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The composition of global agricultural trade is shifting from primary commodities to processed foods in terms of value and quantity. It is important to understand the linkages between agriculture and food processing to identify the sources of the structural change in agricultural trade. The question addressed by this research is whether increasing the level of technology in agriculture may bolster the comparative advantage of the food processing sector. To address the hypothesis, an empirical framework derived from neoclassical trade theory is fitted to panel data comprising of thirteen developed countries over a twenty-year time period. That is, the export share of GNP for each of the two sectors, agriculture and food processing, is specified as a function of respective factor supplies, and productivity growth. Since food processing sectors use agricultural products as intermediates, a technological linkage between the sectors is established through price. Results confirm that the increases in the level of technology in the agricultural sector (i.e. productivity growth) benefits the food processing sectors in the form of lower input prices. Thus, the comparative advantage of agriculture, obtained through productivity growth, is transferred to the food processing sectors as lower procurement costs, which increases the latter's ability to compete in the global market.

Technological Change and Comparative Advantage of the Agricultural and Food Processing Sectors

by

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Technological Change and Comparative Advantage of the Agricultural and Food Processing Sectors

Chapter 1: Introduction

The purpose of this research is to understand how growth and trade of the food processing sector are affected by productivity growth of the agricultural sector. It is crucial to recognize the value of the linkages between agriculture and food processing as they relate to trade, because over $500 billion in agricultural products are traded annually, worldwide. Moreover, the composition of the total value of traded agricultural products is changing from bulk commodities to processed foods. That is, an increasing proportion of traded agricultural commodities pass though a value-added process before shipment. Most countries perceive this trend as beneficial, since processed food products are generally of high-value, and the addition of value to primary products generates employment.

Agricultural trade has attracted more attention and generated a great deal of research over the last 30 years due to its importance in overall trade and dynamic nature. One of the key events that motivated research was the rise in the volume of traded commodities during the 1970s (Abbott and Haley, 1988). This occurred as parts of the world experienced drought, which brought about a large food shortage and forced countries to look outside their borders to meet their food demand. The focus of research shifted to the effects of policy on trade in the 1980s, as world commodity prices fell and governments imposed trade barriers to protect the agricultural sectors that had grown in the previous decade. In the 1990s, research refocused on globalized production through foreign direct investment, as the value of agricultural trade increased due to compositional shifts in trade and on the effects of multilateral trade agreements.

Most of the research on agricultural trade focused primarily on specific commodities, (e.g., Falcon and Naylor, 1998 among many others) particularly the impacts of domestic and trade policies. However, little empirical research has examined the sources of comparative advantage in the agricultural and food processing sectors. The linkages between agriculture and food processing, and their consequences have also received very little attention. Though several authors (Gehlhar and Vollrath, 1997, Cranfield et al., 1998, Coyle et al., 1998) identify that the structure of agricultural trade is changing from bulk commodities to processed foods, few studies have attempted to explain why this is occurring (Gopinath, Roe and Shane, 1996, Hertel, 1997). This is in contrast to the broader economics discipline, which has analyzed trade on a sector level basis, emphasizing factor endowments, technological change, and intersectoral linkages as determinants of specialization and trade.

The purpose of the study is to examine the effects of technology and factor supplies (labor, capital) on specialization within agriculture, i.e., sources of comparative advantage in the primary agricultural sector and processed food of U.S. and major developed countries. In order to achieve this objective, neoclassical trade theory is drawn upon to derive export shares of gross national product in the agricultural and food processing sectors, as functions of factor supplies, productivity growth rates, and the technological linkages between the sectors. Empirically a twenty-year panel dataset of thirteen OECD countries is used to estimate models for the agriculture and food processing sectors. The basic hypothesis tested here is that comparative advantage of the food processing sector may be bolstered by increasing the level of agricultural technology (i.e. productivity growth).

The presented thesis contains seven chapters, starting with this introduction, and then followed by a review of literature, describing the evolution of trade theory and empirical research that has supported or refuted the theories. Also included in this chapter, is a section on agricultural trade theory and related empirical work, as well as a discussion of how this thesis adds to the research continuum. The third chapter describes the theoretical model used in this study, while the fourth chapter presents the empirical framework and estimation methods. A chapter on data and variables follows that discusses data collection, statistical methodology, and expected parameter signs. The sixth chapter presents the results of the estimation and gives insights into the relevance of each variable, while the final chapter summarizes the thesis and provides analysis of potential policy implications of the study.

Chapter 2: Review of Literature

2.1 Heckscher-Ohlin and Ricardian Trade Theory

Studies to explain the motivation for trade have primarily focused on one of two lines of theoretical reasoning, the Heckscher-Ohlin model or the Ricardian approach. The former suggests that trade occurs due to differences in factor endowment levels among countries, while the latter hypothesizes that trade results from differences in production technologies. To be more specific, the Heckscher-Ohlin model states that "a country will export the commodity that intensively uses its relatively abundant factor" (Markusen et al., 1995). Thus, a country with a large population of low-skilled labor will tend to export more labor-intensive goods than countries that are relatively capital abundant. Similarly, a country with a large arable land base is more likely to export agricultural commodities than a country with a small amount of arable land. From the basic Heckscher-Ohlin theory, also known as the *Factor Abundance Hypothesis*, three additional hypotheses evolved. First, *Factor Price Equalization* states that non-traded factors of production will have equal prices across countries when the goods produced by these factors are traded. The implication of this statement is that through trade, all countries will have equal access to fixed resources. Second, the *Stopler-Samuelson Theorem* establishes a direct link to the real return rate of a factor endowment through the price of the traded goods produced with that factor. Therefore, as the price of a commodity increases in world markets, the real return rate of the factor used to produce that commodity will also rise. Finally, the *Rybczynski Theorem* suggests that, assuming constant prices, if the supply of a factor endowment increases, the commodity which uses that factor most intensively will experience an increase in the production of that commodity, while the good that uses the factor less intensively will have a decline in output.

The Ricardian model focuses on the production technologies countries possess, contrary to the Heckscher-Ohlin model that assumes homogeneous production technologies across countries. Thus, Ricardian theory predicts that a country with a relatively more efficient production process of a particular commodity will specialize in the production of that commodity. This commodity will then be traded for goods in which the country has a comparative disadvantage in production. In theory, a country may specialize to the point that it produces only a few select products, using all available resources, and trades for products in which it has relatively poorer production technology. Modern Ricardian theory considers all possible sources of technological change. This is an extension of the original Ricardian theory, which attributed differences in technology solely to labor productivity differentials between countries.

2.2 Empirical Results Supporting Trade Theory

2.2.1 *Empirical Results of the Heckscher-Ohlin Model*

Though both models are intuitively appealing, their performance in empirical testing differs. The Heckscher-Ohlin model has been found to perform poorly under testing with empirical data. As the theory predicts, the US should export capital-intensive goods and import labor-intensive products, due to its relatively larger capital endowment. However, Leontief (1954) found that the US imported capital-intensive goods, suggesting that the US was capital poor and labor abundant. This observation became known as the Leontief Paradox. In 1959, Vanek attempted to explain the paradox by examining a third factor of production, natural resources, and their relevance to US imports. Vanek's theory says that natural resources and capital are complementary, and therefore, the apparent capital-intensity of US imports observed by Leontief may actually reflect the natural resource intensity of those goods. Under this scenario, the US is not capital poor, it is natural resource poor. However, Vanek's work did not clear the Heckscher-Ohlin model from the paradox completely. His results go on to conclude that labor is still more abundant than capital in the US.

Keesing (1966) and Kenen (1965) argued that the Leontief paradox was seen because labor was not categorized by skill, and that heterogeneity exists among country labor forces. Their work introduced some of the first research to estimate human capital, the value added to a product through advanced labor skills and/or education. Kenen estimated human capital and added it to physical capital, using a broad concept of capital, and found the US to be a net exporter of capital-intensive goods. Leamer (1980), using the same data in Leontief's study, also found US exports to be capital-intensive by altering the way in which capital to labor ratios were measured in trade. Leontief had used a capital to labor ratio in export and import substitutes, while Leamer suggested that the proper way to test the Heckscher-Ohlin model was to use the capital to labor ratio of net exports in relation to a country's share of the world income. Thus, a country's net exports of a service produced by any factor are positive, if the country's relative abundance of that factor is above its consumption ranking. Leamer's postulation implies that a country will export the services of the factors in which it is abundant, and import services produced by scarce factors, "when factor abundance is measured relative to a global standard." This result opened the possibility that the paradox never existed. However, even though an explanation for the paradox may have been achieved, this did not validate the Heckscher-Ohlin model. Leamer's theorem was not thoroughly tested against actual country and world factor endowments data until 1987, when the first comprehensive test of the factor proportions theory of Heckscher, Ohlin and Vanek (HOV) was conducted by Bowen et al., "The Multicountry, Multifactor Tests of the Factor Abundance Theory." This model predicted a relationship among three separate measurable items: trade, factor input requirements, and factor endowments. The result of the test, which used data on

367 goods, using 12 broad based resources traded among 27 countries, did not validate HOV. More recently, Trefler (1995) may have put to rest the exclusive use of HOV to explain trade in his well-noted paper, "The Case of the Missing Trade and Other Mysteries." This rigorous study used data from 33 countries, which accounted for 79 percent of world GNP, and used nine groups of factor endowments, and six categories of labor in a traditional HOV framework. The results of the test showed that the model performed poorly. This was a significant paper in that it provided a departure from the exclusive use of HOV, and turned current trade research to focus more closely on technological differences among countries to explain trade, as proposed by David Ricardo.

2.2.2 *Empirical Results of the Ricardian Model*

The primary proposition of the Ricardian model is that a country will export the commodity in which it has higher relative labor productivity (i.e. comparative advantage). One of the first tests of the Ricardian model was conducted by MacDougall in the 1950's, using data from 1937. MacDougall measured average labor productivities of the US and UK, and found that US labor productivity was twice that of the UK. With this finding in mind, it followed that the US should have an export advantage in products that were manufactured with the more efficient labor. This hypothesis was tested using export data on twenty-five products from the US and UK, which were exported to third party countries. The expected result held true for 80% of the observations, supporting Ricardo's theory, with the ratio of US exports to UK exports greater than one when the US held the 2 to 1 labor productivity advantage. Similar studies were conducted by Stern (1950, 1959), who also used the US and UK to test his empirical models. Stern's tests used data from 1950 and found that US wages were 3.4 times as large as the UK, suggesting the US had an comparative advantage in labor-intensive manufacturing. The results of the studies confirmed the Ricardian hypothesis, with 33 of the 39 studied sectors, indicating that the US did indeed have an export advantage over the UK.

Though these studies supported Ricardian theory, the tests were relatively simple, to which some discredit the results. In addition, other opponents point to the possibility that the increase in productivity may be attributed to better access to capital, and therefore, the observed labor productivity advantage may have come from the relatively large capital endowment of the US. Under this scenario, the studies' results support the Heckscher-Ohlin model. This point illustrates the difficulty that has been encountered in determining how to measure productivity, and more specifically, how to separate what proportion of growth is contributed by advances in technology, and what occurs as a result of increasing factor endowments. The testing of technological differences has been complicated due to lack of data in previous years. More recent literature studying technological change has focused greatly on total factor productivity (TFP) and its contribution to economic growth. However, with respect to explaining patterns of trade, TFP has had limited researchers. More often empirical studies have attempted to integrate technology's effect on trade into a Heckscher-Ohlin framework.

Dixit and Norman (1980) and Woodland (1982) have researched technological change and its consequences for trade. Their studies included holding technology as Hicks neutral, sector-specific, and also allowing for factor-biased change. Trefler (1993) offered an explanation for trade patterns due to technological differences using an HOV framework. The framework differed from the traditional HOV model in that factor price differences between countries, which occur as a result of technological differences, are incorporated. Having made this adjustment, the model performed well. In Trefler's 1995 article, he offered alternatives that accounted for technological differences between countries. Specifically, this was achieved by distinguishing between rich and poor countries, using purchasing power parities, and allowing each factor endowment parameter to vary according to the country's wealth. Trefler also offered a model that allowed investment levels to change between countries based on their income levels, and a model that identified Armington consumer product preferences (domestic vs. foreign production). The results of Trefler's studies suggested that a model allowing for Armington home-bias and neutral technological differences performed best. Further empirical credence is given to the Ricardian theory by Harrigan (1997). Harrigan used a flexible composite model, which jointly estimated the impact of differing technologies and differing factor supplies on international trade and specialization. The results of his study were large and significant, suggesting that indeed, Ricardian effects are an important source of comparative advantage. In addition, Harrigan's work supports the use of jointly estimating the impacts of technical change and factor supplies.

2.3 Research on Agricultural and Natural Resource Trade

2.3.1 *Defining Features of Agricultural and Natural Resource Trade*

Numerous authors have specialized their research to focus on trade as it pertains to the areas of agriculture and natural resources. Each of these areas has unique characteristics that distinguish them from other production sectors, and thus, separate branches of research have formed to handle the peculiarities of each sector. Agriculture differs from other sectors in that one of its primary inputs is land. On a country level the amount of arable land available does not change on it's own accord in the short-run. This is not to say it does not change, certainly urban and sub-urban development, government policies, and commodity prices affect the amount of land used in production. However, when compared to other factors of production such as capital and labor, which may be mobile and vary in abundance, the endowment of arable land is relatively constant. Agriculture also differs from other sectors in that governments have traditionally wielded substantial influence over the sector, complicating trade issues.

Natural resources offer their own distinguishing characteristics that affect trade. Some natural resources, such as minerals and fossil fuels are found in finite quantities, and thus, are exhaustible. This forces researchers to evaluate trade in a dynamic setting, accounting for current demand, as well as estimating future demand. Other natural resources are characterized by the biological constraints and variability of their growth. Optimal harvest rates and maintenance of future stocks are important factors that must be considered as trade is evaluated.

In the past, these two branches of economics were considered mutually exclusive (Sutton, 1988). However, as time has progressed, science has shown linkages between the two, often in the form of externalities. For example, intensive cropping may lead to soil erosion that lowers crop productivity and water quality. As the eroded soil enters streams and rivers, a portion of it settles in the spawning beds of fish, lowering the reproductive rate, and thus, the overall population. Now, not only must economists consider arable land as a natural resource that has a productive carrying capacity, they must also weigh the effect intensive cropping and resulting soil erosion have on other biological and economic systems. Another example offered by Segerson (1988), focuses on the effect government policies have on a country's competitiveness in world markets and thus, comparative advantage. Consider a policy such as banning the use of a pesticide or fertilizer in order to alleviate an environmental externality. A particular commodity, which once relied on that chemical, may then lose its comparative advantage and resulting market share. The effects of such a policy may be particularly exemplified if competing countries are not required to adopt similar policies. These are just two examples of several realizations that have come to light in recent years, and provided the impetus to merge research efforts of the two disciplines in the trade arena.

2.3.2 *Agricultural and Natural Resource Trade Theory and Empirical Work*

Consider first the Heckscher-Ohlin theory. Leontief's first test of the theory and resulting paradox may not have as great significance to agricultural trade as it had on other sectors, because Leontief explicitly left agricultural trade out of his analysis (Abbot and Haley, 1988). The issue of land may be of key importance to agriculture when estimating the Heckscher-Ohlin model, and determining whether comparative advantage is derived from land and land quality. As mentioned, researchers investigated the varying classes of labor quality, but little attention had been given to the role of land quality and potential effects it may have on comparative advantage (Haley and Abbot, 1986). However, in support of the Heckscher-Ohlin theory, natural resource economists (Harris, 1981, Kemp, 1980, 1984) have concluded that given an open economy with a relatively larger factor endowment of a non-renewable resource, that country would specialize in the production of resource-intensive goods, and hence export them, until the resource is exhausted, at which time production would switch to secondary products. This conclusion is consistent with the Heckscher-Ohlin theory, in that a country will export products made from factors in which it has a relatively larger endowment.

However, these results differ from the strict Heckscher-Ohlin theory in that production may be specialized as opposed to diversified (Kemp and Long, 1984).

As opposed to Leontief, Ricardo addressed the issue of land's immobility and recognized that rent accrues to land, and thereby, establishes a value for its scarcity (Abbott and Haley, 1988). The concept that land accrues rents is principally how land is valued in the Ricardo-Viner models of trade (Abbott and Haley, 1988). In this model trade is determined by consumers, who maximize utility facing world prices subject to the country's income, as found by solving the producer optimization problem. Kenen (1965, 1968), using a Ricardo-Viner specification, suggested that one of the problems with the traditional Heckscher-Ohlin theory was that capital was considered stagnant. He argued that the productivity of capital could be improved through decisions to invest in technology. His theoretic model also permits the option to view capital as mobile among countries. Jones (1971) also used the Ricardo-Viner framework to integrate land as a factor of production specific to agriculture due to its immobility, thus, providing one of the first specific-factors models. Simple forms of the specific-factor model using one specific factor per sector do not fare well, because they violate factor price equalization (Abbott and Haley, 1988). Other researchers (Krueger, 1974, Deardorff, 1984) varied the specific factors model to incorporate several commodities produced by each sector, allowing the specific factor to move among commodities in the sector, but not to commodities outside the sector. For example, land may be used to produce soybeans or corn, but not automobiles.

In regard to Ricardian technological change, Shultz (1964) advocates that technological change is embodied in factors of production as asserted by Solow. Recent work has continued along this line of thinking using the concept of total factor productivity (Ball et al., 1997). Gopinath et al., (1997) have found empirical evidence to support Ricardian theory. Their study used productivity growth, as measured by sectoral total factor productivity, in conjunction with prices and factor supplies to assess short- and long-run competitiveness of US and European agricultural sectors.

2.4 How this Research Relates to Previous Work

The review above provides a descriptive look at where trade theory and empirical trade research has been and the direction it is headed. It started with the primary Heckscher-Ohlin and Ricardian models and working through to recent efforts to combine elements of both models. This thesis lengthens the research continuum by using and extending the works of Harrigan, and Gopinath and Roe. This research specifically uses Harrigan's empirical framework and the agricultural/food processing linkages discussed by Gopinath and Roe, to understand how comparative advantage derived through technological advances in the agricultural sector may be transferred to the food processing sector.

CHAPTER 3: THEORETICAL FRAMEWORK

3.1 The Revenue Function and its Properties

The following section relies on *Applied Production Analysis* by Chambers (1988). The model chosen for this study is based on the maximization of a revenue function, subject to a bundle of given input endowments. The function is defined as $R(\mathbf{p},\mathbf{v}) = \max\{\mathbf{p}\cdot\mathbf{y} : y \in Y(\mathbf{v}), \mathbf{p} > 0\}$, where **p** is a vector of strictly positive output prices with dimensionality *n*, and **v** is a vector of strictly positive factor endowments with dimensionality *m*. Y(**v**) is a convex production set for a given vector, **v**, of factor endowments. A properly defined revenue function, where Y(**v**) is a producible output set, will satisfy the following properties;

1) $R(\mathbf{p},\mathbf{v}) \geq 0$;

2) $R(\mathbf{p},\mathbf{v}) \geq R(\mathbf{p}',\mathbf{v})$, where $\mathbf{p} \geq \mathbf{p}'$;

3) $R(\mathbf{p},\mathbf{v}) \geq R(\mathbf{p},\mathbf{v}')$, where $\mathbf{v} \geq \mathbf{v}'$;

4) $R(t\mathbf{p},\mathbf{v}) \geq tR(\mathbf{p},\mathbf{v})$ and $R(\mathbf{p},t\mathbf{v}) \geq tR(\mathbf{p},\mathbf{v})$ where $t > 0$;

5) R(**p**,**v**) is convex and continuous in **p**, and concave and continuous in **v**;

6) When R(**p**,**v**) is differentiable in **p** the revenue-maximizing output vector exists

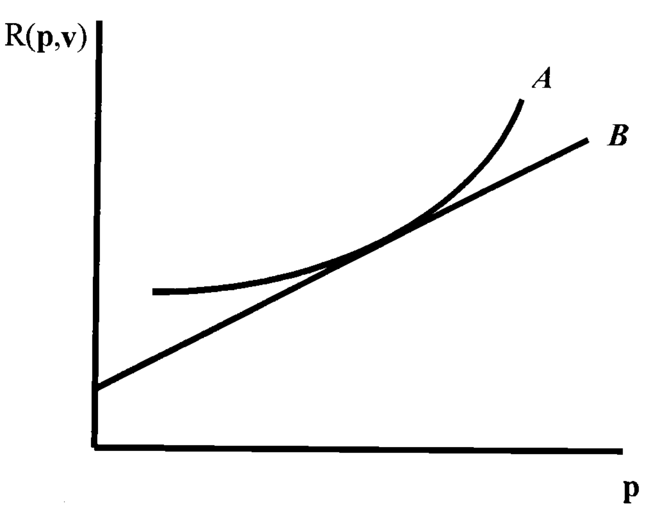
$$\mathbf{y}(\mathbf{p},\mathbf{v}) = \frac{\partial R(\mathbf{p},\mathbf{v})}{\partial p_i}.$$

7) When R(**p**,**v**) is differentiable in **v** the factor return vector exists

$$\mathbf{w}(\mathbf{p},\mathbf{v}) = \frac{\partial R(\mathbf{p},\mathbf{v})}{\partial v_j}.$$

The first property is straightforward; revenue can never be negative given non-negative prices and factor endowments. The second and third properties are similar in that revenue will always be at least as much as before, if there is an increase in either price or endowment quantity. Property four states that as long as all output prices or factor endowments increase proportionately, the revenue maximizing production choice will not change. This is to say that the revenue function is linearly homogeneous in output prices and linearly homogeneous in factor endowments. The revenue function is convex and continuous and therefore, as output prices increase, revenue will increase. Moreover, as output prices increase, a price-taking firm will increase production to capture the added rents available. The convex shape of the revenue function is due to revenue being a function of price. This is seen graphically in scenario ***A,*** shown in figure 3.1 below. At a minimum, the revenue function has a positive slope, the case when output mix is non-responsive to increases in price, scenario ***B.***

Figure 3.1 Convexity of the Revenue Function



In both cases, the revenue function exhibits continuity, which is to say that for any given price, a corresponding revenue is given. Moreover, continuity is important for properties six and seven, along with the requirement that $n \geq m$. Property six states that when R(**p**,**v**) is differentiable with respect to output price, **p**, there exists a unique revenue-maximizing output vector, (*Samuelson-McFadden lemma*). This can be explained using an example. Given price p', revenue can be expressed as $R(p',v) = p' \cdot y'$, where a vector of outputs, y', maximizes revenue given price p'. Knowing that Y(v) is independent of p, it is possible for output y' to be produced for any price vector; therefore, the following inequality exists, $R(p,v) \geq p \cdot y'$. Thus, a minimization problem can be defined as,

$L(y',p,v) = R(p,v) - p{\cdot}y'$, where the global minimum is at $p = p'$ (which is to say $R(p,v)$ has achieved maximum revenue). The first order conditions from the minimization of $L(y',p,v)$ yield the first part of the Samuelson-McFadden lemma,

$$\frac{\partial R(p',v)}{\partial p_i} = y_i .$$

According to property seven, the derivative of the revenue function with respect to a factor endowment gives the factor return for that endowment. Factor returns are the increases in revenue associated with an increase in the quantity of a factor endowment,

$$\frac{\partial R(p',v)}{\partial v_i} = w_i .$$

Given these properties we turn to the second-order conditions. When $R(p,v)$ is twice differentiable the properties given above lead to the following observations:

1. $\nabla_p y(\mathbf{p},v) = \nabla_{pp} R(\mathbf{p},v)$, a positive semi-definite matrix;

2. $\nabla_v w(p,\mathbf{v}) = \nabla_{\mathbf{vv}} R(p,\mathbf{v})$, a negative semi-definite matrix;

3.a. $y(t\mathbf{p},\mathbf{v}) = y(\mathbf{p},\mathbf{v})$, $t > 0$, homogeneity of degree zero in output prices;

b. $y(\mathbf{p},t\mathbf{v}) = ty(\mathbf{p},\mathbf{v})$, $t > 0$, homogeneity of degree one in factor endowments;

4.a. $w(t\mathbf{p},\mathbf{v}) = tw(\mathbf{p},\mathbf{v})$, $t > 0$, factor returns are linearly homogeneous in output prices;

b. $w(\mathbf{p},t\mathbf{v}) = w(\mathbf{p},\mathbf{v})$, $t > 0$, factor returns have homogeneity of degree zero in factor endowments.

The interpretation of the first statement is that as the price of an output rises, the production of that output will increase. The second statement says that as the quantity of a factor endowment rises, the price of that factor endowment will fall. Statements 3.a and 3.b describe the degree of homogeneity of the optimal production level obtained from the Samuelson-McFadden lemma. The first of these states that given an increase in output prices by some factor *t*, output will remain unchanged, given the level of endowments **v**. The next statement says that as endowments are increased by a factor *t*, output will increase by the same proportion given output prices **p**. The final two statements are concerned with the homogeneity of the factor returns. First, 4.a says that as output prices are increased by a factor *t*, factor returns will increase by *t* as well. While 4.b says that if the level of all endowments changes by a factor *t*, factor returns remain unchanged.

3.2 The GNP Function and Trade

In trade theory the basic revenue function is commonly referred to as a gross domestic product (GDP) function, which can be further extended to a gross national product (GNP) function. This extension follows Kohli's (1991) work to include international trade. To begin with, we consider the production of goods in vector **y** to include output specific for domestic consumption and output designated for sale abroad. Also contained within vector **y** are imported products, which lead to the partitioning of the output vector, $\mathbf{y} \equiv (\mathbf{y_d},\mathbf{y_x},\mathbf{y_m})$. However, imported goods, $\mathbf{y_m}$, are not ready for final sale. This is to say that imported goods are intermediate inputs, which must first flow through a domestic value-adding process before final sale. Likewise, exports are also expected to pass through foreign processing channels before final sale to foreign consumers. This processing, at minimum, is likely to include elements of packaging, labeling and other importer marketing prior to retail sale (Kohli, 1991). A corresponding vector of output prices exists, which further exemplifies the disparity between goods destined for export and domestic consumption, $\mathbf{p} \equiv (\mathbf{p_d},\mathbf{p_x},\mathbf{p_m})$.

Now modeling these components within the GDP function we obtain the following GNP function;

$$G\,(\mathbf{p_d},\mathbf{p_x},\mathbf{p_m},\mathbf{v}) = \text{Max } \mathbf{p_d}\cdot\mathbf{y_d} + \mathbf{p_x}\cdot\mathbf{y_x} + \mathbf{p_m}\cdot\mathbf{y_m}$$

$$\text{subject to } \mathbf{y} \in Y(\mathbf{v}),\ \ \mathbf{p}, \mathbf{y} \in \mathbb{R}^{n+},\ \mathbf{v} \in \mathbb{R}^{m+}.$$

The imported quantity of goods is negative, $\mathbf{y_m} < 0$, and the properties of the revenue function continue to hold. Using this information and the Samuelson-McFadden lemma, vectors of output supplies for each type of output may be derived by differentiating the GNP function with respect to export, import, and domestic output prices respectively.

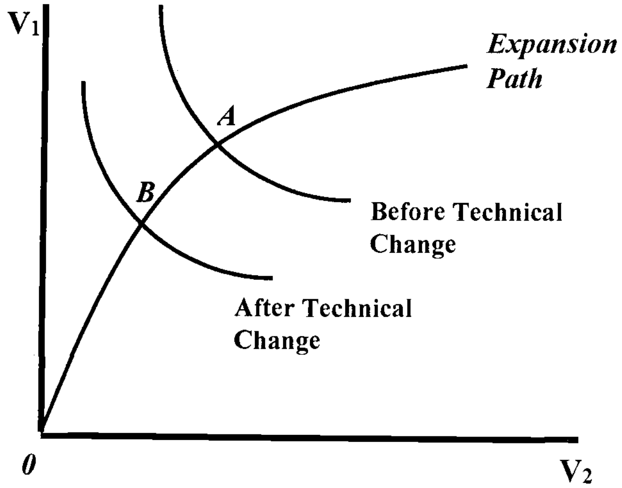
$$\frac{\partial GNP}{\partial \mathbf{p_d}} = y_d(\mathbf{p_d}, \mathbf{p_x}, \mathbf{p_m}, \mathbf{v}),$$
$$\frac{\partial GNP}{\partial \mathbf{p_x}} = y_x(\mathbf{p_d}, \mathbf{p_x}, \mathbf{p_m}, \mathbf{v}),$$
$$\frac{\partial GNP}{\partial \mathbf{p_m}} = -y_m(\mathbf{p_d}, \mathbf{p_x}, \mathbf{p_m}, \mathbf{v}).$$

3.3 Technological Change in the Framework of a GNP Function

The GNP function accounts for output growth attributable to increases in factor endowments and changes in prices. However, growth derived from technological change is not accounted for in its current form. Integration of technological change in this model follows the conceptual work of Woodland (1982), and Dixit and Norman (1980), and empirical applications by Kohli (1991) and Harrigan (1997). More specifically, Hicks-neutral technical change can be incorporated within the GNP function framework.

Technical change is considered to be Hicks-neutral when marginal rates of substitution along an expansion path are not dependent on time. Isoquants shift as a result of time, but the shape of the isoquants relative to one another remains constant. A graphical example readily illustrates this concept. The expansion path in figure 3.2 uses the production factors V_1 and V_2. Technical change moves the isoquant toward the origin along the expansion path from point *A* to *B,* maintaining the same marginal rate of substitution.

Figure 3.2 Hicks-Neutral Technical Change



It is clear that for technical change to be neutral, time must be separable from the factor endowments V_1 and V_2. An example can further illustrate how technology may be modeled. Consider two production functions using the same input vector, **v**, described as $\mathbf{y}_a = \mathbf{y}_a(\mathbf{v}_a)$ and $\mathbf{y}_b = \mathbf{y}_b(\mathbf{v}_b)$. The production functions differ only in the technology used. Production process **a** uses technology represented by the parameter θ_a, while production process **b** uses technology represented by θ_b. Thus, the production functions are $\mathbf{y}_a = \mathbf{y}_a(\mathbf{v}_a , \theta_a)$ and $\mathbf{y}_b = \mathbf{y}_b(\mathbf{v}_b , \theta_b)$. Because technology is separable from inputs in Hicks-neutral technology, the functions may be rewritten as $\mathbf{y}_a = \theta_a \mathbf{y}_a(\mathbf{v}_a)$ and $\mathbf{y}_b = \theta_b \mathbf{y}_b(\mathbf{v}_b)$, respectively. If $\theta_a = \theta_b$, then the technologies used provide equivalent efficiency.

However, if the technology used in production process **a** is more efficient than that used in production process **b**, then $\theta_a > \theta_b$. Therefore, given equal inputs, the quantity produced in process **a** will be greater than that produced by process **b**, $\mathbf{y}_a > \mathbf{y}_b$. Using this information, integration of technology into the GNP function takes the following form, $G(\mathbf{p},\mathbf{v},\theta)$, where θ represents Hicks-neutral technical change.

Chapter 4: Empirical Framework

4.1 Functional Form

Use of the GNP function to model international trade is well established as described in the section above. Understanding the theoretical framework, we now turn to the model used in empirical estimation. Gopinath and Roe (1997), following the work of Diewert, have shown that GDP functions are an aggregate of sectoral GDP functions. This study utilizes that knowledge and focuses on the agriculture and food processing GNP functions. The objectives of this thesis are to determine (i) how technology and factor endowments affect patterns of agricultural trade, (ii) and to determine if comparative advantage, derived through technological change in the agriculture sector, is passed on to the food processing sector.

The flexible functional form chosen for this research is the transcendental logarithmic (translog) functional form, as described by Chambers (1988). The translog is a second-order approximation of the true unknown function. The general form of the translog is described as follows:

$$\ln y = \beta_{oo} + \sum_{i=1}^{N} \beta_{oi} \ln x_i + \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \gamma_{ij} \ln x_i \ln x_j + \varepsilon , \qquad (4.1.1)$$

where $\gamma_{ij} = \gamma_{ji}$ for i, j ≥ 1, and where restrictions such as linear homogeneity in x may be placed on the parameters (γ's). In the context of the GNP function for agriculture the translog functional form for time t, $G(\mathbf{p}_t,\mathbf{v}_t,\theta_t)$, takes the following form:

$$\begin{aligned}\ln G(p_t, v_t, \theta_t) = \alpha_o + &\sum_{j=D,X,M} \alpha_j \ln p_{jt} + \frac{1}{2} \sum_{j=D,X,M} \sum_{h=D,X,M} \alpha_{jh} \ln p_{jt} \ln p_{ht} \\ &+ \sum_{i=R,L,K} \beta_i \ln v_{it} + \frac{1}{2} \sum_{i=R,L,K} \sum_{s=R,L,K} \beta_{is} \ln v_{it} \ln v_{st} + \sum_{j=D,X,M} \sum_{i=R,L,K} \gamma_{ji} \ln p_{jt} \ln v_{it} \\ &+ \delta_1 \ln \theta_t + \frac{1}{2} \delta_2 (\ln \theta_t)^2 + \sum_{j=D,X,M} \phi_j \ln p_{jt} \ln \theta_t + \sum_{i=R,L,K} \tau_i \ln v_{it} \ln \theta_t,\end{aligned} \tag{4.1.2}$$

where indices j and h = D, X, M denote domestic output for domestic consumption, exports, and imports respectively. The factor endowments of the country are denoted by indices i and q = R, L, K representing land, labor and capital stock respectively. The properties of the GNP function dictate linear homogeneity in prices and linear homogeneity in factor endowments, shown as $\sum_{i=R,L,K} \frac{\partial \ln G(\mathbf{p}_t, \mathbf{v}_t, \theta_t)}{\partial \ln p_t} = 1$ and $\sum_{i=R,L,K} \frac{\partial \ln G(\mathbf{p}_t, \mathbf{v}_t, \theta_t)}{\partial \ln v_t} = 1$, respectively. Through mathematical manipulation the following parametric restrictions emerge, $\sum_{j=D,X,M}^{N} \alpha_j = 1$, $\sum_{i=R,L,K}^{N} \beta_i = 1$ and, $\sum_{j=D,X,M}^{N} \alpha_{jk} = 0$, $\sum_{j=D,X,M}^{N} \gamma_{ji} = 0$, $\sum_{j=D,X,M}^{N} \phi_j = 0$, as shown by Kohli (1991) and outlined by Harrigan (1997). For purposes of symmetry $\beta_{is} = \beta_{si}$ and $\gamma_{ij} = \gamma_{ji}$ where $i \neq s$, and $i \neq j$ respectively.

4.2 Share Equations

Now following along the lines of the Samuelson-McFadden lemma we differentiate with respect to the price of an output, in this case the price of exports, $\mathbf{p}_\mathbf{x}$.

$$\frac{\partial \ln G(\mathbf{p}_t, \mathbf{v}_t, \theta_t)}{\partial \ln \mathbf{p}_{\mathbf{x}t}} = \frac{p_{xt} y_{xt}}{p_{dt} y_{dt} + p_{xt} y_{xt} + p_{mt} y_{mt}} = \\ s_{xt} = \alpha_{ox} + \sum_{j=D,X,M} \alpha_{jx} \ln p_{jt} + \sum_{i=R,L,K}^{N} \gamma_{ix} \ln v_{it} + \tau_x \ln \theta_t . \qquad (4.2.1)$$

Note that this result is different from the result given by differentiation of the revenue function by price. By taking the natural log of the GNP function and then differentiating with respect to an output price, the share equation for that output is given. Equation 4.2.1 above specifies the agricultural export share of GNP as a function of prices, factor endowments, and technology. That is, equation 4.2.1 follows from the derivative properties of $G(\mathbf{p}_t,\mathbf{v}_t,\theta_t)$, and yields the share of exports in GNP, where GNP is equal to domestic production and net exports.

The GNP framework described above can be expanded to include a vector of intermediate inputs, as described by Woodland (1982). The case of the food processing sector will utilize this approach. Specifically, the major intermediate input used by the food processing sector is the bulk commodity produced by the agricultural sector. The addition of the intermediate input to food processing sector expands the price vector to $\mathbf{p} \equiv (\mathbf{p}_\mathbf{d}, \mathbf{p}_\mathbf{x}, \mathbf{p}_\mathbf{m}, \mathbf{p}_\mathbf{I})$, where $\mathbf{p}_\mathbf{I}$ represents the price of the bulk commodities. The food processing GNP function is then established as, $G(\mathbf{p}_\mathbf{d}$,

p$_x$, **p**$_m$, **p**$_I$, **v**, θ). Again using a translog functional form with time subscripted as *t*, we differentiate lnG(**p**$_t$,**v**$_t$,θ$_t$) with respect to **p**$_x$ to obtain the food processing export share equation:

$$\frac{\partial \ln G(\mathbf{p}_t, \mathbf{v}_t, \theta_t)}{\partial \ln \mathbf{p}_{xt}} = \frac{p_{xt} y_{xt}}{p_{dt} y_{dt} + p_{xt} y_{xt} + p_{mt} y_{mt} + p_{It} y_{It}} = \tag{4.2.2}$$
$$s_{xt} = \alpha_x + \sum_{j=D,X,M,I} \alpha_{jx} \ln p_{jt} + \sum_{i=R,L,K} \gamma_{ix} \ln v_{it} + \tau_x \ln \theta_t .$$

The technology parameter in equation 4.2.2 differs from that of the agricultural share equation by containing the price of bulk agricultural commodities. As theory predicts, technological growth in the agricultural sector will increase production of agricultural products. This precipitates an increase in the supply of bulk products causing their price to fall (assuming a relatively inelastic demand). Therefore, the price of the intermediate good, **p**$_I$, is a function of the technology used to produce it, and may be represented by **p**$_I$(θ$_a$) (Woodland, 1982).

4.3 Estimable Equations

Before proceeding to the final forms of the share equations, it is important to consider the constraints in assembling a multi-country panel dataset to properly estimate the model. The dataset must be complete and consistent for both the agricultural and processed food sectors across the panel. Three modifications to equations 4.2.1 and 4.2.2 will lead to their estimation. First, the export shares at time *t* are not likely to change vastly from previous years and there arises a need to model sluggish adjustment. Hence, a lagged dependent variable is included in the model. Second, because all revenues (domestic, export, and import) are represented in a common currency (US$), the share equations include real-effective exchange rates as an explanatory variable. Finally, the level of technology, θ_c, is not available at this time on a time-series basis. Furthermore, assembling an inter-spatial database to derive relative levels of technology is beyond the scope of this study. However, relative rates of growth in technology may be used as a proxy. Assuming country c_1 and c_2 have different base levels, the ratio of relative TFP growth rates θ_{c1}/θ_{c2} would provide insights as to the convergence (divergence) of technologies. Thus, increases (decreases) in θ_{c1}/θ_{c2} will reflect either convergence or gains to country c_1 relative to c_2 (Gopinath et al., 1997).

With this information in hand, we more accurately specify the share equations given the data limitations. Using c and t subscripts to indicate countries and years we obtain the following export share equation for agriculture;

$$s_{xct} = \alpha_x + \lambda_{xjt} + \sum_{i=R,L,K}^{N} \gamma_{ix} \ln \frac{v_{ict}}{v_{mct}} + \tau_x \ln \frac{\theta_{ct}}{\theta_{US,t}}, \qquad 4.3.1$$

where $\sum_{k=D,X,M}^{N} \alpha_{kx} \ln \frac{p_{kct}}{p_{mct}}$ is reduced to a time-dependent parameter, λ_{xct}, thereby focusing on the effects of the technology and factor endowments.

The processed food export share equation is derived in a similar manner. However, the technology parameter has been separated into two components to account for growth due to technological change within the processed food sector, and growth due to technological change passed on from the agricultural sector through price as previously described. Using c, t and I subscripts to indicate countries, years, and intermediate inputs we obtain the following export share equation for processed food,

$$s_{xct} = \alpha_x + \lambda_{xct} + \sum_{i=L,K}^{N} \gamma_{ix} \ln \frac{v_{ict}}{v_{mct}} + \tau_x \ln \frac{\theta_{ct}}{\theta_{US,t}} + \psi_{Ix} \ln \frac{\theta_{Ict}}{\theta_{I,US,t}}. \qquad 4.3.2$$

Note that the inputs used in the processed food sector differ in that land, R, is no longer a significant variable used in the production process. Through the identification of the technology components, advances due to technological change from the intermediate input are shown as an explanatory variable in the share equation of the food processing sector, as seen in the last term, $\psi_{Ix} \ln \frac{\theta_{Ict}}{\theta_{I,US,t}}$.

Use of this equation provides insights into two important aspects with regard to technology. First, it can be seen through the share equation that technology directly affects trade. Along the lines of Ricardian theory, differences in technological progress determine trade flows between countries, here expressed in terms of varying export shares of GNP. The interpretation of this is that as θ_c for a given country becomes relatively larger than that of other countries, the given country will have a larger export share, *ceteris paribus*. However, knowing that not all countries are equal, it is not feasible to ascertain the measures of country export shares based on the relative size of θ_c alone. The second issue with regard to trade is that by using an intermediate input, a linkage is established between the primary producing sector and the value-added sector through technology. More precisely comparative advantage derived from relatively greater technological growth rates in the primary sector can be transferred to the value-added sector through price reductions. As θ_l becomes larger relative to other countries, more of the comparative advantage in agriculture is being transferred to the value-added sector. This results in greater export performance of the value-added product, seen as increases in relative export share.

4.4 Estimation Method

4.4.1 *Model Specification*

There are two common methods of estimation available for cross-section time-series data: the random-effects model (error component model), and the fixed-effects model (least-squares dummy variable model). The difference between the two approaches is that one assumes that effects associated with omitted explanatory variables are randomly distributed across the cross-section, while the other assumes the effects are specific to individuals within the cross-section. Kmenta (1986) describes the random-effects model as having a regression disturbance with three independent error components: one associated with cross-sectional units, another handling disturbances in time, and a third that varies in both cross-sections and time. However, a two component error term is more commonly used, which has one term to describe cross-sectional variation of averages over time, and one to describe variation around the cross-sectional averages over time. In either the two or the three component cases, a generalized least-squares (GLS) framework is used to model the effects.

The fixed-effects model is similar to that of the covariance model in that each cross-sectional unit has a distinctive intercept. However, the fixed-effects model differs from a true covariance model in that dummy variables are not used for each time period, as is the case of the covariance model (Kmenta, 1986). Inclusion of the dummy variables occurs in an ordinary least-squares (OLS) framework. The justification for using the fixed-effects method, as opposed to the random-effects model, is that relevant explanatory variables that are omitted from the model do not change over time (Kmenta, 1986). Note that the omitted variables may also be those that change over time but remain constant over the cross-section.

Having explained the difference between the two models, the question of which method to use arises. Mundlak specifically addresses this question and concludes that the choice between random-effects and fixed-effects models or a combination of both is "arbitrary and unnecessary" (1978). He reasons that the effects can be assumed as random from the beginning, and that the fixed-effects model is a "conditional inference, that is, conditional on the effects that are in the sample." However, Hausman points out that the choice of specification rests on two considerations, a logical consideration and a statistical consideration. The logical consideration looks to see whether it is reasonable to assume the individual effects u_i are drawn from an independently random distribution. If this proposition is true, then u_i, the individual effect of country i, may be exchanged with u_j, the individual effect of county j (i.e. $u_i = u_j$). If country i represents the United States and country j represents Cuba the logical consideration may rule out the assumption that the effects are equal. The statistical consideration is to compare the bias and efficiency of the estimators. As Mundlak describes, when the model is properly specified, the GLS estimator is identical to the OLS estimator. Based on this equality, Hausman developed a specification test to determine whether the fixed- or random-effects model should be used, based on the possibility that the random-effects model may be misspecified. If the individual effects, u_i, may be considered random and independent from the explanatory variables X_{it}'s, then the conditional mean of u_i is equal to zero, i.e. $E(u_i \mid X_{it})=0$. A violation of this assumption indicates that the random-effects estimator is biased and inconsistent. If the random-effects estimator is biased and inconsistent then the fixed-effects estimator, which in the asymptotic case is unbiased and consistent, becomes the efficient estimator. The test developed by Hausman, to determine whether misspecification is present in the random-effects model, starts with the null hypothesis that the individual effects are independent. Thus, when the model is correctly specified there is no statistical difference between the GLS and OLS estimator, here represented as, $\hat{q} = \hat{\beta}_{OLS} - \hat{\beta}_{GLS}$, where $\hat{q}$ will be near zero when the null hypothesis holds. Through mathematical manipulation $V(\hat{q}) = V(\hat{\beta}_{OLS}) - V(\hat{\beta}_{GLS})$ can be obtained, and the following specification test derived from $m = \hat{q}'\hat{M}(\hat{q})^{-1}\hat{q}$ where $\hat{M}(\hat{q}) = (X'Q_e X)^{-1} - (X'\hat{\Omega}X)^{-1}$ and M follows a chi-squared distribution with k degrees of freedom (k equal to the number of parameters).

4.4.2 *Homogeneity Restrictions*

The revenue function is characterized by having linear homogeneity of factor endowments and output prices as previously define in the theoretical framework. Following Kohli, when the revenue function is differentiated with respect to an output price, the conditions $\sum_{i=R,L,K} \tau_i = 0$ and $\sum_{j=D,X,M} \phi_j = 0$ are required in order for the share equation to be linearly homogeneous in factor endowments and output prices. In the agricultural share equation, the factor endowments have this restriction imposed by dividing arable land and capital stock by labor. Thus, $\ln(\sum_{i=R,L,K} \tau v_i) = \tau_R \ln v_R + \tau_L \ln v_L + \tau_K \ln v_K$ becomes

$\ln(\sum_{i=R,K} \tau v_i) = \tau_R \ln \frac{v_R}{v_L} + \tau_K \ln \frac{v_K}{v_L}$, imposing the restriction $\tau_R + \tau_L + \tau_K = 0$. The food processing share equation has the homogeneity restriction in factor endowments imposed by dividing capital stock by labor. The price component in both share equations has been reduced to a time-dependent variable, focusing on the effects of the technology and factor endowments.

The homogeneity restriction may be tested with a simple F-test between restricted and unrestricted models, where the null hypothesis is that the restriction is true. The form of the F-test used in this analysis was

$F[J,n-k]=\dfrac{(R_u^2-R_r^2)/J}{(1-R_u^2)/(n-k)}$, where J is equal to the number of restrictions, n and k are equal to the number of observations and number of explanatory variables respectively, and u and r represent the unrestricted and restricted models, respectively.

4.4.3 Rate of Adjustment

As changes occur in prices, endowment quantities, or technology there may be a lag in the production process as input ratios are adjusted. In order to capture the rate of adjustment a lagged dependent variable is used in the shares of exports in GNP. However, in using a one-period lag, the dependence of regressors (lagged dependent variable) and the error term causes the OLS estimator to be downward biased and inconsistent (Hsiao, 1986). By instrumenting the one period lagged dependent variable with a two-period lagged dependent variable, the estimator becomes consistent. The value of the parameter estimate on the lagged variable may be used to determine the rate of adjustment. An estimate close to zero indicates that adjustment occurs quickly, while an estimate closer to one represents slow adjustment in response to changes in technology, prices, or endowment quantities.

Chapter 5: Data and Variables

5.1 Structure and Sources

The panel dataset used for this analysis includes thirteen OECD countries over the years 1974-95. The countries are; Australia, Belgium, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, Norway, Sweden, the United Kingdom, and the United States. The data are consistent in values and statistical methodology used in the data collection. The sources of the data include three OECD databases: the *International Sectoral Database* (ISDB), the *Structural Analysis Database* (STAN), and *the Economic Accounts for Agriculture*. Trade data were provided by the Economic Research Service of the US Department of Agriculture (ERS/USDA). Arable land data are from the Food and Agriculture Organization's Statistical Database, while data on the real-effective exchange rates were collected from the International Monetary Fund's *Financial Statistics Yearbook*.

All of the countries are categorized as developed, with European Union members accounting for eight of the thirteen. Less developed countries were not included in the analysis due to lack of information available to complete the detailed level of data needed to perform the analysis. Even within developed countries such as Korea, Spain, and New Zealand, finding data consistent with the other countries over the entire timeframe was not possible. The year 1974 was the furthest back for which consistent data could be found for all thirteen countries. It is important to note that due to use of a two-year lag of the dependent variable, 1976 is the first year used in estimation.

5.2 Description and Compatibility

5.2.1 *Output and Input Data*

Final agriculture and food processing production data were obtained from the OECD *Economic Accounts for Agriculture*, and STAN databases respectively. These databases have been designed specifically to conduct cross-country analysis and therefore, the data are consistent in statistical methodology across all countries with values given in nominal US dollars. Final agricultural output includes the value of all crops and livestock before processing. This differs from harvest output, in that final output excludes intra-branch consumption and losses between harvest and utilization or storage. Food processing final output data include all commodities that undergo a value-adding process readying the product for final consumption. Beverages and tobacco are also included in the value of final food output in addition to processed food. Production data were complete for all countries and all years except for the 1995 agricultural final output of Japan. This value was estimated using the Least Squares Growth Rate (LSGR) for the years 1974-94 (World Bank, 1997). To obtain this growth rate a regression is run on the natural log of the available data, with the independent variable being time. The parameter estimate obtained is then subtracted from one and exponentiated giving the growth rate. This in turn is multiplied by the last year data is observed to provide the estimate for the following year. For further details on this method see the 1997 World Development Report (World Bank, 1997).

Turning to input data, sectoral gross value-added data and labor compensation data for agriculture and food processing were obtained from the *OECD-ISDB*. This data describe the value added to a product by producers including compensation to employees, operating surplus, consumption of fixed capital, and the excess of indirect taxes over subsidies. The data are consistent in value denomination and statistical methodology. The *ISDB* manual provides complete statistical methodology descriptions for each country and data-series. The next three variables; capital stock, employment, and arable land, are country factor endowments for both agriculture and food processing. Sectoral gross capital stock data and employment data were acquired from the ISDB, which has been specifically designed to aid in the calculation of capital productivity, labor productivity, and total factor productivity indices at the sector level.

First we consider gross capital stock, which is given in 1990 US dollars. The measure of gross capital stock is the total amount of available capital assets in the respective sectors and countries. When possible actual levels of capital stock were used, however, this was not always possible because many countries do not keep detailed information of stock levels. In instances when the stock data were not available the OECD made estimates using perpetual inventory models with gross capital stock formation data. Details of this method are available in the ISDB manual. Several countries however, required further estimations to complete their data-series. In the agricultural sector four countries required estimation to complete their respective time-series; Germany, Sweden, US, and Denmark. Germany and Sweden were missing the 1995 value, which was estimated using LSGR over 1960-94 and 1970-94 respectively. Estimations for 1994-95 were made for the US and 1993-95 for Denmark using LSGR. Within the food processing sector six countries required estimations for gross capital stock; Germany, Italy, Netherlands, Sweden, US, and Denmark. Germany, Italy, and Sweden each were missing the 1995 value, while the US and Denmark each required estimations for 1994-95, and 1993-95 respectively. Estimates for these countries were done using LSGR. The Netherlands had missing data for the years 1975-84. In this situation gross capital stock formation was used as a proxy for gross capital stock. The correlation between the existing gross capital stock and stock formation over the periods that overlapped (1984-94) was 90.3%, indicating strong correlation between the time-series and a good proxy. LSGR was then used to estimate the 1995 value over the timeframe 1975-94.

Secondly, employment data describe the total employment in an sector as opposed to the number of people employed. This definition includes working proprietors, unpaid family workers, and home workers as well as employees. It is also important to note that workers need not be residents of the employing countries. Therefore, migrant workers are included in the total employment data. The data set for food processing labor were complete, while three countries were missing values for agricultural labor: Germany, Sweden and the UK. Germany and Sweden each required only one estimation for 1995, which were estimated over 1960-94 and 1970-94 respectively. The UK agricultural labor data is from the International Labour Organisation for the years 1975-93 and estimated values for 1994-95 using LSGR.

Finally, arable land data from FAO are given in hectares and defined as both fields for cropping and pasture land for grazing. The data are consistent and complete for all 13 countries. Arable land includes temporarily fallow land (less than 5 years), grazing meadows, gardens, as well as permanent cropping acreage. It is worth noting that arable land defined in this manner is not equivalent to land that is potentially cultivable.

5.2.2 *Trade Data*

Data on imports and exports of agricultural commodities and processed food goods were provided by ERS-USDA. These data were disaggregated into four categories: fresh horticulture, bulk commodities, intermediate processed foods, and finished processed foods. As in the final output data, fishery and forestry data are not included in the agriculture or food processing data. The categories of fresh horticulture and bulk commodities were combined to create the agricultural trade data, while intermediate and finished processed foods were combined for the processed food trade data. The data series was complete for all countries, with values given in nominal US dollars.

A real-effective exchange rate index is based on the relative consumer prices and was available in the IMF International Financial Statistics yearbook. This index was chosen over others because it is based on data from 20 countries, including the 13 used in this analysis. In addition, it is weighted using disaggregated trade data for both primary products and manufactured goods. Other comparable indices either did not include all the countries in the analysis or did not use data on primary products.

5.2.3 *Total Factor Productivity*

The final data-series, TFP, represents technological change, which occurs within each sector. The change in total factor productivity is calculated as value-added divided by the share-weighted average of the product of total employment and gross capital stock using the standard form of a Cobb-Douglas production function. Multiplying labor compensation by the ratio of total employment to total employees and dividing by value-added derives the labor share-weight. Using this employment ratio allows the share to account for self-employment. This calculated TFP data are available from the OECD-ISDB for both the agriculture and food processing sectors. For further details on the methodology used in the calculation refer to the ISDB User's Guide (1997). This variable required a number of estimations which were based upon computation of the TFP growth rate, calculated using existing values of sectoral employment, capital stock, value-added and previous year's TFP level. Germany, Italy, Netherlands, Sweden, UK, US, and Denmark all had missing TFP observations.

The following table (5.1) lists the mean values of the variables used in estimation over the years 1974-1995. Agricultural and food processing labor are given in thousands of employees, while agricultural and food processing gross capital stock are presented in millions of 1990, US dollars. Arable land is given in thousands of hectares. The real-effective exchange rate index has a base value of 100, while the total factor productivity indices have a base values of one.

Table 5.1: Variable Means by Country (1974-1995)

	Ag Labor Employees (1,000)	*Food Labor Employees (1,000)*	*Ag Cap. Stock (1990 US$ mil.)*	*Food Cap. Stock (1990 US$,mil.)*	*Arable Land (Ha, 1,000)*	*Real Exchange Rate Index*	*Ag TFP Index*	*Food TFP Index*
Australia	412,498	177,793	36,662	13,807	45,639	116.9	0.903	0.944
Belgium	103,188	105,755	8,816	8,972	800	102.2	0.937	0.951
Canada	572,600	260,797	56,183	16,377	45,559	106.4	0.866	1.015
Denmark	167,589	90,763	24,132	8,862	2,572	97.2	0.778	0.905
France	1,531,145	585,815	77,678	56,579	17,802	99.3	0.827	0.992
Germany	1,184,252	865,100	141,900	65,294	11,915	101.5	0.844	0.945
Italy	2,549,550	400,530	193,900	38,950	9,092	90.9	0.995	0.924
Japan	6,542,550	1,533,700	341,150	77,066	4,195	86.8	0.903	1.113
Netherlands	266,594	165,651	26,135	16,609	834	99.5	0.856	0.935
Norway	145,750	52,180	17,358	5,716	860	98.7	0.956	1.194
Sweden	197,528	82,348	15,720	6,109	2,896	106.0	0.813	1.030
UK	610,420	638,015	40,197	48,267	6,718	105.2	0.888	0.928
US	3,124,900	1,678,100	445,950	188,950	186,927	101.4	0.789	0.955

Chapter 6: Results

6.1 Test Results

6.1.1 *Homogeneity*

The model was run independently for agriculture and food processing share equations. The revenue function is linearly homogeneous in prices and factor endowments, therefore, the share equation must be homogeneous of degree zero in factor endowments. In order to test this restriction parameter estimates were obtained from running regressions on both the restricted and unrestricted the share equations. Having obtained these results an F-test was performed to determine if the restriction was valid using the R^2 values of the regressions. Section 1 of table 6.1 shows that the restriction cannot be rejected for the food processing share equation as the calculated statistic, 3.4795, is less than the critical value, 3.8783. However, the agricultural calculated statistic, 4.1062, is larger than the critical value indicating that the null hypothesis is rejected and the restriction does not hold true in the agricultural model.

6.1.2 *Specification*

The second test performed was the Hausman specification test, which was described in section 4.4.1. This test was conducted to determine whether or not the random-effects model was correctly specified. If individual country effects are indeed random and uncorrelated with the regressors in nature, then the random-effects model will provide the best estimates. On the other hand, if the country effects are correlated, then the fixed-effects model generates better parameter estimates. Sections 2 and 3 of table 6.1 describe the Hausman test results for the homogeneity restricted and unrestricted cases. Considering first the homogeneity restricted models, it can be seen that for both agriculture and food the calculated Hausman statistics, 73.74 and 83.76 respectively, are greater than the critical chi value, 12.59. This indicates the null hypothesis, that the individual country effects are uncorrelated (i.e. H_0: $E(X'e) = 0$ for the random-effects estimator), should be rejected, and that the fixed-effects model provides better specification. This result is also seen in the unrestricted case, as the Hausman statistics for agriculture, 67.81, and food, 81.46, are larger than the critical chi value, 12.59.

Table 6.1: Hypothesis Testing

I. Testing Restrictions	
F-Test	H_o: $\alpha_R + \alpha_K + \alpha_L = 0$
Agriculture	4.1062
Food	3.4795
Critical Value	3.8783
II. Restricted Model	
Hausman Test	H_o: $E(X'e) = 0$ *for GLS Estimator*
Agriculture	73.74
Food	83.76
Critical Chi Value	12.59
III. Unrestricted Model	
Hausman Test	H_o: $E(X'e) = 0$ *for GLS Estimator*
Agriculture	67.81
Food	81.46
Critical Chi Value	12.59

6.2 Parameter Estimates

6.2.1 *Structure of Discussion*

The primary focus of this section will be on the restricted forms of the share equations for agriculture and food processing, tables 6.2 and 6.3 respectively. The restricted form takes precedent over the unrestricted form because theory dictates the homogeneity restriction, even though the F-test for the linear homogeneity restriction indicated that the unrestricted model is preferred for the agricultural share equation. However, it worth mentioning that parameter estimates change only slightly between the restricted and unrestricted models. The results of the unrestricted estimation are provided in the appendix for the agricultural and food processing export share equations, respectively. Furthermore, as indicated by the Hausman specification tests, the fixed-effects models provide better estimations than the random-effects estimator and will draw the focus of the results discussion.

6.2.2 *Interpretation of the Agricultural Share Equation Estimates*

Beginning with the restricted agricultural share equation it can be seen from table 6.2 that labor, capital stock, arable land, the exchange rate and the lagged share are all significant at the 1% level. The R^2 value for the model is 0.95, indicating that the share equation fits the data well. The lagged share represents the rate of adjustment from one year to the next. An estimate that is close to one indicates that the adjustment process occurs slowly in response to exogenous changes, while an estimate that is near zero indicates that the sector responds quickly to changes. Thus, the parameter estimate of 0.3533 roughly indicates that just over 35% of the current year's export share may be explained by the previous year's share.

Table 6.2: Restricted Agriculture Model

Share of Agricultural Exports in Agriculture GNP				
	Fixed Effects Model (OLS)		*Random Effects Model (GLS Fuller-Battese)*	
Variable	Estimate	Standard Error	Estimate	Standard Error
Lagged Share	0.3533 ***	(0.0531)	0.5730 ***	(0.0472)
Labor	0.0305 ***	(0.0012)	-0.0374 ***	(0.0004)
Capital Stock	0.1418 ***	(0.0388)	0.0313	(0.0223)
Land	-0.1632 ***	(0.0617)	-0.0061	(0.0127)
Exchange Rate	-0.1235 ***	(0.0414)	-0.0675	(0.0419)
Ag. TFP	0.0412	(0.0297)	0.0359	(0.0339)
EU Dummy			0.0355	(0.0340)
Intercept			0.0451	(0.3058)
Belgium	-1.4510 **	(0.6765)		
Canada	-1.2499 **	(0.5512)		
France	-1.5933 **	(0.6375)		
Germany	-1.7856 ***	(0.6778)		
Italy	-1.8942 ***	(0.7203)		
Japan	-2.1723 ***	(0.8070)		
Netherlands	-1.6289 **	(0.7332)		
Sweden	-1.6749 ***	(0.6407)		
UK	-1.6709 **	(0.6508)		
US	-1.4699 **	(0.5826)		
Australia	-1.2300 **	(0.5308)		
Denmark	-1.7311 ***	(0.6601)		
Norway	-1.9156 ***	(0.7081)		
	R^2	0.9527	R^2	0.4043

*** Significant at 1% ** Significant at 5% * Significant at 10%

Turning to the factor endowments, whose parameters are restricted to sum to zero, we see that labor and capital are positive. Capital plays a larger role in the estimation of agricultural export shares with a parameter value of 0.1418, than labor, 0.0305. This indicates that the production of agricultural products destined for foreign markets is relatively capital-intensive. Several explanations may exist for this phenomenon. It could be that the production of agriculture in general is capital-intensive, and thus, the production of agricultural products bound for export are also capital-intensive. Or it could be that the very nature of producing commodities for export inherently relies on more capital. This could be due to the need for more machinery to package the product prior to export. The larger positive parameter estimate of capital stock also supports the Rybczynski theory in the Heckscher-Ohlin model. As capital stock accumulates in the agricultural sector of a country, that country is more likely to export bulk commodities. Arable land as it turns out has a negative parameter, but remains significant. As a result of the imposed homogeneity restriction one of the parameters must be negative, but the question remains why land turned out to be the negative parameter. It is interesting to note that in the results of the unrestricted agricultural model (see appendix) that the parameter on land is still negative. An explanation for this may be that land used in the production of export commodities is not as important relative to other factors used in the export process. Some of the factors outside the framework of this analysis include: added health and sanitary service expenditures to meet international product safety codes, specific packaging requirements to ensure product quality during transit, additional administrative costs incurred through the export process, and transportation costs. The relative importance of land in relation to labor, capital, and these additional factors specific to export may be lessened, thereby giving the parameter estimate for land a negative sign.

The real-effective exchange rate as expected has a negative sign, -0.1235. As the domestic currency appreciates relative to foreign currency, the amount of products exported is expected to decline. This occurs as theory would suggest, and is intuitively apparent, because the real value importers must pay for the product has risen, thus import demand falls. It is of interest to note that the exchange rate is the most consistent variable, next to the lagged share, in terms of significance and sign throughout the various estimation methods.

The final exogenous variable is relative agricultural TFP, which is positive as expected, but not significant. The positive sign on TFP supports the Ricardian theory that as a country improves its technology relative to other countries in a given sector, that country will gain comparative advantage in the production of products, and thus, export more of them. With respect to the variable not showing significance, it may be the case that other factors inherent to export play a larger role in the production of agricultural commodities for export than that of relative agricultural TFP. Interpretation of the country dummy variables parameter estimates will follow discussion of the food processing results. For now it is important to note that the estimates are significant at least at the 5% level, and are relatively large.

6.2.3 *Interpretation of the Food processing Share Equation Estimates*

The estimation of the processed food share equation has an R^2 value of 0.99 indicating that the share equation fits the data well. Furthermore, it can be seen in table 6.3 that the parameter estimates for the lagged share, labor, capital, the exchange rate and agricultural TFP are all significant at the 1% level. Starting with the adjustment rate, as indicated by the lagged share, it can be seen that the adjustment process is relatively slower in food processing (0.5174) than in agriculture (0.3533). Therefore, it takes longer for food processing exports to respond to exogenous changes than agriculture. This finding maybe counterintuitive to some, however, I think this is the expected result. When the structure of agriculture is considered in relation to processed food, we find that the government plays a much greater role in supporting agriculture. This occurs not only through the support of expansive research and development in agriculture, but also through production guarantees and price floors. Agricultural producers do not always need to find a market in which to sell their product. The government supplies the market for them by purchasing the product and storing it. Therefore, in times when the foreign market demand wanes the government has the ability to absorb much of the excess production. The food processing sector does not have the luxury of a supported market in which to sell its product. It is expected then that the rate of adjustment from one period to the next will be slower.

Food processing is a capital-intensive sector and evidence of this is reflected in the positive parameter estimate of capital compared to the negative parameter estimate of labor. Once again, the share equation is homogeneous of degree zero in factor endowments, forcing one of the endowment parameters to be negative. However, like the agricultural case, it is worth noting that in the unrestricted model for food processing labor has a negative parameter estimate as well (see appendix). A combination of several factors may produce this result. Variables specific to export such as specialized packaging for sale abroad, increased services to meet customs requirements, transportation cost and others maybe more important to the production of the export product than labor itself.

Table 6.3: Restricted Food Model

Share of Food Exports in Food GNP				
	Fixed Effects Model (OLS)		*Random Effects Model (GLS Fuller-Battese)*	
Variable	Estimate	Standard Error	Estimate	Standard Error
Lagged Share	0.5174 ***	(0.0491)	0.8674 ***	(0.0314)
Labor	-0.0581 ***	(0.0102)	-0.0187 *	(0.0112)
Capital Stock	0.0581 ***	(0.0102)	0.0187 *	(0.0112)
Exchange Rate	-0.0688 ***	(0.0160)	-0.0474 ***	(0.0167)
Ag. TFP	0.0508 ***	(0.0129)	0.0351 **	(0.0149)
Food TFP	0.0206	(0.0163)	0.0030	(0.0180)
EU Dummy			0.0168	(0.0123)
Intercept			0.0295	(0.1397)
Belgium	-0.1713	(0.1263)		
Canada	-0.2573 **	(0.1274)		
France	-0.2542 *	(0.1301)		
Germany	-0.2820 **	(0.1298)		
Italy	-0.3010 **	(0.1302)		
Japan	-0.2972 **	(0.1234)		
Netherlands	-0.0620	(0.1244)		
Sweden	-0.2865 **	(0.1289)		
UK	-0.2965 **	(0.1303)		
US	-0.3378 **	(0.1337)		
Australia	-0.1596	(0.1260)		
Denmark	-0.1224	(0.1260)		
Norway	-0.3155 **	(0.1308)		
	R^2	0.9926	R^2	0.8269

*** Significant at 1% ** Significant at 5% * Significant at 10%

The real-effective exchange rate is significant and exhibits the expected negative sign for the food processing share equation as it did for agriculture. Indicating that as an exporting country's currency appreciates relative to the importing country's currency, the export share of the exporting country is expected to fall.

Agricultural TFP is in the food processing export share equation through the realization that comparative advantage of the agricultural sector is transferred to the food processing sector. This occurs as advances in technology in the agricultural sector increase production, which lowers commodity prices and overall production costs of the food processing sector, thus, enabling the sector to become more competitive in global markets. Through the lower procurement costs of agricultural commodities, the food processing sector essentially gains through a transfer of the comparative advantage developed by the primary agricultural sector. The findings in this analysis help validate this assertion. From table 6.3 it can be seen that agricultural TFP in the food export share equation is positive and significant at the 1% level, as expected. As the results indicate, agricultural TFP provides nearly the same contribution to processed food export shares that capital does. TFP for food is only significant at the 20% level, but is positive as expected, indicating that as technology improves in food processing relative to that of other countries, that country which experiences the improvement will likely increase its export share of processed food. This finding supports the Ricardian theory that states as a country enhances technology relative to that of other countries in a given sector, the country with the technological advantage will gain comparative advantage in the production of that good, and thus, export more of that product.

6.2.4 *Interpretation of Dummy Variables*

The results of the dummy variables vary somewhat in the food processing sector when compared to the consistency of the agricultural sector. In processed food it can be seen that all parameter estimates are negative, however, not all are significant. It can also be seen that the parameter estimates for food processing are substantially smaller, in absolute value, than that of agriculture. An explanation for this may lie in the previous discussion of government's larger influence in the agricultural sector. Because the model did not contain a variable to represent government policy effects on the sectors, the country specific dummy variable is likely capturing these effects. Hence, the parameters estimates for agriculture are much larger and significant, compared to the limited nature of the government influence on food processing, whose estimates are smaller and not all significant.

6.3 Long-Run Effects of Technology and Factor Endowments

6.3.1 *Long-Run versus Short-Run Effects*

In an effort to investigate the effects technological change and altering factor endowments have on trade over time, table 6.4 was constructed. These results illustrate the effect each of the variables have on export shares given that the adjustment process is instantaneous, as is assumed in the long-run. Therefore, the lagged share variable would have a value of zero and the remainder of the variables explain trade, and thus, the long-run parameter estimates are larger than the short-run results provided earlier. Table 6.4 offers a side-by-side comparison of the effects, with long-run effects listed on the left and short-run effects provided on the right.

In the agricultural share equation, it can be seen that in the long-run, the effects of the exogenous variables will be nearly 55% greater than in the short-run. While in food processing we may expect the effects of the exogenous variables to contribute over 105% more in the long-run.

Table 6.4: Long Run Effects of Technology and Factors

Agricultural Export Shares		
Variable	Long-Run Effects	Short-Run Effects
Labor	0.0472	0.0305
Capital Stock	0.2192	0.1418
Exchange Rate	-0.2523	-0.1632
Arable Land	-0.1910	-0.1235
Ag. TFP	0.0638	0.0412

Processed Food Export Shares		
Variable	Long-Run Effects	Short-Run Effects
Labor	-0.1205	-0.0581
Capital Stock	0.1205	0.0581
Exchange Rate	-0.1425	-0.0688
Ag. TFP	0.1053	0.0508
Food TFP	0.0426	0.0206

The repercussions of this finding are interesting. For example, let us analyze the contribution of agricultural TFP in the share equations. If the level of agricultural TFP increases by 5%, we may expect that the contribution agricultural TFP plays in the export share of agriculture to rise, but not as greatly as we expect the contribution in the processed food share to rise in the long-run. This result is important for policy makers to consider when determining the long-run effects an agricultural policy may have on not only agriculture but also the processed-food sector.

6.3.2 *Computation of Long-Run Effects*

The results in table 6.4 were computed using the restricted fixed-effects model estimates and by dividing the exogenous parameter estimates by one minus the lagged-share estimate. Shown here as, $\alpha_{ij} / (1\text{-}\lambda_j)$, where the indices *i* and *j* represent the exogenous variables and the two share equations respectively. The parameter estimate for the exogenous variables is denoted by α, while λ is the parameter estimate of the lagged shares.

Chapter 7: Conclusions

This research has been motivated by the desire to better understand the effect of productivity growth in the agricultural (primary) sector on growth and trade of the food processing (value-added) sector. A multitude of government interventions in agriculture necessitates an understanding of the linkages and potential effects of agricultural policies on the food processing sector in order to maintain a competitive food system.

Prior research on the linkages between primary and value-added sectors suggested that productivity growth in agriculture is a contributing factor to the competitiveness of the food processing sector. Evidence that the productivity growth in agriculture results in a decline of commodity prices, and in turn, lowers procurement costs for the food processing sector, has been found elsewhere. However, little research exists that focuses on how the productivity linkage between the sectors affects trade. This study examines the possibility that comparative advantage in the agricultural sector, derived through productivity growth, may be transferred to the food processing sector.

Theoretically, this research used a revenue function, and extended it to incorporate trade, i.e. a GNP function approach to modeling imports and exports. Outputs are partitioned into domestic and export goods, while imports are treated as intermediate inputs, which must first flow through a domestic value-adding process before final sale. The model for processed food accounts for intermediate inputs from the primary agriculture sector, which provide a technical linkage for the transfer of efficiency gains from agriculture to food processing.

The empirical model used a translog functional form and derived the export share equations for the agricultural and food processing sectors. These share equations, which are consistent with theory, are a function of labor, capital stock, land, and the relative growth rate of technology for each respective sector. The share equations were fit for thirteen developed countries using output, technology, and factor endowment data from the OECD, and trade data from ERS/USDA. The use of export share equations with this data establishes a testable link between technology and trade, i.e. differences in technology explain variations in the export shares of GNP among countries.

The research results revealed that the rate of productivity growth, coupled with augmentation of factor supplies, significantly impacts agricultural patterns of trade. First, in accordance with Rybczynski type effects, food export production uses capital more intensively than labor, and thus, export shares rise as capital accumulates in the sector. Similarly, export production in the agricultural sector is capital and labor intensive relative to land. This result is not surprising since exports involve a number of additional services. The most striking result is that growth in the level of technology of the agricultural sector has a positive effect on the exports of the food processing sector. This significant finding, in support of Ricardian assertions, suggests that comparative advantage is not static, and can be improved by promoting the accumulation of factors such as knowledge and human capital. Accretion of such factors can be achieved by investing in research and development, which advances technical knowledge and promotes productivity growth.

To expand on this study, a number of areas may be targeted to add robustness to the empirical model. Examination of government policies and their effects on production and trade is one area that may provide new insights to the analysis. Inclusion of policy instruments to the model may unlock some of the information currently being captured in the country specific dummy variables. A second area that may be improved upon is the modeling of technology. This study uses relative TFP growth rates to represent technology; however, technology may be more accurately modeled using TFP levels. Though calculation of actual TFP levels was outside the scope of this study, the effect of their addition would increase the robustness of the results. Finally, prices in this study were reduced to a time-dependent parameter. If price data on inputs and outputs as well as imports and exports were available, the structure of the export share equations could be improved.

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APPENDIX

Table A: Unrestricted Agriculture Model

Share of Agricultural Exports in Agriculture GNP				
	Fixed Effects Model (OLS)		*Random Effects Model (GLS Fuller-Battese)*	
Variable	Estimate	Standard Error	Estimate	Standard Error
Lagged Share	0.3125 ***	(0.0564)	0.6694 ***	(0.0330)
Labor	0.0036	(0.0348)	0.0019	(0.0051)
Capital Stock	0.1042 **	(0.0426)	0.0040	(0.0050)
Land	-0.3134 ***	(0.0953)	-0.0509 ***	(0.0070)
Exchange Rate	-0.1179 ***	(0.0412)	-0.0805 ***	(0.0104)
Ag. TFP	0.0365	(0.0296)	0.0471 ***	(0.0086)
EU Dummy			-0.1359 ***	(0.0172)
Intercept			0.0451	(0.1163)
Belgium	0.6135	(1.2068)		
Canada	1.5249	(1.4497)		
France	1.0535	(1.4326)		
Germany	0.8153	(1.4310)		
Italy	0.6909	(1.4447)		
Japan	0.3299	(1.4555)		
Netherlands	0.5026	(1.2655)		
Sweden	0.5966	(1.2733)		
UK	0.7845	(1.3561)		
US	1.6082	(1.6026)		
Australia	1.5090	(1.4304)		
Denmark	0.5393	(1.2826)		
Norway	0.1693	(1.2327)		
	R^2	0.9567	R^2	0.9490

*** Significant at 1% ** Significant at 5% * Significant at 10%

Table B: Unrestricted Food Model

Share of Food Exports in Food GNP				
	Fixed Effects Model (OLS)		*Random Effects Model (GLS Fuller-Battese)*	
Variable	Estimate	Standard Error	Estimate	Standard Error
Lagged Share	0.5090 ***	(0.0491)	0.8278 ***	(0.0347)
Labor	-0.0076	(0.0289)	-0.0314 **	(0.0127)
Capital Stock	0.0702 ***	(0.0120)	0.0201 *	(0.0114)
Exchange Rate	-0.0758 ***	(0.0164)	-0.0489 ***	(0.0166)
Ag. TFP	0.0540 ***	(0.0129)	0.0389 ***	(0.0150)
Food TFP	0.0350 *	(0.0180)	0.0051	(0.0180)
EU Dummy			0.0167	(0.0131)
Intercept			0.1688	(0.1626)
Belgium	-0.9968 **	(0.4600)		
Canada	-1.1336 **	(0.4866)		
France	-1.1884 **	(0.5173)		
Germany	-1.2385 **	(0.5288)		
Italy	-1.2142 **	(0.5064)		
Japan	-1.2814 **	(0.5417)		
Netherlands	-0.9149 **	(0.4737)		
Sweden	-1.0938 **	(0.4514)		
UK	-1.2345 **	(0.5193)		
US	-1.3413 **	(0.5542)		
Australia	-1.0450 **	(0.4754)		
Denmark	-0.9415 **	(0.4566)		
Norway	-1.0962 **	(0.4383)		
	R^2	0.9927	R^2	0.8133

*** Significant at 1% ** Significant at 5% * Significant at 10%