus long-run relevance of the results has not been entertained in any published IIT study yet. Along the same line, what are the implications of data nonstationarity for the IIT results? Since it is well known that most macroeconomic variables contain unit roots, this issue is particularly relevant for IIT studies employing time series data in their analysis. Since differences in factor endowments is the key driver of specialization and trade according to the H-O-S trade model, what is the threshold differences in factor endowment that changes vertical IIT into inter-industry trade? Is this threshold commodity specific or does it vary across countries? Does it vary over time? What factors contribute to changes in the threshold over time, across industries and among different trading partners? All these issues are relevant for future progress in modeling trade is differentiated products.

PRODUCT DIFFERENTIATION MODELS APPLIED TO AGRI-FOOD TRADE

More than fifteen years ago, MacLaren (1990) reviewed various product differentiation models used in modeling agricultural trade with imperfect substitutes. At that time, with the exception of the Armington model, important product differentiation models developed in the eighties recognizing the role of increasing returns to scale and monopolistic competition were not applied on a large scale in agricultural trade modeling. Since then, the landscape has changed and various models of product differentiation have been developed and routinely applied by agricultural trade modelers. These studies can be classified into three distinct streams. The first stream is more empirical by nature and aimed at estimated import demand for agricultural commodities econometrically, using the notion of national product differentiation. While most of these studies used a theoretical framework inspired by the Armington model, the empirical models estimated often incorporated some refinements of the original Armington specification. So far, most of these empirical studies have been applied to raw agricultural commodities, with only a few applications to processed agri-food products (Surry *et al.,* 2002)[2].

The second stream of agricultural trade-related studies based on product differentiation models focus on the assessment of the impacts of agricultural trade liberalization using calibrated partial equilibrium and applied general equilibrium models. This group of studies started during the mid-1980s with the initiation of the Uruguay Round negotiations and benefited enormously from the development of the GTAP project and GTAP network in the early 1990's at Purdue University under the leadership of Dr. Tom Hertel (1997). Most of these studies are policy-oriented and are based on the notion of national product differentiation using either the Armington specification or one of its generalizations. The third stream of agri-food trade

[2]National product differentiation models have been used for the following agricultural commodities: corn, cotton, fruits and vegetables, individual fruits (such as apples, citrus fruit and grapefruits), soybeans, tobacco, wheat, poultry products and red meat. Applications of national product differentiated models to agri-food processed products have generally been undertaken at a rather aggregate level (three-digit classification of the Standard International Trade Classification (SITC) and were part of a more general emprical work covering a wide range of manufacturing and mining sectors (for examples of such studies, see Brenton (1989), Reinert and Roland-Host (1992), and Gallaway *et al*. (2003)).

related studies based on product differentiation models consider product differentiation not to be exogenous as in national product differentiation models. In these studies product differentiation is endogenized at the firm or consumer level by assuming either horizontal or vertical product differentiation. Many of these studies employing econometric analysis have already been reviewed in the previous section. In this section attention is focused mainly on those studies that used theoretical and calibrated models to study the effects of agricultural trade policies.

Providing a thorough overview of all product differentiation models developed over the last fifteen years and applied to agri-food trade using the former classification would be a monumental task that goes beyond of the scope of this paper. Our intention is to provide in this section an account of the main *trends* in the application of product differentiation models applied to agri-food trade. For this purpose, three appendices at the end of this paper summarize notable examples of studies that applied product differentiated models to agri-food trade. These studies are categorized according to the three types of product differentiation (national, horizontal and vertical) commonly used in the international trade and industrial organization literature[3]. These studies have been selected because they either made some original contributions to agricultural trade modeling or synthesized the state of the arts on this topic[4]. An inspection of all the selected studies indicates that agricultural trade models based on national product differentiation are mainly based on the Armington specification (appendix 1). Applications of horizontally differentiated trade models would attempt to adapt the Dixit-Stiglitz and Lancaster models to agri-food markets (appendix 2). Finally, notable progress have been made over the last fifteen years concerning the use of vertical product differentiation models to analyze a wide range of old as well as new trade policy problems in agri-food markets such as price discrimination strategies by state trading agencies, labeling and the consequences of adopting genetically-modified crops (appendix 3). All these studies use the Mussa-Rosen model of vertical product differentiation.

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[3] Another dimension of product differentiation which consists of distinguishing a good according to certain attributes has been adopted to model trade for some agricultural commodities such as wheat that is divided into classes (defined in terms of protein content, etc..). In this context, the various classes are viewed as given and could be considered as many different products of the good under study. It is not our objective to discuss this kind of product differentiation as such when it is viewed as exogenous Rather, what will be undertaken is to refer to this kind of agricultural trade studies that would combine classes of a good with national product differentiation. For an application of such a study, see Haley (1995) for a calibrated model of the world wheat sector combining classes of wheat and a (Armington) national product differentiation dimension (appendix 1). On the empirical side, a trade model with similar characteristics with a more general specification than Amington has been developed by Henning and Martin (1988).

[4] Readers will note that a detailed description of each selected study in the various appendices is given. This can be justified on the grounds that any differentiated product model has been used in agricultural trade in two different settings: i) such models are used on their own to study a specific agricultural market or commodity. In such circumstances, these models are often so complex that they require stating its underlying assumptions and giving its most important characteristics; ii) the second setting is that most of these product differentiated models could be part of a larger framework, the characteristics of which need to be known so that it is possible to see how the product differentiation model specification fits into such a global model. This state of affairs is especially prevalent in the case of CGE models used to simulate agricultural trade liberalisation scenarios. It should also be stressed that in order not to complicate the layout of these appendices, there are no references to econometric-based works of product differentiation models applied to agri-food commodities. Such studies have already been reviewed in Section IV of the main text.

National Product Differentiation: The Armington Model and its Generalizations

The Armington model has been and continues to be the workhorse of (agri-food) trade modeling. Conceived originally by Armington (1969) in the late sixties to explain trade among countries, this model has gained popularity during the 1980s and 1990s with the growth in applications of computable general equilibrium (CGE) models to study global trade policy problems. The Armington model is based on a weakly separable utility function which assumes a two-stage process in consumers' purchase decision. First, the total import quantity of a product is first determined and then it is allocated among competing import supplies of different sources of origin. Such a model specification is then implemented by assuming that import supplies of different origin are imperfect substitutes among each other and are determined by constant elasticity of substitution (C.E.S.) demand functions. The existence of a homogeneous and weakly separable utility function also implies that the demand function for each source is characterized by a unitary elasticity with respect to the total import quantity (expenditures) demanded for the product.

Implementation of the Armington specification in CGE models occurred through a multi-stage process where a representative consumer determines the aggregate demand functions for a basket of goods that are derived from a weakly separable utility function maximization problem subject to a consumer income constraint. Then having determined the total demand for each goods, the representative consumer determines how much he will purchase on the domestic market or import from the Rest of the world. Finally, in the last stage, he decides how total imports must be supplied and allocated between the various sources of foreign supplies. Since the fact that the Armington specification rests upon the use of the self-dual C.E.S. functional form, it can be implemented either in its dual or primal forms. Another attractive feature of the Armington model is that it could take care of two-way trade and captures the existence of trade policies that affect simultaneously imports and exports of a particular product (van Tongeren *et al.*, 2001).

The Armington specification could also be used in CGE models to represent exports and the various sources of supplies of intermediate inputs consumed by various industries. In the former case, modeling exports with an Armington specification was made possible by allowing firms in a given industry to segment export and domestic markets through the adoption of constant elasticity of transformation function. In the latter case of modeling supplies of intermediate inputs, firms are assumed to minimize the costs of their intermediate input supplies (domestic and imported) subject a technology constraint represented by a C.E.S. production function. Such a specification is very helpful to model trade in bulk agricultural commodities as they are used as inputs by food and feed manufacturing sectors.

During the second half of the 1980s, when the CGE trade models were gradually implemented to study the economy-wide effects of agricultural policy reforms, some questions were raised about the relevance of the Armington specification in representing agricultural trade (Stoeckel *et al.,* 1989). Many of these questions centered on the notion that agricultural commodities are homogeneous goods and that trade in agricultural commodities represent more of inter-industry trade rather than of intra-industry trade. This view is no longer tenable in light of the growing importance of trade in processed agri-food food products, particularly among the OECD countries. Moreover, there have been several empirical applications showing that raw agricultural products might not be homogeneous (see for instance Larue and Lapan (1992) for wheat) as it has been argued in the literature.

The Armington modeling framework has been used in many empirical (econometrically estimated) agricultural trade modeling exercises[5] but only a few studies have used this approach in calibrated partial equilibrium trade models over the last twenty years.[6]. Representative of this latter stream of agricultural trade studies are Haley (1995) and Kim and Lin (1990) on wheat, Peterson et Orden on poultry (2005) and Weber (2003) on Russia and Kazakhstan agricultural trade[7]. Recently, an option in the UNCTAD global trade model ATPSM (Peters and Vanzetti, 2004) allows users to incorporate the Armington specification.

The use of Armington models in analyzing agricultural trade has raised a number of interrelated problems of different nature dealing mainly with its specification and its empirical estimation. Concerning the former, extensive recourse of the Armington specification to model trade in CGE models led to the emergence of larger than expected terms of trade effects in trade policy simulation exercises, that influence significantly, and sometimes in unexpected ways, the welfare results (Brown, 1987)[8]. Furthermore, the fact that Armington elasticities are assumed constant among different sources of imports has been challenged by several trade modelers who have used more general functional forms (Pogany, 1996).

On the empirical side, most of the studies that have estimated the Armington model econometrically have obtained rather low estimated values of the elasticity of substitution among imported sources of supplies. In their review of the topic, McDaniel and Balisteri (2003) observed that the following robust findings emerge across many reviewed studies: i) long run estimates of the elasticity of substitution are higher than their short run counterparts, ii) the more disaggregated the data sample is, the higher the elasticity of substitution, iii) cross sectional studies generate estimates that are higher than those provided by time series data and iv) parameter estimates are sensitive to model misspecification (i.e. endogeneity of explanatory variables, underlying theoretical model structure etc.). These above empirical problems associated with the likelihood of obtaining low estimates of Armington elasticities would equally apply for agricultural and processed food commodities.

In their empirical works applying the Armington model, agricultural economists seemed to have concentrated their efforts on testing and assessing its basic characteristics that are frequently violated (Alston *et al.*, 1990). Hence, the assumption that elasticities of substitution among pairs of import sources are constant is often not supported by the data in many cases. In

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[5] See Surry *et al.* (2002) for a review of these studies.

[6] Although this present review of product differentiated trade model is limited to the last fifteen to twenty years, we should note in passing that the trade modeling works of Grennes *et al.* (1979) on international wheat markets, and the IATRC trade embargo study (USDA, 1986), that have used the Armington modeling approach. In addition, applications of the USDA SWOPSIM model (Dixit and Roningen, 1986) have been specified with an Armington assumption in the late 1980s.

[7] Haley's, Peterson and Corden's, and Weber's studies are reviewed in appendix 1.

[8] To address this issue more thoroughly, CGE modellers undertake systematic sensitivity analysis of the Armington elasticities when they conduct trade policy simulation scenarios

addition, it is often found that the various imported supplies were sensitive to the size of the market, implying that the elasticity of each import source with respect to total imports is not unitary anymore. Another issue that has been overlooked is the inability of the Armington model to deal with the question of separability between home production and different sources of imports (Surry *et al.*, 2002).

Over the last fifteen to twenty years, a wide range of solutions has been implemented to overcome the weaknesses of the Armington model. They led to the development of more refined national product differentiation models with varying elasticities of substitution. Indeed, it has not been a difficult task to develop more general national product differentiation model specifications that could overcome the basic assumptions of the Armington model such as separability and homogeneity. To do so, a two-pronged strategy has been adopted. The first one consisted of relaxing some of the assumptions of the Armington model such as homogeneity or constant elasticity of substitution (see for instance Hjort (1988) and Ito *et al.* (1990) for agricultural-related applications). The second approach to refine the Armington model has been to use the more general functional forms and/or models that could account for non-homogeneity, non-separability and varying elasticities of substitution, simultaneously. Hence, following the seminal paper of Winters (1984), a long list of econometric studies was published, dealing with the estimation of import demand models by geographical sources using flexible functional forms such as AIDS, translog, generalized Leontief and normalized symmetric quadratic functional forms[9].

Agricultural trade modelers have been involved in adopting flexible functional forms or more general models to study the import demand for agricultural commodities by geographical sources of origin. In particular, it is interesting to observe that a large portion of such agricultural-based import demand studies published during the nineties was often based on the use of the AIDS demand framework or the use of the Barten-Theil differential approach (Rotterdam demand model or some of its variants such as CBS, NBR or AID). Some of these studies even refined the AIDS import demand framework by allowing the possibility to estimate import demand that could be at the same time source-differentiated and differentiated by sources of production (Yang and Koo, (1994); Carew *et al.* (2004)). In all these empirical studies, the question of home production and different sources of imports is hardly addressed. This state of affairs is quite understandable in light of the difficulties to obtain comparable price data for domestic production and various sources of import supplies.

The important recurrent question of rather small values of Armington substitution elasticities can be addressed by employing cross-section data within which prices are assumed constant. To obtain such estimates of the elasticities of substitution is undertaken by exploiting the spatial (country) variation of tariffs and trade (transportation) costs that are part of the arguments of the Armington model. This approach has been successfully applied by Hummels (1999) who derived much greater estimates than those "produced" with time series data[10]. In this respect, Keeney and Hertel (2005) used Hummel's estimates of Armington elasticities in

[9] In this respect, let us mention in passing the works of Brenton (1989), Kohli (1991) and Lawrence (1989), who have used such flexible functional forms to trade modelling.

[10] An inspection of Armington elasticity estimates obtained by Hummels indicates that they vary from 2.4 to 8 with an average of 4.54 for agricultural commodities and food processing activities.

the recent agricultural-specific version of GTAP model (GTAP-AGR) (appendix 1). Panel data as used by Erkel-Rousse and Mirza (2002) could also be another way to generate greater estimates of the Armington elasticities.

In calibrated (agricultural) CGE and partial equilibrium models, there have been some attempts to use more general specifications than Armington to represent trade. Hence, in a CGE model context, Robinson *et al.* (1991) applied an AIDS model to represent imports by geographical sources. In the same vein, Winter and Frohberg (2004) employed the McFadden flexible functional form to model agricultural trade flows in calibrated policy models. In CGE models characterized by multistage separable structures, economists cannot employ non-homogeneous national product differentiation trade models in order to ensure that price aggregators defined at the various stages of the model are consistently defined and thus are independent from quantities. This major constraint cannot be ignored in the calibration and specification of national product differentiation models applied to trade. This is the major hurdle that explains why non-homogeneous model structures are hardly applied in calibrated trade models. Given this dilemma, is it possible to use more generalized versions of the Armington specification in calibrated national product differentiation trade models? The answer to this question is affirmative: there are ways to do so by refining the Armington model framework through the addition of a new layer consisting of endogenizing the product differentiation through the behavior of national agents This leads to a new category of trade models based on horizontal and vertical differentiation that are discussed now.

To conclude the section on national product differentiation models, the Armington model is still the "workhorse" in agri-food trade modeling. Despite its weaknesses, it has been routinely used in trade policy assessment as well as in empirical trade studies. Concerning the latter, it is important to note that the Armington specification has been used to provide a theoretical justification of the empirical gravity models used for more than 50 years to explain bilateral trade flows.

Horizontal and Vertical Product Differentiation Models (Dixit-Stiglitz, Lancaster, and Mussa and Rosen):

Endogenizing product differentiation in agri-food trade models has been pursued through the use of three horizontal and vertical product differentiation models developed in the seventies and eighties. As explained earlier, the first of these three models is the one specified by Dixit and Stiglitz (1977), which assumes horizontal differentiation on the demand side, imperfect competition and increasing returns to scale (that are internal to the firm) on the supply side. The underlying utility function is based on a two- stage structure of the consumer preference. The utility function is homothetic in its arguments. The lower stage is made up of sub-utility functions that depend upon the varieties of each product demanded by the consumer. Usually, these sub-utility functions are represented by a C.E.S. functional form with constant elasticities of substitution among varieties of the same product that greater than one. In a trade context, the Dixit-Stiglitz model is specified in such a way that the demand for each product is first distinguished by domestic and import sources (Armington specification). Then within each source of supplies, various varieties are explicitly introduced as arguments of a CES sub-utility function. Often the imperfect market structure adopted in such a model is monopolistic competition, while other forms of imperfect market structures such Cournot-Nash hypothesis can also be incorporated.

The Dixit-Stiglitz model has been used to conduct both partial and general equilibrium analysis of agri-food trade policies. In the former case, interest stems from the fact that food manufacturing sectors in industrial economies are highly concentrated and face trade impediments when they purchase agricultural inputs and sell differentiated final products. Under such circumstances, the analytical effects of trade policy reform could be ambiguous. Lanclos and Hertel (1995) addressed this issue in the context of five selected U.S. food processing industries. For this purpose, they developed an appropriate (two country) partial equilibrium trade model with an horizontally differentiated product produced by a monopolistically competitive food processing sector purchasing an homogenous, traded intermediate (agricultural) input. A description of this study with the model and its main findings is presented in appendix 2. Lanclos *et al.* (1996) applied this model at a more disaggregated level for 33 U.S. food processing sectors. Their main finding was to show that "the effects of input tariff reform outweigh the effects of output tariff reform in the U.S. food manufacturing sector". As a result, U.S. food manufacturing firms reduce their production costs and this increase their competitiveness in the world market. By contrast, output tariff reform favours the compositeness of foreign manufacturers, As the net effects of the two tariff reforms are ambiguous, this requires to be analyzed empirically. Offering interesting insights on the effects of joint tariff reforms in the intermediate and final output markets, this type of trade policy analysis of the food processing sector should be extended to other developed countries (like E.U. member countries).

It is however in a general equilibrium context that the Dixit-Stiglitz model framework has been used the most to study the economy-wide effects of agricultural policy reforms. For this purpose, global CGE trade models would generally assume that agricultural sectors are perfectly competitive and characterized by constant returns to scale. On the other hand, imperfect competition, increasing returns to scale and consumer demand for horizontally differentiated products will characterize manufacturing and service sectors. Various forms of imperfect market structures have been adopted, although the most popular one is monopolistic competition. Such global CGE models based on the Dixit-Stiglitz specification began to be implemented in the midnineties with studies aimed at quantifying the outcomes the Uruguay round on the world economy. At that time, it was acknowledged that the conventional standard CGE model based on perfect competition and constant returns to scale was inadequate to capture the imperfect market structures of industrial sectors and the heterogeneity of consumer preferences. Swaminathan and Hertel (1996), Harrison *et al.* (1997) and Francois (1998) among others developed global CGE models that incorporated the Dixit-Stiglitz product differentiated specification. In doing so, they were able to show that incorporating horizontal product differentiation and increasing returns to scale could explain a major portion of the welfare benefits resulting from the implementation of the Uruguay Round. Further applications of global CGE models with horizontally differentiated products and imperfect markets structures have been used extensively to analyze the economy-wide effects of the Doha round (see for instance Laborde and Le Cacheux (2003) and Francois *et al.* (2005)).

The second endogenous product differentiated model approach applied to (agri-food) trade has been introduced by Lancaster (1980) who considered that consumer prefers a particular variety, called "ideal" and will choose a variety that is closest to the ideal one, should the latter not be available. In such a model, consumer preferences are asymmetrical. The model is implemented by assuming that the differentiated product in the underlying utility function depends upon this ideal variety[11]. When the Lancaster model is adapted to study international trade, it is combined with a partial or general equilibrium model that also assumes imperfect market structures. Unlike the previous Dixit-Stiglitz model framework, this one has not been used extensively in agri-food trade. To our knowledge, we have been able to find the work of Philippidis and Hubbard (2001, 2003) who analyzed the economic costs of the Common Agricultural Policy (CAP). Their basic argumentation was that negative utility effects associated with the loss of domestic food varieties could offset the potential efficiency gains of reforming the CAP. To address this question, they assumed that consumers have preferences that allow distinguishing between food products according to their domestic and imported varieties. In addition, they assumed imperfect market structures for processed food products (for more details on this model, see appendix 2). When comes the interpretation of the policy results generated by this model, it is found that that consumer preference heterogeneity has a negligible impact on the net cost of the CAP.

The third model we refer to in this section is the Mussa-Rosen based on vertical product differentiation[12]. In such a context, consumer would prefer the highest quality variety. Although ideally suited to study the demand for consumer goods by capturing consumers' heterogeneity in purchasing quality good, this model could also be used for intermediate products. In this latter case, what is interesting to study is the heterogeneity of firms' technology and their output's characteristics (Lavoie, 2001). In appendix 3 are presented four studies that have adapted the Mussa-Rosen model to address different questions or issues found

[11] When such a consumer preference structure is implemented, different functional forms could be adopted to represent the associated (sub-) utility function. For instance, Phillipidis and Hubbard (2001, p. 382) used the following C.E.S. sub-utility function for the differentiated products:

$$U_{i,s} = A_{i,s}\left[\sum_{r}\delta_{i,r,s}Q_{i,r,s}^{-\rho_i}Z_{i,r,s}\right]^{-\frac{1}{\rho_i}} \text{ for } r \neq s,$$

where $U_{i,s}$ is the level of sub-utility from the consumption of differentiated commodity i in region s, $Q_{i,r,s}$ is the consumer demand in region s for representative variety i from region r, subscripts r and s represent (geographical) varieties, $\delta_{i,r,s}$ is a C.E.S. distribution parameter, $A_{i,s}$ is a scale parameter, and ρ_i is a substitution parameter. $Z_{i,\ r,s}$ which represents a bilateral hierarchical utility associated with the consumption of the representative variety is given by the following expression:

$$Z_{i,r,s} = \left[1 + V_{i,r,s}\right]^{\gamma_{i,s}} \text{ with } \gamma_{i,s} > 0.$$

where $V_{i,r,s}$ is the preference value of the variety measured in relation to the "ideal" and $\gamma_{i,s}$ is the preference heterogeneity parameter. The larger the parameter γ is, the more strongly the consumer identifies with varietal choice. On the other hand, a zero value for the parameter γ implies that all representative varieties have the same hierarchical utility value, which also means preference homogeneity. It can be seen that $Z_{i,r,s}$ is strictly increasing in V. Varieties with higher preference values ($V_{i,r,s}$) result in higher amounts of hierarchical utility ($Z_{i,r,s}$) compared to less favoured varieties.

[12] More specifically, as explained by MacLaren (p. 118), "vertical product differentiation refers to preferences about the quality of a good, where a quality reflects the absolute amounts of the characteristics contained in the product".

in agri-food trade analysis[13]. Hence, the work by Bureau *et al.* (1998) showed how it is possible to study the welfare effects of trade liberalisation in the case of a credence consumer good (i.e. the EU-US trade dispute hormone-treated beef). In Cooper *et al.* (1995) and Lavoie (2005), the Mussa-Rosen problem is applied to the study of intermediate agricultural commodities (sweetener market in the EU and Canadian bread wheat, respectively). Finally, the work by Sobolevsky *et al.* (2005) shows how the Mussa-Rosen framework used to study the the market repercussions of GMO varieties in the international soybean complex could be incorporated into the well kown spatial trade equilibrium model developed by Samuelson (1952), and Takayama and Judge (1971).

To sum up, the applications of various endogenous product differentiation models in agri-food trade area show that when these models are applied properly to address both old and new issues useful insights can be gained. The limited number of applications that have been reviewed in this section suggest that such product differentiation models offer significant potentials for innovation that have not yet been fully exploited in the study of agri-food trade.

LOOKING FORWARD

This rather non-technical review of various product differentiation models has shown how they have been applied to agri-food trade. In addition, an attempt was made to show how the "New trade theory" that relies on product differentiation and imperfect market structures could be used to explain the development of IIT in agri-food products. Important questions and issues have been raised in this review. We have now to ask ourselves whether all these (product differentiation) trade models would continue to be relevant in the future to explain trade in agri-food products.

At the outset, we must acknowledge that the new trade theory will continue to be relevant in agricultural trade analysis. It is our belief that more and more applications of product differentiation models to agricultural trade will occur in light of the evolution experienced by the international agricultural trade complex. Thus, foreign trade in agricultural and food products would be more and more characterized by processed products. In addition, the international agricultural trading system is becoming more globalized with the need for food processing firms to remain competitive internationally. This trend appears to be accelerating with the growing importance of information technology in international trade. International trade disputes in agriculture would likely concern more and more issues dealing with technical regulations and phyto-sanitary questions. Consumer concerns about food safety and the growing role of biotechnology in agriculture are also elements that would influence trade in agri-food products in the future. Given all these emerging issues, there is no doubt that traditional trade models based on the notion of homogeneous products and preferences will be less and less suited to study trade in agri-food products. By contrast, trade models based on product differentiation would be more appropriate to capture most of the elements appearing in the international agricultural system. As a result, we could predict that product differentiated models would play an ever growing role in agricultural trade analysis in the future.

Turning to some specifics, what kind of trends could we expect for various product differentiation models that have been reviewed in this paper? The national product differentiation model and its emblematic representative, the Armington model, will continue to be used as a cornerstone in agri-food trade modeling. However, additional efforts need to be directed to enhance its partial equilibrium version to enable researchers to study the impacts of trade policies and assess the trade effects of technical regulations in agri-food markets. Concerning the use of Armington models in calibrated CGE models, further progresses need to be made to tackle the issue of functional form and separability. In this regard, it would be useful to replace the conventional CES functions with more general and flexible functional forms that satisfy global regularity conditions, As far as separability is concerned, further improvements in trade modeling could be made in CGE models by adopting for instance the notion of latent separability (see Gohin for more details on this question). As expressed in this review, one major problem with the Armington model is that econometric estimates of the underlying elasticity of substitution tend to be low. In this area, more empirical studies based on cross-sectional and panel data should occur and apply to trade in agri-food products. If this trend towards the use of panel were really taking place, it would likely imply some improvements in the theoretical foundations of the Armington model by adopting a notion of product differentiation that should rather be grounded at the firms' or consumers' levels.

Turning to the horizontal and vertical differentiation models that have been reviewed, we do not see any reason for a decline in their use. The Dixit-Stiglitz model combined with monopolistic competition market structures will become a standard tool in agricultural trade policy analysis. The important contributions made recently by some analysts adapting the Mussa-Rosen model (vertical differentiation) are good signs that more complicated issues such as food labeling, environmental concerns and food safety could be handled with this category of product differentiation models.

As ITT in agri-food products will continue its expansion in the future, the profession should focus additional efforts to explain such trends. The quality and findings of such empirical studies will indeed be enhanced if there are more available trade data that capture patterns in product differentiation among trade flows in agri-food products. This area is often neglected and more resources should be provided so that necessary agri-food trade data become available to agricultural economists.

Recently, there has been a revival of the role of trade costs in applied trade analysis (Anderson and van Wincoop, 2004). This results in part from recognizing the new role of economic geography in economic theory and its extensions in explaining trade patterns (Fujita *et al.*, 1999). This area has not been reviewed in this paper because we did not find any emerging trends but potentials to apply such theoretical tools to trade in agri-food products do exist.

CONCLUDING REMARKS

The Heckscher-Ohlin-Samuelson theory of international trade focuses primarily on the supply side of the economy and suggests that the volume and composition of trade between countries are driven by differences in factor endowments across countries. On the demand side this model assumes that consumers in all countries have identical and homothetic preferences and that all countries trade in homogeneous products. A casual observation would reveal that many products (either manufactured or agri-food) traded between countries today are not homogeneous and are, in fact, differentiated by brand names, factor contents or by other forms. Product differentiation is so prevalent today that researchers need to justify the use of models with homogeneous products only. Thanks to Helpman and Krugman (1985), a rich theory now exists to guide the empirical trade research that incorporates product differentiation and scale economies and is capable of explaining the growing importance of intra-industry trade. An attempt is made in this paper to provide an overview of this literature, highlight major developments since the mid 1980s and how various product differentiation models have been applied to model trade in agri-food products.

While the researchers now have at their disposal a number of alternative theoretical models to guide empirical trade research, the developments since the 1990s suggest that there is empirical relevance to both the H-O-S model of trade and trade based on increasing returns to scale and product differentiation. The results also suggest that the new trade theory need to be broadened to explain trade flows among developing countries and between developed and developing countries.

Despite the growing importance of product differentiation and intra-industry trade in agri-food products, particularly among OECD countries, relatively few attempts have been made to investigate the extent of intra-industry trade in agriculture and to determine the factors driving intra-industry trade. A few attempts that have been made did not explicitly model imperfect competition in their empirical model. Instead, they start with the theoretical prediction of Helpman and Krugman model or Falm and Helpman model to identify the variables, specify the proxy variables and conduct standard regression analysis to determine which factors have contributed to the growing importance of horizontal and vertical intra-industry trade. While some progress have been made since the mid 1990s in refining empirical analysis, the results of our synthesis suggest that more needs to be done in this area. For example, while the separation of total IIT into vertical and horizontal IIT has been a useful exercise in agri-food trade, the results are disappointing for the vertical IIT model relative to those for the horizontal IIT model. Following relevant trade theories closely to develop testable hypothesis and focusing alternative specification of proxy variables could help in this regard. Secondly, theoretical predictions are considered to be relevant in the long run but most of the empirical studies conducted so far (dealing with both agri-food products and manufacturing) appear to have produced results that are more relevant in the short run. The issue related to short-run versus long-run relevance of the results has not been entertained in any published IIT study yet. Along the same line, what are the implications of data nonstationarity for the IIT results? Since it is well known that most macroeconomic variables contain unit roots, this issue is particularly relevant for IIT studies employing time series data in their analysis. Finally, since differences in factor endowments is the key driver of specialization and trade according to the H-O-S trade model, what is the threshold differences in factor endowment that changes vertical IIT into inter-industry trade? Is this threshold commodity specific or does it vary across countries? Does it vary over time? What factors contribute to changes in the threshold over time, across industries and trading partners? Future modeling endeavors to address these issues will enrich the current state of knowledge in product differentiation and trade.

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Appendix 1: Product-differentiated models applied to agricultural and food processing commodities: The case of national product differentiation

Authors	Commodity coverage	Study's objectives	Model characteristics	Main findings
Haley (1995)	Wheat	To assess the impact of U.S. export subsidy programs (E.E.P.) in the cases of differentiated and homogeneous wheat trade.	-Wheat differentiated by quality (classes) et geographical sources of origin - Three-stage model: For a given region, the model determines how much wheat to import, then wheat classes and finally the sources of suppliers. -Imperfect substitution among wheat classes and geographical sources of supplies through constant elasticities of substitution (use of C.E.S. functions). - Comparative static world model (six exporters, 26 importers and seven classes of wheat) calibrated for the period 1986-1991.	- Need to differentiate wheat by end use and country of origin. - E.E.P. policy impacts are dependent upon the extent of differentiation. Thus, removing E.E.P subsidies over the period 1986-1991 induced an average 16% reduction in U export volume for the case where wheat is an homogeneou product while the same effect would be 11% for the differentiated case. - If wheat were homogeneous, the EEP is calculated to h expanded export revenue above the cost of the program 13% between 1986-1991. This figure would only be 4% the case of differentiation as assumed in this study.
Weber (2003)	Wheat Coarse grains, Oilseeds, Sugar, Vegetables and potatoes, Fruits, Cotton, Milk, Ruminant meat, Pork, Poultry	To assess the impacts of agricultural trade liberalization if Kazakhstan and Russia form a common agricultural market (CAM) with other CIS countries and became members of WTO.	- Comparative static, partial equilibrium model of Russia and Kazakhstan agricultural sectors broken down into eleven commodities. The model includes four regions (Russia, Kazakhstan, CIS and non-CIS countries) and is calibrated for 1997. -Product differentiation by sources of origin (imports) and destination (exports) for each agricultural commodity. -Simultaneous determination of agricultural prices in Russia and Kazakhstan. In the other two regions, prices are exogenous. - Multistage model specification for the supply side. At the top level, supply and input demand for each agricultural commodity are derived from a multi-output symmetric Generalised McFadden profit function. At the intermediate stage, imperfect transformation (based on a CET function) between domestic and export supplies is assumed for each agricultural commodity. At the bottom stage, various export supply functions (by destination) are derived assuming a CET transformation function. -Three-stage model specification on the consumer demand side. At the upper stage, demand functions for each agricultural commodity are derived from a normalized quadratic expenditure function. Then, consumers determine the demand for domestically produced and imported products based on a CES aggregator functions. Finally, various import demand by geographical sources are derived at the lowest stage from a CES aggregator function. -Various agricultural policy instruments (import tariffs and subsidies, export subsidies and direct payments) enter the various price transmission equations.	- The implementation of the CAM scenario results in a modest decline (2%) in net producer revenues and a slight increase (less than 1%) in consumer welfare. As governme loses revenues from import tax collection, the overall economic welfare is negligible. -In Kazakhstan, the implementation of the CAM scen induces a 14% decline in net producer revenues, w consumers experience a modest increase (0.5%) in welf Government experiences a modest decline in reve stemming from import tax collection. Overall, there i small improvement of overall economic welfare agricultural markets of Kazakhstan. - Product differentiation seems to matter in analysing effects of liberalized trade on CIS agro-industries. Stror national product differentiation would benefit single sec of the agro-industrial complex in reducing negative imp on their profits.

Appendix 1 (continued)

Authors	Commodity coverage	Study objectives	Model characteristics	Main findings
Peterson and Orden (2005)	Poultry	To evaluate the effects of sanitary barriers to poultry trade in combination with non-technical barriers in the forms of tariffs and tariff-rate quotas (TRQs).	- Distinction between "high-value " (white meat) and "low-value" (dark meat) poultry products. - Joint production of these two categories of poultry products. - Four-stage model: For a given region, the model first determines the total demand for poultry, then the demand for high- and low- values poultry products, then demand for domestically produced and total imports and then sources of imports. -At the various stages of the model, substitutability patterns are captured by C.E.S. (sub)utility functions. -Static world model (eight regions including USA, Brazil, Rest of World exporting region (ROWE), EU, China, Japan, Russia and Rest of World importing region (ROWM)) calibrated for 1998. -Government policies included are the various tariffs, TRQ for the EU and sanitary (SPS) regulations.	-Simulation results tend to show that nontechnical barriers trade have significant effects on world trade. Hence, removing all these technical barriers to trade would expan global trade by 25%. It is also expected that the USA coul gain additional access to the EU market. - When Brazil is assumed to enter low-value poultry mar of Russia and the ROWM region as new markets, effects production and exports resulting from trade policy reform reduced for the US and the EU and their exports are dive to China.
Keeny and Hertel (2005)	-29 sectors highlighting agricultural (12) and food processing (8) sectors -6 other industrial sectors -3 service sectors	To provide a better assessment of multilateral trade liberalization scenarios of agricultural markets, taking into account the specificities of agricultural sectors. This is implemented by introducing in the standard GTAP model additional relationships (behavioural, technical) representative of agricultural sectors. This new agricultural–based version of GTAP is called GTAP-AGR.	- Labour and capital are segmented between agricultural and non-agricultural sectors, while they are perfectly mobile within both groups (agricultural and non-agricultural). To capture this former segmentation, a CET function with fixed factor endowments is specified. Within agriculture, land is also segmented according to final use: This is again implemented using a CET function. - A nested-CES production function is specified for each agricultural sector, the output of which is produced by combining purchased and farm-owned (value-added) inputs. - Explicit modelling of crop-livestock interactions by separating among purchased agricultural inputs feedstuffs from the rest. -The same two-stage consumer structure as in GTAP (based on the use of the CDE specification) is kept in GTAP-AGR. It is however assumed that food and non-food commodities are separable. -Elasticity of substitution among imports in GTAP-AGR that are econometrically estimated and on average greater than those used in GTAP. -Explicit model representation of OECD farm households in GTAP-AGR. This is done by assuming that farm households share the same utility function as the representative GTAP household but they differ in their earnings. -Explicit representation of agricultural policy instruments to reflect their changing nature over time. Thus, special care is given to the representation of decoupled programs (payments) in the EU. -GTAP-AGR is made up of 23 regions and calibrated for 2001.	- In terms of model validation, it was found that GTAP-A was doing reasonably well in reproducing the economy-w and global impacts of weather-induced shocks. Even in so cases, it was performing better than the conventional GT model framework. -Concerning policy simulation scenarios on multilateral tr liberalization under the WTO Doha round, GTAP-A generates impact results for overall trade, world price national welfare aggregates, that are of similar magnitud those obtained with the conventional GTAP mo framework. -Where GTAP-AGR "produces" different impact res from the conventional GTAP model has to do with repercussions on farm specific variables such as farm lab and farm household welfare. For instance, the fact imperfect labour mobility is assumed in GTAP-AGR indu moves of unskilled labour out of agriculture such as in Ja EU and the USA, that are much more moderate that th obtained with the conventional GTAP model.

Appendix 2: Product-differentiated models applied to agriculture and food processing commodities: The case of horizontal differentiation

Authors	Commodity coverage	Study's objectives	Model characteristics	Main findings
Lanclos and Hertel (1995)	Processed food products in the United States, including fruits and vegetables, milled consumer goods, beverages, confectionary products and other food products.	-To study the effects of tariffs on intermediate inputs and final goods in monopolistically competitive industries. -Theoretical propositions are derived and comparative static results are generated and compared to an Armington-like model based on prefect competition. - The model propositions are then tested and checked on several U.S. food industries.	-Adaptation of Venables, two-country, two-product model with a homogeneous, traded, intermediate input produced under perfectly competitive conditions. - The model is of partial equilibrium nature and assumes that the first country applying a tariff is a small importer while country 2 represents Rest of world. - On the consumer side, a two stage separable, homothetic preference structure is assumed with two products, one being an homogeneous *numeraire*, while the second one is a differentiated (food) product. -A CES sub-utility function *à la* Dixit-Stiglitz is defined for the varieties making the differentiated commodity. - On the producer side, representative firms maximize profits assuming fixed cost of entry, operating under conditions of monopolistic conditions (free entry and zero profit) and subject to the second-stage demand function. - It is assumed that consumers exhibit a preference for domestic varieties. -Variables of interest in this model are the number of firms, the output per firm, sectoral output and unit expenditures	-The effects of a tariff on intermediate farm and food inputs used by food processing industries induce a decline in output per firm and a decline i firm numbers. -These former results are compared with those obtained under perfect competition. It is found th the decline in total industry output is much larger under monopolistic competition. - The impacts of combined tariff shocks to both intermediate inputs and final goods induce a reduction in output per firm while effects on changes in firm numbers and total sectoral output are ambiguous. The change in total output under perfect competition under perfect competition is also characterized by a similar ambiguity.
Philippidis and Hubbard (2001, 2003)	Seventeen sectors highlighting agriculture (9 sectors) and food processing (6 sectors) plus manufacturing and services	-To study the economic inefficiency of the Common Agricultural Policy (CAP) when varietal utility and patriotic preference are taken into consideration explicitly. - A full trade liberalisation of the CAP is implemented.	-The varietal utility and patriotic preference specification is captured through an endogeneous hierarchical consumer preference based on the region of origin. An additional layer allowing for food patriotic preference (specification based on the Lancaster model) is added to the exogenous region-of-origin approach maintained under the Armington assumption (see text for more details on this question) -The GTAP model is used and aggregated in two rnegions (EU and Rest of World) and considers only 17 sectors focusing agriculture and food processing. The food processing sector, manufacturing and services sectors are imperfectly competitive. Varietal effects occur only for food processing in both regions. Primary factors are perfectly competitive. -CAP instruments refer to the McSharry reform. Most of the instruments are expressed in tariffs equivalent forms. However, all the de-coupled area and headage-payments from the cereal ands and livestock sectors (that were considered as output subsidies) are re-calibrated as input subsidies. Set-aside payments are decoupled and treated as a ″fictional payment to agricultural household″ and thus viewed as a provision for land owners. - The CGE model is calibrated with the version 4.0 of the GTAP data base (1995)	-The CAP may have a significant effect increasing varietal diversity in the EU through expansion in domestic food processing industries -Removal of the CAP reverses this effect, caus hierarchical losses. These are offset by posi varietal effects in manufacturing and services stronger allocative effects than under prefere homogeneity. -Preference heterogeneity has a marginal impact the net cost of the CAP (estimated for the EU 0.19% of GDP.

Appendix 3: Examples of vertically-differentiated product models applied to agriculture and food processing commodities

Authors	Commodity coverage	Study's objectives	Model characteristics	Main findings
Cooper *et al.* (1995)	EU sweetener sector	-To assess the potential magnitude of the penetration of isoglucose into the EU sweetener market and its possible impact. - The study assumes that the EU sugar regime as given and attempts to find the best response of isoglucose producers to sugar prices and to derive the welfare impact of the production of isoglucose. -A demand model of vertical product differentiation is developed.	-Sweeteners are intermediate products that are differentiated according to two parameters: sweetness content and physical form (isoglucose or sugar). In addition, divisibility of the products is allowed. -Food processing manufacturers minimize the cost of sweeteners subject to technological constraints on the levels of sweetness and on bulk content. - Aggregate demand for the two sweeteners are assumed to be price inelastic (zero price elasticity) and the associated demand functions depend upon the various levels of sweetness per unit of sweetener, the maximum quantity of sweetener and a cumulative distribution function associated with the random quality parameter on physical form.	- It is shown that liberalisation o isoglucose market in the EU could not inc welfare if it is not accompanied by a redu in the sugar quota. - If production of isoglucose were unrest in the EU, it could replace 25% o industrial use of sugar. -It is shown that sweetness viewed as an i of quality is of crucial importance.
Bureau et al. (1998)	Beef	-To study the welfare effects of trade liberalisation in the case of a credence good, using the case of the EU-US trade dispute hormone-treated beef. - A stylised vertically differentiated product model is developed and used to undertake comparative welfare analysis under three situations: autarky, free trade without identification of the quality of the product and free trade with a quality label.	-The analytical model framework is based on a one-period two-region partial equilibrium model under vertical differentiation with two qualities for a single good. -Quality is referred to a single attribute, i.e hormone-treated or non-treated. Quality of the product could be perceived and/or expected by consumers and this specific feature attributed to this manifestation of quality is incorporated into the model through a relevant specification of the demand functions. A parameter defining perceived quality and taking values over the interval [0 1] is defined. A value closed to zero would indicate that the quality of imported beef is of lower quality than the hormone-free domestic beef. On the other hand, if this parameter is close to 1, consumers perceived no quality differences between imported and domestic beef. - The model is then used to generate welfare results for consumers, producers and the EU as a whole.	-The lack of product diversity limits dor welfare under an autarky situation uncertainty on quality would occur and will be none of the problems linked to ac selection. -Under a trade liberalisation situation w labelling, the parameter defining perc quality plays a key role in welfare re Thus, promoting trade liberalization foreign products are perceived of lower q than domestic goods could lead to n inefficiencies (adverse selection) and mu equilibria. -The effects of trade liberalisation w quality label are ambiguous. Domestic w losses could occur, depending upon the associated with the label and upon the ext how consumers perceive a signi difference between the two qualities of be

Appendix 3 (continued)

Authors	Commodity coverage	Study's objectives	Model characteristics	Main findings
Sobolevsky *et al.* (2005)	Soybean and byproducts	-To assess the trade, price and market repercussions of introducing genetically modified varieties on the soybean complex.. -To attain this objective, a global, spatial, partial equilibrium model allowing for product differentiation and cost segregation is developed for the world soybeans, soybean oil and soybean meal markets. In addition, this model allows the production of conventional and GM-grown soybeans.	- Four regions (including US, Argentina, Brazil and rest of World) are included in this model. Soybeans and soybean oil are made up of two varieties: GM (a variety produced with a herbicide-resistant technology) and conventional. -Only, ROW region is modelled with differentiated demand. The demand for GM products is assumed to be a weakly inferior substitute. This is implemented through the use of the vertical product differentiation model of Mussa and Rosen (with unit demand). Consumers have heterogeneous preferences with respect to GM and conventional food products. Linear forms are adopted for the various demand variables. -The impacts of biotechnology innovation of the GM variety on soybean production and demand for soybeans and soybean products are explicitly represented in the model through an appropriate specification. To capture the segregation costs to maintain identity preservation, it also implies a separation of conventional and GM soybeans and soybean product activities and markets. -Trade is allowed all along the supply chain of the soybean complex but also among regions. This feature of the model "allows to study whether different models are affected differently by the introduction of Roundup Ready (RR) technology and to model region-specific policy actions". -Market clearing conditions requiring that total world soybean demand is equal to the total world supply for each variety. -The model is calibrated for the 1998-1999 marketing year. - U.S. support price policies for soybeans are incorporated into the model.	- In a world situation with no fe segregation technology, the long equilibrium state of the world after cost- RR technology is introduced is th complete worldwide adoption. This quili is characteriosed by lower prices for soy and byproducts and a U.S. lead on soybean exports. – In a situation with f government intervention and trade regul and with a segregation technology positive costs, the US is the only producing both RR and convent soybeans. All other regions specialize production. - When the ROW and Brazil prohib production of RR products, the ROW benefit from such a ban relative to the r scenario as long as the segregation cos not too low. In Brazil only farmers benefit from such regulation.
Lavoie (2005)	Wheat	-To study the behaviour of state-trading enterprises like the Canadian Wheat Board (CWB) to price discriminate in wheat exports. -A conceptual model based on the assumption of vertical differentiation is first developed, specified and resolved to determine and explain the price discriminating behaviour of the CWB. - The hypothesis of price discrimination is then tested through a reduced-form model using confidential data on monthly price and total quantity of Canadian Wheat Red Spring (CWRS) of grade 1 and 2 over a period November 1982 to July 1994.	-The model of Mussa and Rosen is used to represent an importer's wheat market. Wheat is viewed as an intermediate good used by millers to produce a final good (flour) with desired qualities. -The model considers two importer's markets and two exporters (US and Canada) and three qualities of wheat (domestic, Canadian and US). It is assumed that importer's domestic wheat is of lower quality than its US counterpart that in turn is inferior to Canadian wheat. -Demand relationships for the three categories of wheat in each importer's market are derived from a representative miller that minimizes its cost of producing flour by blending qualities of wheat through a Leontief technology. -On the supply side, it is assumed that US wheat producers behave as profit maximizers operating in perfectly competitive environment, while the CWB acts as a monopolist with the objective of maximizing producers' surplus through a price discrimination strategy on its various export destination subject to a constraint that the amount exported cannot exceed the total production of wheat in a given year. Resolution of the first order conditions associated with the CWB"s optimised objective function results in the determination of export prices high quality wheat, that depend upon the wheat quality variables, processing costs and "instruments" of price discrimination (such as exchange rates, government policy instruments, etc..) - The resulting empirical model links through a linear regression price differences of Canadian export prices as a function of wheat quality variables, processing costs and instruments of price discrimination.	- The empirical model is tested with Ca wheat export prices representative o importers markets including Japan, UK of World-West Canadian ports (excl. and Rest of World-East Coast ports UK)). -Empirical results seem to indicate that do price discrimination by charging di f.o.b. prices to different countries for the grade and protein content. - Statistical tests support the hypothesi the CWB exerts market power resulting product differentiation and uses it to discriminate across export markets. -empirical results seem also to show that is not fully using the instruments of discrimination to pursue its stated obje (like Canadian wheat producer revenues)