An Investigation of the Leontief Paradox using Canadian Agriculture and Food Trade: An Input-Output Approach

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Abstract

This study investigated whether the Leontief Paradox existed for Canadian agriculture and food trade in 2006. Factor intensities in exports and import replacements of agriculture and processed food commodities were estimated using both the Leontief and Leamer approaches. The Leamer approach provided additional information on factor endowment abundance. Statistics Canada's 2006 Input-Output tables were modified to provide an input-output model that was disaggregated in both agriculture and processed food sectors and in agriculture and food commodities. The modified version of the Input-Output model was used to estimate the factor intensity and factor abundance in Canadian agriculture and food trade. Production factors included in this study were capital, labour, and land.

The results from both the Leontief and Leamer approaches suggested that Canadian agriculture and food exports were relatively capital and land intensive, while its import replacements were relatively labour intensive in 2006. This finding does not support the existence of the Leontief paradox for Canadian agriculture and process food trade. In addition, the Leamer approach suggests that Canada has an abundance of capital and land in comparison to labour.

Résumé

Cette étude a examiné si le paradoxe de Leontief existe pour l'agriculture et le commerce des aliments transformés au Canada. Les facteurs d'intensité pour les exportations et les importations des denrées alimentaires agricoles et transformées ont été estimés en utilisant à la fois le cadre d'analyse de Leontief et l'indice de Leamer. L'indice Leamer a servi à fournir des informations supplémentaires sur l'abondance de dotation en facteurs. Pour répondre aux objectifs de cette étude, les tableaux entrées-sorties de Statistique Canada de l'année 2006 ont été modifiés afin d'estimer les besoins en facteurs dans les secteurs de l'agriculture et du commerce des aliments transformés canadiennes. Les facteurs de production inclus dans cette étude ont été le capital, le travail, et la terre.

Les résultats des analyses selon l'approche de Leontief et l'indice Leamer suggèrent que, en 2006, les exportations canadiennes des denrées alimentaires agricoles étaient des relativement intensifs en capital et en terre, tandis que les importations ont été intensives en labeur. Cette constatation ne supporte pas l'existence du paradoxe de Leontief pour l'agriculture et le commerce des aliments transformés au Canada. En outre, l'indice Leamer suggère que le Canada a une abondance de capital et la terre par rapport au travail.

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Chapter 1: Introduction

1.1 Trade theories

The analysis of trade has attracted the interests of economists since the beginning of modern economics. Adam Smith (Jenkins 1949) argued that the direction of trade was determined by the absolute advantage of a country given labour as the only factor in production. The other important development in classical trade theory was comparative advantage by David Ricardo (Sraffa and Dobb 1953). His theory of comparative advantage states that a country would import commodities that have relatively higher opportunity costs if produced domestically as compared to other commodities. A country would gain from international trade even if it is efficient in producing all goods compared to other countries. Neoclassical economists modified the comparative advantage theory by emphasizing factor endowments (Ohlin 1933). Factor endowment theory argues that the determinant of international trade is the difference in production factor endowments between countries. The Heckscher-Ohlin (H-O) model (Ohlin 1933) was an essential development in factor endowment theory. The model describes the situation in which a country that is relatively well endowed with capital would export capital intensive products and import labour intensive products. The H-O model continues to be modified. However, this model is still widely applied to the study of factor endowments and trade patterns.

1.2 The Leontief Paradox

Prior to the 1940's, economists had very little systematic knowledge of the productive structure of any national economy. Therefore, it was difficult to empirically investigate factor endowments and trade patterns of a country. In the early 1940's, Leontief (1941) developed the Input-Output model, which described the structural relationships among industries in the USA. He used the Input-Output model to study factor intensities in US trade as a test of the H-O theorem. He found that the US exports were relatively labour intensive and its imports were relatively capital intensive. This finding was contrary to what was suggested by the H-O theorem. This theory suggested that the US should export capital intensive products and import labour intensive products, given the widely held belief that the US was well-endowed with capital rather than labour. Several studies by Leontief (1953) and other scholars (Brecher and Choudhri 1982;Casas and Choi 1985;Leamer 1980;Valavanis-Vail 1954) have tried to explain this paradoxical finding, which has been identified as the Leontief Paradox. The testing of the Leontief Paradox using an Input-Output modelling framework for other countries than the US has rarely occurred, which leaves space to further study the level of general implication of such a paradox. This study investigated whether the Leontief Paradox existed for Canadian agriculture and processed food trade. The Input-Output model of the Canadian economy was used to investigate the trade intensities in Canadian agriculture and processed food trade.

1.3 The Input-Output model

An Input-Output model describes the structural relationships between industries in a particular economy. It is based on the System of National Accounts for a country. The Canadian Input-Output model uses a rectangular accounting framework, where the number of commodities is greater than the number of industrial sectors. This accounting framework allows any industrial sector to produce more than one commodity.

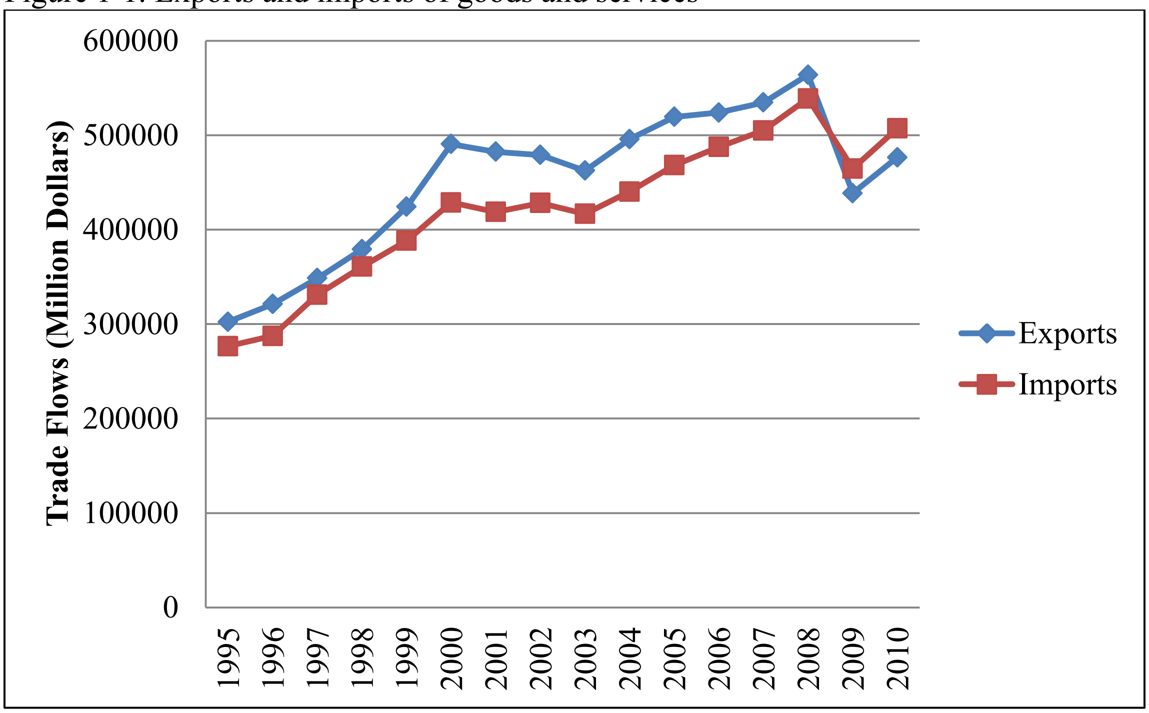
The Input-Output model used in this analysis is a modified version of the 2006 Statistics Canada Input-Output model for agriculture. This modified version of the Canadian Input-Output model has a detailed disaggregated agriculture and food processing sectors, while the other industrial sectors are at a more aggregated level. This model was used to investigate the factor intensities for Canadian agriculture and processed food trade.

1.4 Canadian trade

Canada as an open economy relies heavily on international trade, particularly for its natural resources. In 2009, exports accounted for 30% of Canada's GDP. Between 1995 and 2008, Canada's exports and imports increased by more than 50% (564 and 539 billion dollars for exports and imports respectively). This was followed by a sharp decline of 22.2% for exports and 13.7% for imports in 2009 mainly due to the financial crisis originating in the US from 2008 to 2010. This occurred because the US is Canada's largest trading partner. As can be seen in Figure 1-1, Canada's trade balance with the rest of the world swung from a surplus of $24.9 billion CAD in 2008 to a deficit of $26.1

billion CAD in 2009, which was the first deficit since 1975 for Canada. Despite the drop in trade in 2009 as a result of the decline in the global economy, Canada's exports and imports are expected to increase in the long run. International trade is a crucial part of the Canadian economy. Understanding trade for Canada is an important step towards understanding the Canadian economy.

Figure 1-1. Exports and imports of goods and services



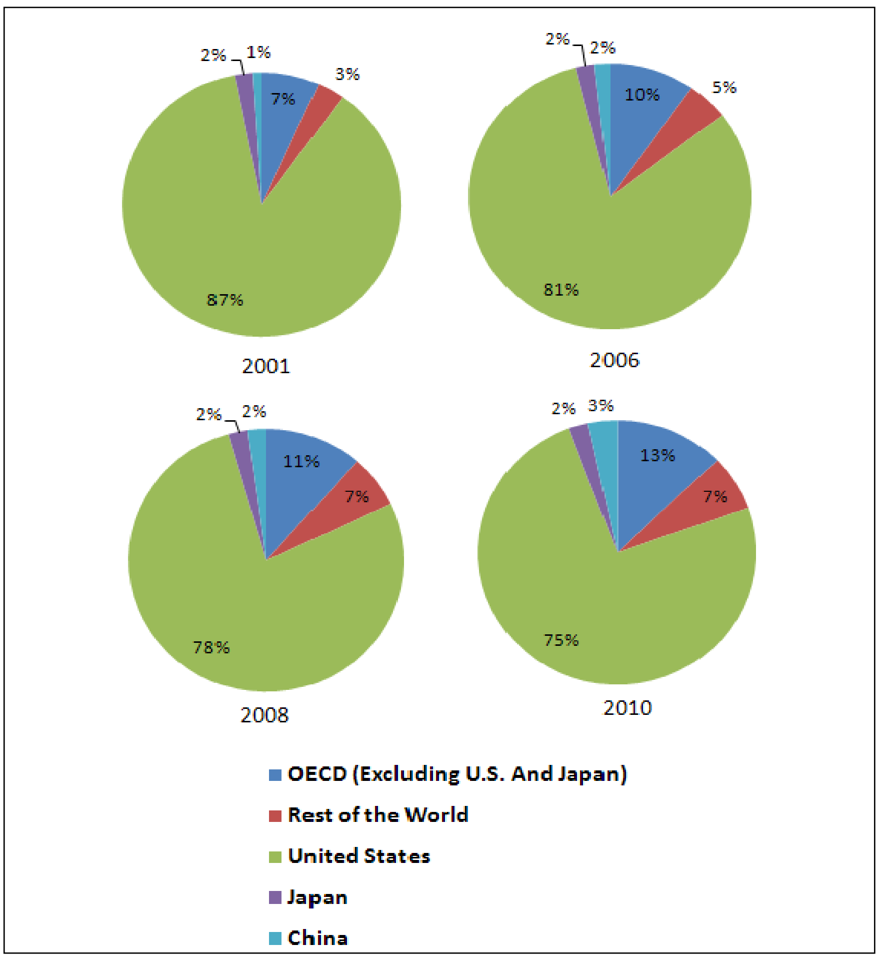
Source: Statistics Canada 2010

1.4.1 Canada's trading partners

The distribution of Canada's trading partners determines its trade patterns. As an open economy, Canada's trading partners are distributed internationally. However, the US is by far the largest trading partner accounting for 75% of exports and 50% of imports in 2010, followed by China and Japan.

Figure 1-2 shows the share of Canadian exports by partner. Canada exports over 70% of its goods to the US. However, Canada's reliance on the US decreases over time, as its exports to other OECD countries and to developing countries have increased from 9% and 4% respectively in 2001 to 15% and 10% in 2010 respectively. In recent years, developing countries, such as China, has started to become an important trading partner for Canada, which has led to changes in the structure of Canadian trade.

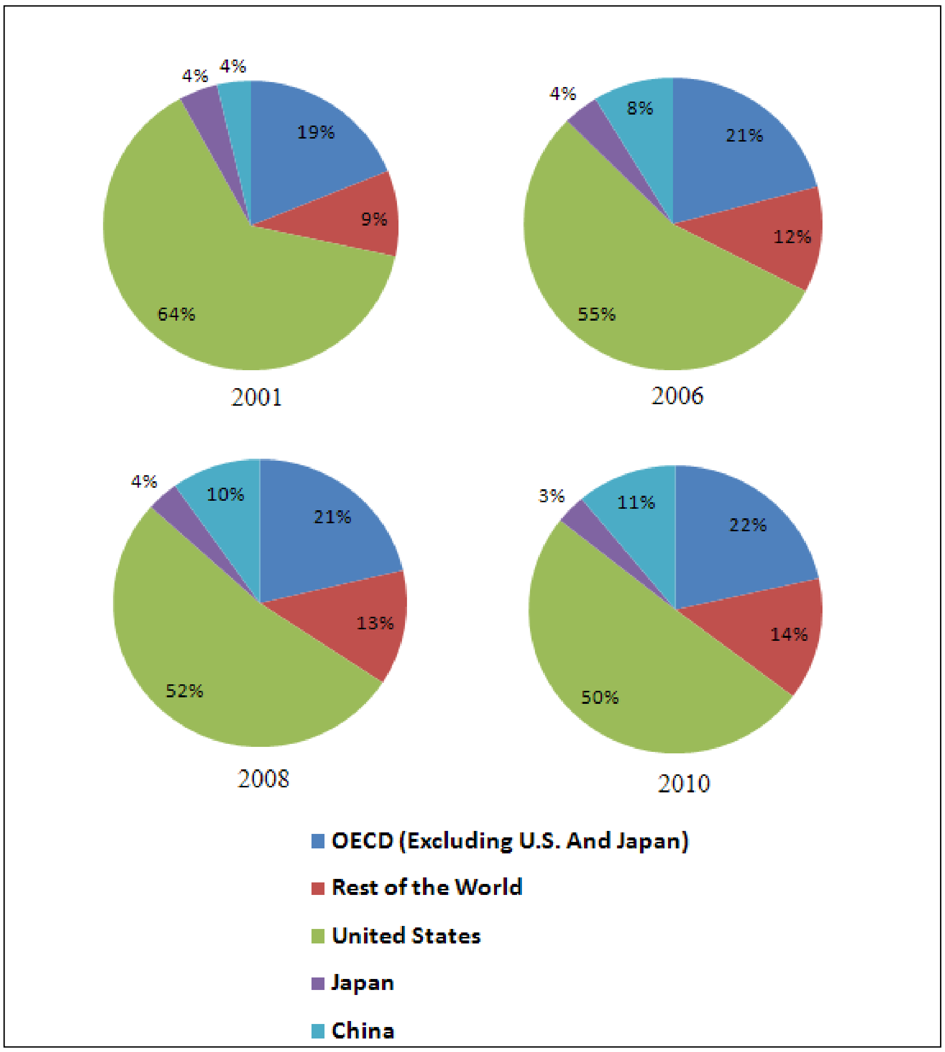
Figure 1-2.Exports by partner



Source: Statistics Canada 2010

Similar to exports, over 50% of Canadian imports come from the US. This reliance has declined over the years (from 64% in 2001 to 50% in 2010), (Figure1-3). Imports from China have increased dramatically from 4% to 11% over the period of 2001 to 2010. In 2010, China became Canada's second largest trading partner overtaking Japan.

Figure 1-3. Imports by Partner

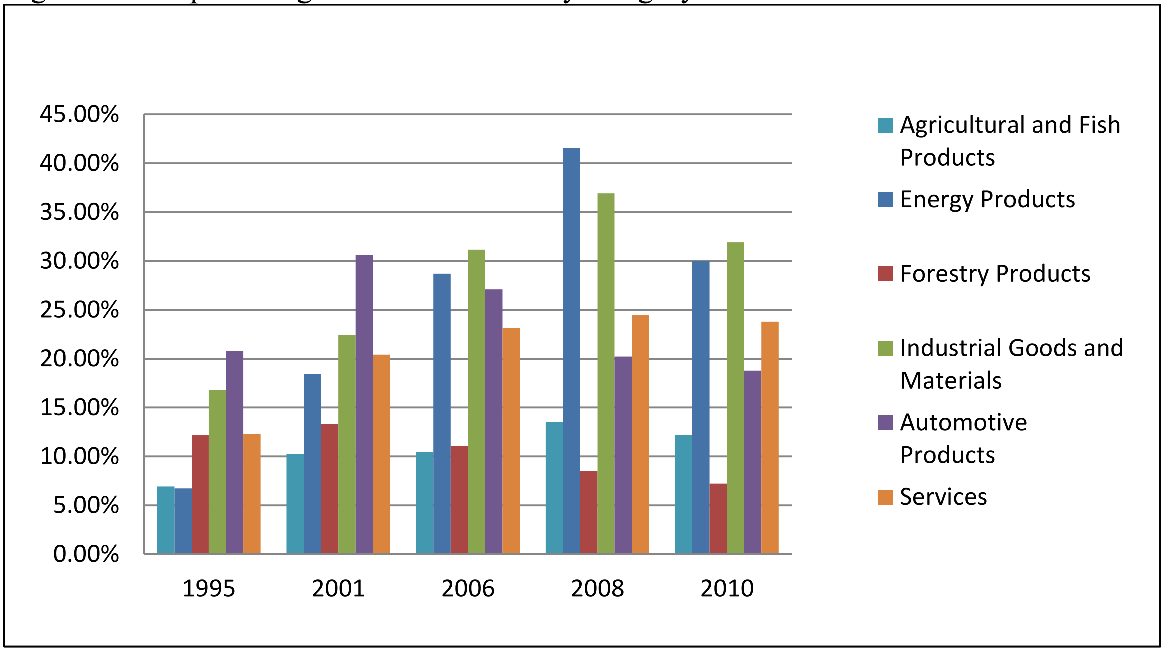


Source: Statistics Canada 2010

1.4.2 Agriculture trade in Canada

Canada is one of the world's largest suppliers of agriculture products, particularly of wheat and other grains. Figure 1-4 shows the changes in export share by category from 1995 to 2010. Canada's exports of agriculture and fish products increased from 6.5% of total exports in 1995 to 7.5% in 2010. Similar to overall trade, the US is Canada's largest agriculture products export market, taking over 50% of agriculture and fish product exports, followed by Japan and China, taking 8% and 7% respectively. In terms of the balance of trade with the world, Canada has run a surplus in agriculture and fish products trade, which is mainly due to its abundant endowment of natural resources. Referring to the Heckscher-Ohlin-Vanek (H-O-V) theorem (Vanek 1968) that country exports commodities using its relative abundant factors of production, Canada's agriculture and fish products trade would support this statement if natural resources are included as a production factor. Trade flow data, however, does not provide conclusive evidence on the patterns of trade in Canada. In order to undertake this type of analysis, the factor intensity of agriculture trade is needed. This study computed the factor requirements in agriculture and processed food exports and imports and its relationship with agriculture and food products trade flows.

Figure 1-4. Exports of goods and services by category



Source: Statistics Canada 2010

1.5 Problem statement and objectives

The problem to be addressed in this study is whether the Leontief Paradox existed with agriculture and processed food trade for Canada. This was tested by estimating the factor intensities for exports and import replacements of agriculture and food commodities. The following objectives have been identified.

The first objective is to test the accuracy of the modified Input-Output model. The modified Input-Output model uses data from different aggregation levels of the published Statistics Canada tables for 2006. This method was used because of the confidentiality problems with the published data set. Using different aggregation levels of data can minimize confidentiality problems. However, the modification may create aggregation bias problems. The model was designed in the way that the agriculture and processed food sectors and commodities were at the most disaggregated level, while the other sectors and commodities were at a more aggregated level. To determine the accuracy of the modified Input-Output model, a comparison was made between the modified Input-Output model and the confidential Statistics Canada model.

As a developed economy Canada is expected to be a capital abundant country relative to the rest of the world. Therefore, according to the H-O theorem, Canada is expected to be an exporter of capital and importer of labour for trade overall and for agriculture and processed food trade. The modified Input-Output model for 2006 was used to investigate the factor intensities of Canadian agriculture and processed food trade using the same approach as Leontief (1953). Imports and exports of agriculture and food commodities were used to shock the modified Input-Output model to measure the factor intensities of agriculture and processed food trade. As with the original research work, the import replacements approach was used to analysis factor intensities in Canadian imports.

In the development of the H-O model, some economists argue that apart from labour and capital, natural resources is an essential factor of production, especially for agriculture sectors. Therefore, land as the third production factor apart from capital and labour was included in this study. Land intensities in agriculture and processed food trade were estimated in order to understand whether and how land affects the direction and structure of Canadian agriculture and processed food trade. Apart from Leontief's approach, factor intensities of net-exports of Canadian agriculture and processed food trade were also computed. This test is comparable with Leamer's (1980) proposition that factor intensities in net-exports should be used to investigate trade patterns rather than comparing the factor intensities in exports and imports. Moreover, factor requirements in domestic consumption were compared to those for net-exports. Applying different methods to investigate the factor intensities in agriculture and processed food trade allows the comparison between studies and solidifies the conclusion on whether the Leontief Paradox existing for Canadian agriculture and processed food trade. Understanding the pattern of Canadian agriculture and processed food trade is essential for policy makers, in particular for agricultural policies that provide subsidies.

1.6 Organization of the Research

The thesis is composed of five chapters, including the introduction. In Chapter 2, a literature review on the development of trade theories, the Leontief Paradox, and the explanation/disputing/re-affirming of the Leontief Paradox are presented. Chapter 3 provides an explanation on the Input-Output model and its modification. It also explains the theoretical basis and methods that were applied in this study. In chapter 4, the results are presented, and the interpretation of the results is discussed. A conclusion follows in Chapter 5 with a review of the results of this study and possible directions for future study.

Chapter 2: Literature Review

2.1 Trade theories

Understanding the determination of trade patterns is important in the study of international trade. The absolute and comparative advantage theories, developed by A. Smith (Jenkins 1949) and D. Ricardo (Sraffa and Dobb 1953) respectively, are based on a one-factor model. They assumed that in a two country case, the differences in productivity of that factor are the only determinant of international trade. This model is the simplest version of the study of patterns in international trade. In the real world, more than one factor is involved in industrial production. Moreover, the differences in productivity of a factor between two countries can be one explanation to the observed differences in comparative factor costs. However, other explanations such as the difference in factor endowments may also contribute to the differences in comparative factor costs, or even directly to patterns of international trade.

Heckscher (1919) stated that the difference in comparative costs between countries would lead to international trade. However, such differences are not necessary for the continuance of established trade. Instead, the differences in comparative costs of trading goods across countries are doomed to disappear along with international trade in the long term. He continued to assume that factors were immobile between countries. Heckscher argued that if factors were immobile and technologies were identical across countries, the difference in the relative scarcity of production factors between countries would be a necessary condition for international trade. Even with the absence of movement of production factors, the prices for the production factors in all countries tend to be the same with international trade. His statement furthermore revealed the determinants of international trade and the relationship of the production factors with international trade.

Ohlin (1933) continued with Heckscher's study developing the conditions for trade including factor endowments in production. To acknowledge Heckscher's original contribution to the factor endowment theory, Ohlin named his model the Heckscher-Ohlin (H-O) model. The factor endowment theories in modern international economics are based on comparative advantage theory. They suggest that differences in factor endowments between countries determine trade patterns. The Heckscher-Ohlin Theorem (1933) is the most widely accepted theorem that explains trade patterns using factor endowments. The H-O model assumes the following:

1. Two trading countries with two production factors (capital and labour);
2. Both countries produce two goods: "A" and "B";
3. Countries have different relative scarcities in production factors;
4. Identical technologies are used to produce the same product in each country;
5. Factor intensities in product "A" and "B" are different;
6. Production factors are immobile across countries, but are mobile across industries;
7. Inequality in the price of factors between countries are sufficient to cause differences in commodity prices and thus to cause trade.

The H-O theorem states that the country that is endowed with abundance of capital will export capital intensive products to the country that is relatively in scarcity of capital.

Trade tends to equalize factor prices between countries and also to equalize the price of trading commodities.

After Heckscher and Ohlin, many economist developed a generalization version of the H-O model (Melvin 1968;Samuelson 1948;Travis 1972;Vanek 1968). They studied the multiple factors and multiple countries scenarios. These generalizations are closer to the actual situation. However, the H-O theorem remains the basis for the factor endowment theory as to understand the role that factor endowments play in international trade.

The theoretical development of the H-O theorem was followed by the empirical testing of this theorem (Hufbauer 1970;James and Elmslie 1996;Jones 1956;Leontief 1956;Maskus 1985). One of the most controversial and influential studies was undertaken by Leontief (1953). He was the first one to use a direct measurement of trade patterns to test the H-O theorem. He first tested the factor endowment theory with the US trade patterns in 1947. His findings were contrary to what was suggested by the H-O theorem.

2.2 Leontief Paradox and its development

Little systematic knowledge of the productive structure of any national economy was known prior to the 1940s. This made it difficult to empirically test the H-O theorem. It was only after the establishment of the System of National Accounts and the pioneer work of Leontief (1953), those empirical tests of international trade theory could be undertaken.

2.2.1 The Leontief Paradox

In the early 1940's, Leontief (1953) developed the Input-Output model of the US economy. This model estimated the relationships between industrial sectors and between industrial sectors and final demand. The development of this model allowed researchers to investigate trade patterns of the US economy and test the applicability of trade theory with empirical data. As suggested by the H-O theorem, Leontief assumed that: (1) the production function in the US was identical to that of the rest of the world; (2) the direct input factor requirements were the same across countries; and (3) the US was endowed with an abundance of capital and was scarce of labour. As a result, the US had a comparative advantage in producing commodities that were more comparatively capital intensive than labour. Hence, the US should export capital intensive products and import labour intensive products.

The Input-Output model developed by Leontief (1953) can be used to determine the impact of a given change in final demand on an economy. The impact on the economy is estimated as the change in industrial output that is required to satisfy the change in final demand. From this estimate, Leontief was able to estimate the factor requirements, i.e. capital and labour, which were needed to satisfy the change in final demand.

To test the H-O theorem, Leontief (1953) computed the total input requirements from the US economy to satisfy $1 million dollars of exports and import replacements. He used the 1947 Input-Output table and computed the direct plus indirect capital and labour requirements to satisfy the $1 million dollars of exports and import replacements respectively. This was the first empirical test of the H-O model. Leontief found that an average $1 million dollars of exports from the US used relatively less capital and more labour than that of import replacements. This finding suggested that the US resorted to international trade to economize on capital and dispose of abundant labour. This finding was contrary to what was suggested by the H-O theorem, that the US was expected to export capital intensive products and import labour intensive products, given it is believed that the US was relatively endowed with abundance of capital and was scarce of labour compared to the rest of the world. This finding was then named the "Leontief Paradox".

2.2.2 Leontief's interpretation

Leontief (1953;1956) tried to explore the possible explanations for this paradoxical finding in order to reconcile it with the H-O theorem. He argued that if one assumed that one year of labour productivity in the US was equivalent to three years of foreign labour productivity, the US labour force in 1947 would increase from 65 million US man years to 195 million of equivalent foreign years. The adjusted figure suggested that the US capital supply per "equivalent labour" was relatively smaller than that of the rest of the world. The abundance of labour in the US determined that the US resorted to international trade to optimize its capital and dispose of its abundance of labour.

Leontief (1956) further investigated the determinants of US foreign trade by allowing other production factors to be different between countries. He stated that apart from the difference in labour productivities, natural resources could also be important in determining the pattern of US foreign trade.

2.2.3 Observation of the Leontief Paradox in other studies and possible explanations

A large amount of literature has emerged discussing the Leontief Paradox. Several studies have investigated the trade directions of production factors. Many of these studies (Baldwin 1971;Brecher and Choudhri 1982;Hufbauer 1970;Vanek 1963;Weiser 1968) have reaffirmed the Leontief Paradox and have provided possible explanations for the results.

2.2.3.1 Natural resources

Inspired by the Leontief Paradox, the H-O theorem was expanded to include natural resources as a production factor to study patterns of international trade. Most of the studies confirmed that natural resources were crucial in determining the structure of trade. As a result, additional empirical work (Baldwin 1971;Swerling 1954;Vanek 1968;Vanek 1963;Weiser 1968) was undertaken to determine if adding natural resources as the third production factor would eliminate the Leontief Paradox. Vanek (1963) was the first to explore the role that natural resources played in the US trade. He observed that the US changed its position as an exporter of natural resources to an importer of natural resources after 1900. Using the 1947 Input-Output model of the US and the labour and capital requirement computed by Leontief, Vanek further computed the direct and indirect natural resource requirements of US exports and competitive imports. He confirmed his earlier argument that the US was relatively scarce in natural resources. By comparing the ratio of factor requirements (capital, labour, and natural resources) between exports and import requirements respectively, he observed a strong complementary relationship between natural resources and capital. These results suggested that the factor structure of US trade was primarily a reflection of the relative scarcity of natural resources instead of capital. Even if capital was a relative abundant factor in the US in 1947, it entered productive processes only in conjunction with a relatively small amount of natural resources. This caused the observation of the U.S being an exporter of labour and importer of capital. Therefore, to comprehend trade patterns for a country, natural resources as a production factor must be included together with capital and labour.

Followed by his empirical evidence, Vanek (1968) expanded the H-O model to include multiple production factors in his study. Accepting the assumption of the H-O model, he assumed that there were more than two factors involved in industrial production. In the two-country model, both countries specialize in production of different products. Assuming the factor endowments in the domestic and foreign country are X_j and Y_j respectively, where j=1, 2,…,J representing the production factors. The ratio of factor endowments between the two countries is given by the following relationship (Vanek 1968):

$$\frac{X1}{Y1} \geq \frac{X2}{Y2} \geq \cdots \geq \frac{Xi}{Yi} \geq \cdots \geq \frac{X_J}{Y_J} \qquad (2\text{-}1)$$

One country would be a net exporter of services of X1 to Xi and an importer of services of Xi+1 to X_J where i≠J. Such ranking of endowment ratio between two countries should be revealed by the net factor-flows through international trade of commodities, if the factor-income shares follow the same ranking. This model was named the H-O-V model. This model was widely adopted in studies investigating trade patterns and testing the Leontief Paradox (Casas and Choi 1985;Daviset al. 1997;James and Elmslie 1996;Lee, Wills and Schluter 1988;Marshall 2011;Maskus 1985).

Baldwin (1971) computed the factor intensities of US trade by using the 1962 trade figures and reaffirmed the Leontief Paradox in his study. To further understand the source of the Leontief Paradox, Baldwin computed the factor requirements of trade according to US trading partners. He found that the Leontief Paradox did not exist in trade between the US and Japan and Western Europe. Tatemoto (1959) also compared the trade between the US and Japan for 1951 and found a similar conclusion in that Japan exported relative labour intensive commodities to the US. However, Baldwin did find that the Leontief Paradox was observed for trade between the US and Canada, less developed countries (LDCs), and other countries. This observation may be explained by the abundance of natural resources in the developing countries and Canada. Given the strong complementary relationship between capital and natural resources suggested by Vanek (1963), the trade patterns between the US and Canada, and developing countries were not unexpected. Naya (1967) investigated the factor reversal caused by including natural resources as a production factor in the H-O model. He investigated the capital intensities for Japanese exports and imports and found that natural resources have an influence on the pattern of Japanese trade. He found that the capital-labour ratio for exports was greater than that of import replacements when all sectors were included, while the capital-labour ratio for exports was smaller than that of the import-replacements if natural resource sectors were excluded. This change had a different direction than the Vanek (1963) study, where he found that if natural resource sectors were excluded the capital-labour ratio for exports in the US was higher than that ratio for import replacements. This difference between two countries is mainly due to the difference in direct factor coefficient for the agriculture sector in the US and Japan. When excluding the agriculture sector from all industries, the results for Japan reconciled with Vanek (1963) study. Moreover, for US-Canada trade, Young and Kreinin (1965) found that the labour efficiency in Canada and the US was the same and thus provided support to the argument of the dominant role natural resources play in US-Canada trade. Excluding natural resources from the US exports and import replacements, it was shown that the ratio of capital per labour embodied in import replacements versus exports fell close to 1. This change suggested that natural resource were a crucial factor in determining trade patterns in the US, which supported the validity of the multiple-factor version of the H-O theorem, i.e. the H-O-V model. Weiser (1968) computed the factor requirements in the US between 1947 and 1962 by trade with all sectors, excluding the agriculture sectors and natural resources commodities respectively. He found that the Leontief Paradox continued to hold from 1947 to 1962 for the above three cases. Weiser observed a decrease in the ratio of capital per man year embodied in import replacements versus exports when natural resources were included. This result suggested that natural resources may be a determinant of trade patterns; especially to natural resource commodity trade. However, it did not reverse the Leontief Paradox in patterns of US trade over the period 1947-1962. This would suggest that the absence of the third production factor; i.e. natural resources, was not fully responsible for the existence of the Leontief Paradox.

2.2.3.2 Skilled labour and human capital

Leontief (1956) and other researchers (Branson 1971;Keesing 1965;Kreinin 1965;Travis 1972) suggested that the difference in endowment of human capital between the US and the rest of the world could be another explanation for the finding of the Leontief Paradox. Branson (1971) investigated the labour differences between the US and the rest of the world and argued that in a two factor model (capital and labour), human capital was included in the calculation of the labour requirement. Since the US was relatively more abundant in human capital as compared to physical capital, the US was observed as an exporter of labour and an importer of capital in a two-factor model. Branson (1971) estimated multiple regressions relating net-exports of different industries to production characteristics including human capital and physical capital for the 1964 trade data. He found a significantly positive relationship between net exports of human capital per man year and its negative correlation with physical capital exports. Branson (1971) concluded that the US was human capital intensive in exports and physical capital intensive in imports. The reason for including human capital and physical capital in the analysis is because a physical investment in creating human capital can move as freely as physical capital in the long run. However, most of the studies in international trade and factor endowments are undertaken in the short term. Given the assumptions of the Input-Output model it is difficult to draw conclusions on factor endowments when both human capital and physical capital are included in the analysis.

To take this into account, many studies compared the amount of skilled labour, unskilled labour, capital, and other production factors as a means to determine trade patterns between nations. For example, Baldwin (1971) compared the ratio of research and development (R&D) costs involved in import replacements and exports and the ratio of the number of skilled workers engaged in import replacements with exports. He concluded that the US exports incorporated more skilled labour than its import replacements. Keesing (1965) computed the capital per man-year embodied in exports by countries (developed countries) and by type of labour (skilled labour to unskilled labour) and concluded that skilled-labour availability shaped trade patterns. More specifically, the availability of labour skills determined patterns of trade for products that were not closely tied with natural resources. Lowinger and Thomas (1971) compared the skilled labour proportion in the total economic activities between Brazil and its major trading partners (Western Europe and North America) in the1960's. They found that Brazil had lower levels of skilled labour endowments as compared to Western Europe and North America. Moreover, the exports of Brazil were relatively less "human-capital" intensive compared to its imports. No significant evidence was found to conclude any relationship between physical capital endowments and patterns of trade in Brazil. Morrow (2010) tested the trade patterns of 22 countries and found that countries with a relative abundance of skilled labour produced and exported relatively more skilled labour intensive goods. This result is consistent with the H-O theorem.

One of the few studies that disagreed with skilled labour results was undertaken by Kreinin (1965), he found that the superior level of the US skilled labour was not significant enough to offset its scarcity of labour. The quality of labour did play a role in patterns of international trade. However, it could not explain the existence of the Leontief Paradox.

2.2.3.3 Other possible explanations

Apart from natural resources and skilled labour, several other potential explanations have been proposed by researchers. These include: (1) when factor-intensity reversals are large enough to fail the H-O proposition; (2) demand in the US is strongly biased towards capital intensive products causing the US to import even more capital;(3) trade-distortion policies favours the production of labour-intensive products and prevents the imports of these products at the same time.

2.2.4 Refuting of the Leontief Paradox

Despite the continued observation of the Leontief Paradox in US trade, some economists have argued that the existence of the Leontief Paradox is primarily due to errors in methodology or misunderstanding of the basic theories (Valavanis-Vail 1954). In the Input-Output model the estimation of changes in exports and import replacements relies on the assumption that the technology coefficients are constant. However, some economists argued that as domestic production changes, the scale of the economy should change as well. Using a static Input-Output model to study dynamic changes in international trade might be inappropriate. However, the Input-Output model remains the most detailed systematic estimation of domestic production as well as international trade. Regardless of the concerns about the assumption of constant returns to scales, the empirical testing of the Leontief Paradox continues to use the same basic approach by Leontief. Kreinin (1965) argued that Leontief's finding was just the result of an unusual year. This argument is easy to dispute based on other research findings concerning the Leontief Paradox for US trade in other years.

Leamer (1980) argued that Leontief's work was based on a conceptually misinterpretation of the H-O theory. If the "correct" theory was applied, there would be no Leontief Paradox in the 1947 US international trade situation. Leamer argued that assuming the identical technologies across countries and homogeneous utility functions in the world based on the H-O-V theorem, a country's total factor requirements in consumption can be expressed as a proportion of the total world factor endowments,

$$A * Ci = Ew * \alpha i \qquad (2\text{-}2)$$

where, A is the total technology requirement matrix, Ci is country i's consumption, Ew is the world total factor endowments, αi is the proportion of that factor requirement in country i's consumption to the world factor endowments.

The total factor endowments in country i would be equal to the sum of the factor requirements in net exports and the factor requirements in domestic consumption for country i. This could be expressed as,

$$Ei = A * Tnx + A * Ci \qquad (2\text{-}3)$$

where, Ei is the factor endowment in country i, Tnx is the net exports.

Leamer redefined whether or not a country is endowed in labour or capital in terms of its relative position to total world stock. For example, country i would be relatively endowed with abundance of capital if its share of world capital stock exceeds its share of world labour stock. Using Leamer's definition (1980), this relationship can be expressed as,

$$\frac{Ki}{Ki - Knx} > \frac{Li}{Li - Lnx} \qquad (2\text{-}4)$$

where, Ki and Li are the capital and labour endowment in country i, Knx and Lnx are the capital and labour requirements for net exports.

The above relationship can be interpreted as a country's capital endowment is larger than its labour endowment. This is because the ratio between capital endowment and the capital absorbed in domestic consumption in country i is greater than the ratio of labour endowments to the labour absorbed in domestic consumption of country i. Given the redefinition of capital and labour endowments, country i would be considered endowed with relatively abundant capital if one of the following three conditions would hold (Leamer 1980):

1. $Knx>0, Lnx<0$
2. $Knx>0, Lnx>0, Knx/Lnx>Kc/Lc$
3. $Knx<0, Lnx<0, Knx/Lnx<Kc/Lc$

where, Kc and Lc are the capital and labour absorbed in domestic consumption respectively.

Leamer (1980) empirically tested his propositions with the same data used by Leontief; i.e. the 1947 US data (Leontief 1953). He concluded that the US was a net exporter of both capital and labour when the capital and labour requirements of imports over exports were compared. As a result, it is inappropriate to draw conclusions on factor intensities in US trade. To address this problem, Leamer (1980) computed the capital and labour requirements in US net exports in 1947 and compared it with the capital and labour requirement in US consumption. He found that the capital per man year embodied in the US net exports was greater than that in US consumption. Therefore, Leamer suggested that the Leontief Paradox did not exist for US international trade. However, it is important to note that even with Leamer's adjustments the Leontief Paradox observed by Baldwin (1971) would still exist.

2.2.5 Other studies on the Leontief Paradox

Brecher and Choudhri (1982) examined Leamer's propositions and argued that the statement by Leamer (1980) that a country was a net-exporter of labour service if and only if its aggregation expenditure was less than that in the rest of the world was paradoxical. In 1947 worker expenditures were larger in the US than the rest of the world, while the US was found to be a net-exporter of labour. This brought questions on Leamer's conclusion that the Leontief Paradox did not exist for the US economy. They proposed that a country was a net-exporter of labour only if the ratio between world consumption (Cw) and world labour endowment (Lw) was greater than the ratio for that particular country (Ci/Li). This can be written as:

$$L_T > 0 \text{ if and only if } Cw/Lw > Ci/Li, \text{ under any condition} \qquad (2\text{-}5)$$

where, L_T is the net-exports of labour in international trade.

In a situation where trade is balanced; i.e. world consumption is equal to world production and country i's consumption is equal to its total domestic production. The above condition can be rewritten as,

$$L_T > 0 \text{ if and only if } Li/Lw > Yi/Yw \qquad (2\text{-}6)$$

Using the above relationships, Brecher and Choudier (1982) found that the Leontief Paradox continued to exist for US trade in 1953. Casa and Choi (1985), following the model of Brecher and Choudhri, showed that under balanced trade the net-exports of production factor A (A_T) can be expressed as:

$$A_T = Ai[\,1 - (Yi/Ci)(Ac/Ai)] \qquad (2\text{-}7)$$

where, Ac is factor requirements of A for consumption, Ai is the endowments of A in country i.

Therefore, they argued that factor A was abundant in country i if the ratio of the absorption of factor A in domestic consumption to the endowments of A was smaller than the ratio of domestic absorption to income. In this case the US would have imported labour and its scarcity in labour would have been revealed if trade was balanced.

Maskus (1985) used the H-O-V model and followed Leamer and Brecher and Choudhri's propositions to study trade patterns for the year 1958 and 1972 respectively. He ranked the ratio between factor content as total requirement of trade and the factor absorbed in domestic total production. In both years skilled labour (in this case engineers and scientists) and human capital were relative more abundant, while unskilled labour and physical capital were relatively scarce in the US. This finding supported the Leontief Paradox that the US import replacements were relatively capital intensive. Given these results Maskus concluded that the Paradox continued to exist in 1958 and 1972.

Trefler (1993) examined the factor intensities for US trade in 1983. His result was similar to what was found by Leontief (1953), Trefler (1993) further argued that the US was not only scarce in labour, but also in terms of capital.

Lee and Wills (1988) tested the Leontief Paradox for US agricultural trade in 1977 and 1982. In their study they used Leontief's (1953) and Leamer's (1980) calculation to investigate factor scarcities in the US. They computed capital, labour, and land intensity for US agricultural trade. No evidence of the Leontief Paradox was found in either calculation.

2.2.6 Investigation of the Leontief Paradox in other countries

The studies on the investigation of the Leontief Paradox were widely replicated in the US. However, such analysis was rarely applied in the rest of the world. As a result, the scope test of the Leontief Paradox was relatively limited. In this case the scope test would apply the same methods of calculating factor scarcity or intensity to other economies. Following are some of the studies that used the Input-Output modeling framework to test factor intensities.

Tatemoto (1959) studied the Japanese trade patterns for 1951 and found that Japan exported relatively capital intensive products and imported relatively labour intensive products compared to the rest of the world. He also compared Japan-US trade in 1951 as a contrast to total trade patterns and found that Japan exported relatively labour intensive products to the US and imported relatively capital intensive products. Given that 25% of Japanese exports went to developed countries and 75% of its exports went to developing countries, this finding suggested that the Leontief Paradox did not hold for the Japanese economy in 1951.

Stolper and Roskmap (1961) used the Input-Output model to study Eastern Germany's trade and found that Eastern Germany exported capital intensive products and imported labour intensive products. They concluded that no Paradox was found in Eastern Germany trade. They explained the results by noting that 75% of total trade of Eastern Germany went to the communist bloc and Eastern Germany was relatively endowed with an abundance of capital.

Wahl (1961) investigated the Canadian capital-labour ratios for exports and import replacements. He found that the average total exports for Canada in 1949 were more capital intensive and less labour intensive than would have been required for the average import replacements. Moreover, contrary to Baldwin's (1971) findings, Wahl found that Canadian exports to the US were also revealed to be capital intensive. The difference in results for Canada-US trade may be due to the different data sources used. Wahl measured labour intensity for Canada using wages rather than physical units. This change in the factor intensity measure made the estimates by Leontief and Baldwin not directly comparable. Canada's trade was highly dependent on the US economy. Its exports and imports to the US take up to 75% of its total trade value with the world. If it is assumed that in 1949 the US was relatively more endowed with capital, the finding by Wahl would suggest another Paradox for Canadian trade in 1949.

Yokoyama (1989) studied the trade patterns of Japan, Korea, Taiwan, and Malaysia in two years; 1970 and 1975. He found the result of Leontief and Leamer indexes were quite similar. Japan and Korea were found to be net-importer of both capital and labour, while Taiwan and Malaysia were both net-exporters of capital and labour. Both Leontief and Leamer indexes showed that in 1970 Japan and Korea were capital abundant and Taiwan and Malaysia were labour abundant. In 1975, Japan was capital abundant and the other three countries were labour abundant.

Bharadwaj (1962) investigated the factor intensity of India's bilateral trade with the U.S. economy and found that India was revealed by trade to be capital abundant relative to the US. This result refuted the H-O theorem of trade and supported the Leontief paradox. Sikdar and Chakraborty (2011) examined the factor intensity of the bilateral trade between India and Sri Lanka. Their results showed that India exported capital intensive goods to Sri Lanka and imported labour intensive goods. Therefore India's trade with Sri Lanka was in line with the comparative advantage of India. However, no explanation of such finding was provided. Dasgupta, Ghosh and Chakraborty (2011) further studied the trade patterns for India. They found that India was a net importer of capital and natural resources, while was a net exporter of labour. The factor intensities for net-exports and domestic consumption were compared, it was concluded by the authors that the trade patterns in India during its reform period was consistent with the H-O-V theorem.

2.3 Conclusion

This chapter reviewed the development of trade theory and its applications. One of the most famous empirical finding in international trade was the Leontief Paradox. This finding challenged the factor endowment theory in explaining trade patterns. A large number of studies emerged that did not reject this paradoxical finding. Some of them reaffirmed the existence of the Leontief Paradox, while some of the studies disputed the existence of the Leontief Paradox in US trade. However, there is no comprehensive explanation of the Leontief Paradox. One of the research topics related to the Leontief Paradox is whether the Leontief Paradox can be found in countries other than the US. This study will address this issue for Canadian agriculture and processed food trade.

Chapter 3: Methods and Procedures

3.1 The Input-Output Model

3.1.1 The Leontief Input-Output Model

There has been a rapid development in Input-Output modelling since the World War II (Rose and Miernyk 1989). Leontief (1941) in the early 1940's first introduced the Input-Output framework for the US economy. The basic Input-Output framework is constructed from observed economic data and it is fundamentally designed to analyze the interdependence of industries in an economy. The Leontief Input-Output model uses a symmetric framework and describes the activities of a set of industries that are both producers and consumers in the production of each industry's output. In a symmetric Input-Output framework one industrial sector can only produce one output.

3.1.1.1 The Leontief Input-Output Modelling Framework

The Input-Output model can be used to estimate the impact of an increase/decrease in final demand on the domestic production of all industrial sectors in the economy. The change in final demand is referred to as a "shock" to the economy. Letting NI represent the number of industries, the basic mechanism for the Leontief Input-Output model can be expressed as follows:

$$g = Ag + F \tag{3-1}$$

where, g = a NI by 1 industrial output vector;

A = a NI by NI technical (input-output, or direct input) coefficient matrix;

F = a NI by 1 final demand vector.

The Input-Output structure of an economy is represented by the matrix A. Reading across the rows of this accounting framework shows how output from an industrial sector is distributed to other industrial sectors and final demand. Reading down the columns provides an estimate of the intermediate inputs required by each industrial sector to produce their outputs. The multiplication Ag gives an NI by 1 vector expressing the value of total intermediate demand by industrial sector. The final demand vector F is a composite of personal expenditures, government expenditures, changes in inventories, exports and imports, and capital investments. Summing these two vectors provides an estimate of the total industrial output. The total output changes required to satisfy an exogenous shock in final demand can be determined from:

$$g = (I - A)^{-1} F \qquad (3\text{-}2)$$

where, I= an identity matrix.

The expression $(I - A)^{-1}$, sometimes referred to as "L", is known as the Leontief inverse or the total requirement matrix. The Leontief inverse can be used to compute the direct plus indirect requirements to satisfy a change in final demand.

Equation (3-2) is the basic computation that is required when analyzing the impact brought about by an exogenous change in final demand. It calculates the industrial output changes to satisfy the change in final demand.

Since the late 1950's, various countries started to build the Input-Output tables on an annual basis, based on the Leontief Input-Output framework. The development of the Input-Output tables and the associated Input-Output model has made this approach one of the most widely used macroeconomic tools. The Input-Output framework provides a means to estimate the impact of a change in final demand from a region or country and the impact of changes to the economic structure of that region or country.

3.1.2 The Canadian Input-Output Model

The Canadian Input-Output accounts together with the income and expenditure accounts, balance of payments, and the financial and wealth accounts form the Canadian System of National Accounts (CSNA). It is complied by Statistics Canada on an annual basis at the national and provincial levels. Square accounting tables have been an international standard for most countries since the beginning of Input-Output modelling development. However, the Canadian Input-Output accounting tables are based on a rectangular accounting framework where the number of commodities and services exceeds the number of industries. This design has advantages in that it provides more details on the use of intermediate inputs, the distribution of industrial outputs, and in analyzing residuals and by-products of industrial production. The Canadian Input-Output model consists of three basic matrices (tables), i.e. Use Matrix, Make Matrix, and Final Demand Matrix. The Use Matrix is a commodity by industry matrix that shows the intermediate inputs used by each industrial sector to produce their outputs. The Make Matrix is an industry by commodity matrix that describes the distribution of commodity outputs by each industrial sector. The Final Demand Matrix is a commodity by final demand category matrix that describes the transactions of commodities by final demand categories. The framework of the Canadian Input-Output model can be illustrated with the following table:

Table 3-1. The accounting Framework of Canadian Input-Output Tables

	Commodities	Industries	Final Demand	Total
COMMODITIES		U	F	q
INDUSTRIES	V			g
PRIMARY INPUTS		YI	YF	
TOTAL	q′	g′		

Source: Lixon, Thomassin, and Hamaide (2008)

where, U is the matrix of intermediate inputs by industrial sectors;

V is the Make Matrix, documenting the share of each commodity produced by each industrial sector;

F is the Final Demand Matrix, allocating the flow of commodities to final demand categories;

YI is a matrix of primary inputs used by all sectors;

YF is a matrix of primary inputs used in final demand categories.

q is a vector of the total demand for commodities; i.e. intermediate inputs plus final demand by commodity;

g is a vector of the total value of industrial output by industrial sector;

The Use Matrix equals to the sum of matrix U and YI.

From the above framework, q can be expressed as:

$$q = Ui + Fi \qquad (3\text{-}3)$$

where, i = a column vector whose elements are unity with appropriate row dimensions; i.e. number of industries, commodities and services, or final demand categories.

The above equation can be interpreted as the value of the total demand for commodities equals to the intermediate input demand for commodities plus the demand for commodities. Similarly, g can be expressed as:

$$g = Vi \quad (3\text{-}4)$$

The total value of industrial outputs equals to the sum of the value of the industrial outputs by commodity.

3.1.2.1 The commodity-demand driven Input-Output model

One of the assumptions that the present general equilibrium accounting framework follows is that all commodities, including main products and by-products, made by an industrial sector are produced with the same technical production structure. This is called the industry-based technology assumption. An input coefficient matrix B can be estimated using this assumption as follows:

$$B = U\hat{g}^{-1} \quad (3\text{-}5)$$

where, "^" indicates a diagonal matrix;

superscript "$^{-1}$" represents a vector or matrix inverse.

The input coefficient matrix is a commodity by industry matrix. Each coefficient is the percentage of that input as a function of the total cost for that sector.

Similarly, the industrial sectors share of the total market for commodities can be represented by a matrix of commodity output proportions, also called the market share matrix, "D". This can be expressed as follows:

$$D = V\hat{q}^{-1} \quad (3\text{-}6)$$

The market share matrix is an industry by commodity matrix. Each cell in a column is the output share of a commodity by industrial sector. Rewriting equation 3-5 and 3-6, U and V can be expressed as:

$$U = B\hat{g} \quad (3\text{-}5)'$$

$$V = D\hat{q} \qquad (3\text{-}6)'$$

$$q = B(\hat{g}i) + Fi = Bg + Fi \qquad (3\text{-}7)$$

$$g = D\hat{q}i = Dq \qquad (3\text{-}8)$$

Rearranging (3-7) by replacing g according to (3-8), (3-7) can be rewritten as:

$$q = (I - BD)^{-1}Fi \qquad (3\text{-}7)'$$

where I is an identity matrix with appropriate dimensions; i.e., industry by industry or commodity by commodity.

Equation (3-7)' is used to estimate the commodity output change due to a change in the final demand for commodities. This model is called the Commodity-Demand Driven Model (Miller and Blair 2009). The industrial output changes to satisfy an exogenous shock by final demand can be written as:

$$g = [(I_I - DB)^{-1}D]Fi_C \qquad (3\text{-}9)$$

The bracketed quantity $[(I_I - DB)^{-1}D]$ is an Industry by commodity total requirement matrix. This matrix is called the impact matrix. The impact matrix is used to estimate the direct plus indirect impacts in industrial output that are required to satisfy a change in final demand for commodities.

Leakage

A leakage can be defined as commodities that are used to satisfy either intermediate or final demand but are not supplied by the Canadian economy. Leakages are included in the model in order to provide a better estimate of the impact of a change in final demand. In this model, the leakage is defined as the import share to the domestically available goods and services and is represented by a commodity by 1 vector, "a". Equation (3-9) can be rewritten to incorporate the leakage as follows:

$$g = [(I_I - D(I_C - \hat{a})B)^{-1}D]Fi \quad (3\text{-}10)$$

Equation (3-10) will be used to estimate the direct plus indirect impacts on industrial sectors that are required to satisfy changes in final demand.

3.1.2.2 Levels of aggregations and classifications

The Input-Output accounts are prepared and balanced at the most detailed level; i.e. the "Worksheet" (W) level. The Worksheet level consists of 303 industries and 727 commodities, services and primary inputs. The final demand matrix includes 172 disaggregated final demand categories. The industrial sectors in the 2006 Input-Output tables are classified by the North American Industrial Classifications (NAICS 2002). This system of classification for commodities and final demand are based on hierarchical orders, which are identical to the classifications in the Canadian System of National Accounts. The Worksheet level industry, commodity, and final demand categories can be integrated to more aggregated levels using a set of concordance and aggregation parameters.

Statistics Canada aggregates the complied Worksheet level Input-Output model to different levels of aggregations, namely: Link (L), Medium (M), and Small(S) levels. The number of industries and commodities in each aggregation are given:

Table 3-2. Aggregation dimensions for Input-Output tables

Aggregation Level	**Industry**	**Commodity+ Services+ Primary Inputs**	**Final Demand**
Small	25	59	18
Medium	62	111	37
Link	117	469	122

Source: Statistics Canada 2009

Statistics Canada has prepared an agriculture sector extension to the Input-Output tables based on the Worksheet level Input-Output tables for the purpose of agriculture research and policy making. The agriculture sector ("Crop and animal production") in Statistic Canada's Worksheet level model is disaggregated into 13 agriculture sectors. This allows the interrelation between the agriculture sectors and other industrial sectors in the Canadian economy to be studied in more detail.

Some of the entries in the matrices in the Input-Output tables are confidential and are thus missing from the published tables. The number of confidential cells in the matrix increases with the level of disaggregation in terms of industrial sectors and commodities. The problem with having missing data due to confidentiality is that it can cause problems for the inversion of the matrix. One means of addressing this problem is to modify the Input-Output tables with industrial sectors and commodities from different levels of aggregation. This approach minimizes the number of confidential cells while allowing the analysts to build a model that has the details in industrial sectors and commodities of interests.

3.2 The modified Input-Output model

Since confidentiality exists in the published Input-Output tables, it is pertinent to modify the Input-Output model in a way that the estimated impacts on industrial outputs from the modified model are a close approximation to the estimates that are generated by the Input-Output model that has the confidential data (the confidential Statistics Canada Input-Output model). The industrial sectors and commodities that fall into the scope of concentration of the study remain at the Worksheet or Link levels of disaggregation, while the rest of the industrial sectors and commodities are integrated at the Medium level of aggregation.

This study used the 2006 Statistics Canada Input-Output model that had been extended with the disaggregated agricultural sectors. This model was used because it is the most recent model with the disaggregated agriculture sectors. It was deemed to be the most appropriate model to study the factor intensities of exports and import replacements of agriculture and food commodities in the Canadian economy. The extended agriculture Input-Output tables were used to build the agriculture sectors in the modified tables, while the food and beverage processing industrial sectors were obtained from the Link level of aggregation, and the other industrial sectors were from the Medium level of aggregation.

There are 84 industrial sectors in the modified Input-Output model. These included 13 agriculture sectors from the Worksheet level (Table 3-3), 12 processed food, beverages, and tobacco industries from the Link level (Table 3-3), and the rest of the industrial sectors were kept at the Medium level.

Table 3-3. Agriculture and processed food sectors in the modified Input-Output model

Agriculture sector	**Processed food sector**
Greenhouse, Nursery and Floriculture Production	Animal Food Manufacturing
Wheat	Sugar and Confectionery Product Manufacturing
Feed grain	Fruit and Vegetable Preserving and Specialty Food Manufacturing
Oilseed	Dairy Product Manufacturing
Potatoes	Meat Product Manufacturing
Fruits & Vegetables	Seafood Product Preparation and Packaging
Other Crops	Miscellaneous Food Manufacturing
Animal Aquaculture	Soft Drink and Ice Manufacturing
Dairy	Breweries
Cattle	Wineries
Hogs	Distilleries
Poultry and eggs	Tobacco Manufacturing
Other livestock	

The modified model consisted of 168 commodities, services, and primary inputs[1]. The agriculture and processed food commodities were kept at the Link level, and included 75 commodities. Other categories of commodities, services, and primary inputs were kept at the Medium level. The list of industrial sectors and commodities, services, and primary inputs in the modified Input-Output model are shown in Appendix A and B respectively.

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1 Primary inputs at the Medium level are classified into 8 categories: indirect taxes on products, subsidies on products, other subsidies on production, other indirect taxes on production, wages and salaries, supplementary labour income, mixed income, and other operating surplus. These primary inputs can be utilized to estimate the Gross Domestic Production (GDP) at both basic and purchaser prices.

The modified Input-Output model used the rectangular accounting framework, i.e. the number of commodities is larger than the number of industrial sectors. It is expected that the estimated impact using the modified Input-Output model will not be a good approximation of the estimates from the confidential Statistics Canada Input-Output model. Equation (3-10) was utilized to estimate the impact on industrial sectors of an exogenous shock in final demand.

3.3 The accuracy of the modified Input-Output model

As mentioned above, the main purpose for modifying the model was to deal with the confidential data influence on the accuracy of the estimated impact of a change in final demand. Before applying the modified model, it is important to test how the modified model performs in comparison with the confidential Statistics Canada Input-Output model. It is expected that there would be some variance in the estimation from the same shock to the modified Input-Output model and the confidential Input-Output model. However, if the estimation falls within 10% of the confidential Statistics Canada model impact, the modified Input-Output model will be deemed acceptable to be used in the analysis.

3.3.1 Procedure

The total domestic final demand vector for 2006 was used to test the validity of the modified Input-Output model. Total domestic final demand for any commodity equals the total final demand for that commodity minus the exports, assuming inventories being constant. Therefore, when organizing the final demand vector for 2006, the values for "inventory withdrawals" and "inventory additions" were excluded from the total final domestic demand. The values in the "imports (international)" sectors were also excluded from the total when the final domestic demand vector by commodity was estimated. This is because some of the commodities were not produced in Canada in 2006 or the major sources of some commodities are from imports. Including the imports in the final domestic demand vector could result in negative values, which is not compatible with the assumption used in the Input-Output model.

Some commodities (detailed at the Worksheet level of aggregation) were not produced domestically in Canada in 2006. As a result, they were excluded from the shock. The lists of these commodities at the Worksheet level are given in Table 3-4.

Table 3-4. Commodities excluded from the shock

Number	**Commodity**
97	Infant and junior foods in airtight containers
319	Other kitchen utensils
381	Used motor vehicles (business to persons)
465	Naphtha
476	Cellulosic plastic film and sheet
502	Deuterium oxide (heavy water)
717	Tropical fruit

Source: Statistics Canada 2006

The identical shock was run on both the modified Input-Output model and the confidential Statistics Canada Input-Output model. The data was first organized at the Worksheet level because the confidential Statistics Canada model is run at the Worksheet level. This shock vector was sent to the Industry Division of Statistics Canada who run the shock on their model. The domestic final demand vector was also aggregated according to the parameters of the modified Input-Output model. Therefore, the results from the confidential Statistics Canada Input-Output model can be compared to the modified Input-Output model results.

Equation (3-10) was used for both the model to estimate the impact on industrial outputs:

$$g = [(I_I - D(I_C - \hat{a})B)^{-1}D]f_{dx}$$

where x = 1, 2 for the different shock vectors explained in the following sections.

The number of commodities and services in the modified Input-Output model was 160. The final demand vector "f_{dx}" had dimension of 160 by 1. There were two shocks run for this test. The first shock vector was the total domestic final demand for all commodities and services[2]. This shock vector was called f_{d1}. The second shock vector was the total domestic final demand for agriculture and processed food commodities only. This shock was called f_{d2}. A shock vector of total domestic final demand for agriculture and processed food commodities was used because these are the commodities and industrial sectors that are of most interest for this analysis. This is why these commodities and sectors were kept at their greatest level of disaggregation.

The results of the above shocks were compared to the shocks run by Statistics Canada. The impacts of the shock are expressed as vectors with dimensions of the number of industrial sectors by one. Therefore, for test one and two, the results can be

2. Primary inputs were not shocked in the model.

compared by industrial sectors and by the total output (the sum of output by all industrial sectors).

3.4 Testing of the Leontief Paradox on Canadian agriculture and processed food trade

One of the main objectives of this study is to test whether the Leontief Paradox exists for Canadian agriculture and processed food trade. In order to do this, factor intensities (capital, labour, and land) for Canadian agriculture and processed food trade in 2006 were computed. The modified Input-Output model for 2006 was used to conduct this analysis. The capital, labour, and land coefficients for each Canadian industrial sector were computed and these coefficients were used to estimate the factor requirements for agriculture and processed food trade. Equation (3-10) was used to compute the direct plus indirect impacts on industrial outputs to satisfy the final demand for these commodities. Final demand vector "F" changes according to different types of shock.

A factor coefficient matrix, "Z", can be estimated that can be used to estimate factor intensities. This matrix has the dimensions of the number of factors by the number of industrial sectors. The approach taken to investigate the production factors for Canada is similar to that suggested by Vanek (1963); i.e. capital, labour, and land. The factor requirements needed to satisfy the change in final demand can be written as:

$$\text{Factor requirements} = Z * [(I_I - D(I_C - \hat{a})B)^{-1}D]Fi \qquad (3\text{-}11)$$

3.4.1 Leontief's Approach

As discussed in chapter two, Leontief computed the factor requirements for a million dollar shock for exports and import replacements respectively, and compared the ratio of factor intensities for US exports and imports to draw his conclusions. A similar approach was taken in this study, in which the shock was a million dollar shock vector to agriculture and food commodity exports and import replacements. This one million dollar shock was allocated proportionally to agriculture and processed food commodities based on their percentage of total agriculture and food commodity exports. The same procedure was applied to import replacements with the only difference being that the allocation of the one million was based on the import vector for agriculture and food processing commodities. Import replacements can be interpreted as a decrease in the imports of agriculture and food commodities to Canada. This reduction in imports would be replaced by domestic production. It is assumed that the production functions and factor coefficients are identical between Canada and the rest of the world. Therefore, using "X" and "M" to represent 1 million dollar of agriculture and food commodity exports and imports respectively, the factor requirements for one million dollar of agriculture and processed food exports and imports can be rewritten as:

$$Z_X = Z * [(I - D(I - \hat{a})B)^{-1}D]X \qquad (3\text{-}12)$$

$$Z_M = Z * [(I - D(I - \hat{a})B)^{-1}D]M \qquad (3\text{-}13)$$

The one million dollar shock to agriculture and processed food exports and import replacements are listed in Appendix C.

After computing the capital, labour and land requirements for a million dollar shock to agriculture and processed food exports and imports, the ratio of capital (labour and land) embodied in imports versus exports can be computed. The ratio between capital per working hour of labour (land per working hour) in imports over exports can also be computed. If the ratio between capital per working hour of labour in imports over exports is smaller than 1, the Canadian agriculture and processed food exports are relatively capital intensive and its imports are relatively labour intensive.

3.4.2 Leamer's computation

In addition to using the Leontief approach to measure factor intensity, the approach used by Leamer to investigate factor intensities was also applied to Canadian agriculture and processed food trade. As mentioned in chapter two, a country is revealed by trade to be capital abundant if one of the following three relationships hold (Leamer 1980):

1. The country is a net exporter of capital and net importer of labour;
2. The country is a net exporter of both capital and labour, when the ratio between net capital over labour is greater than the ratio of capital over labour absorbed in domestic consumption;
3. The country is a net importer of both capital and labour, when the ratio between net capital over labour is smaller than the ratio of capital over labour absorbed in domestic consumption.

Therefore, in this study, instead of computing the absolute factor requirements by exports and imports respectively, the factors embodied in net-exports and domestic consumptions were computed.

Leamer also suggested that a country's factor endowments are revealed by comparing factor intensities in production and domestic consumption. In order to estimate this, factor requirements by production and domestic consumption was computed.

The ratio between capital and labour (land and labour) in net exports, domestic production, and domestic consumption for agriculture and processed food products were computed. These allows for an estimate of factor intensities for Canadian agriculture and processed food net-exports, production, and consumption. The factor abundance in trade can then be revealed.

3.4.3 The production factors

3.4.3.1 Capital

Capital coefficients were collected and computed based on the KLEMS database built by the Micro-Economic Analysis Division, Statistics Canada. The capital stock defined by Statistics Canada consists of 15 types of equipment, 13 types of structures, and land and inventories adding up to total 30 types of assets (Baldwin, Gu and Yan 2007). The KLEMS database provides the value of capital stock in current dollars at the Link level of aggregation by industrial sectors. As a result, the capital coefficients for industrial sectors at the Link and the Medium levels of aggregation were computed directly by using the data provided by the KLEMS database. The coefficients are the ratio of the total capital stock of each industrial sector to its total output according to the Input-Output tables. However, the KLEMS database does not provide detailed allocation of capital stock by the disaggregated agriculture sectors. The KLEMS database provides a total capital value for the crop and livestock activity. To allocate this total to the agricultural activities in the model, the "Canadian Farm Financial database" (Statistics Canada and Agriculture and Agri-Food Canada 2009) was used as a reference. The 2006 shares of assets by farm type in the 2009 Farm Financial Survey 2009 was used to allocate the capital stock to agricultural activities. Table 3-5 below provides the asset share by farm type.

Table 3-5. Assets by Farm type (million dollars)

Farm type	**Value (million dollars)**	**Share (%)**
Total crop and animal production	***196,321.33***	***100%***
Grain and oilseed farms	61,787.33	31.47%
Dairy cattle and milk production farms	40,384.03	20.57%
Hog and pig farms	9,045.03	4.61%
Beef cattle ranching and farming, including feedlots	43,583.49	22.20%
Poultry and egg farms	10,199.41	5.20%
Fruit and nut farms	4,417.53	2.25%
Other vegetable and melon farms	2,417.16	1.23%
Potato farms	3,330.82	1.70%
Greenhouse, nursery and floriculture farms	4,217.72	2.15%
Other crop farming	8,138.18	4.15%
Other animal production	8,800.58	4.48%

Source: Statistics Canada and Agriculture and Agri-Food Canada CFFD 2009

The share of assets by farm type was calculated based on the assets value of each farm type. The computed share was used to allocate the capital stock for the crop and animal production from the KLEMS database. A comparison of the KLEMS database capital stock value and the Canadian Farm Financial Database are given in Table 3-6 for 2005 to 2007. The total assets value in the Canadian Farm Financial Database (CFFD) was on average 90% of the value in the KLEMS database.

Table 3-6. A comparison between the KLEMS capital stock value and the value of total assets in the Canadian Farm Financial Database

Year	KLEMS (million dollar)	Farm Financial Survey (million dollar)	Difference[3]
2005	208,375.88	186,372.15	10%
2006	218,124.74	196,848.75	9.75%
2007	233,496.60	211,318.04	9.50%

Comparing the two databases, the results would indicate that the share of capital by farm type collected in the CFFD should give a close approximation to the capital stock by activities in the Input-Output model. Agricultural activities wheat, feed grain, and oilseed were integrated as one farm type called the grain and oilseed farms. To allocate the capital stock of the total for grains and oilseed farms to these three activities, the ratio of operational surplus found in the Input-Output table were used. According to the Input-Output table, the operational surplus for wheat, feed grain, and oilseed were 3,005, 2,945, and 3,509 million dollars respectively. The capital stocks of these three sectors were calculated as 21,809, 21,374, and 25,467 million dollars respectively. Capital coefficients

3. The difference was calculated by(value in KLEMS database – value from Farm Financial Survey)/Value from farm Financial Survey * 100%

for these sectors were calculated the same as the other sectors. The capital coefficients used in this study are listed in Appendix D.

3.4.3.2 Labour

Labour coefficients for most industrial sectors were derived from the KLEMS database. In this study, working hours were used to measure the labour used in each industrial sector. For agricultural activities, The KLEMS database aggregated the agriculture sectors to 4 sectors; i.e. greenhouse, nursery and floriculture production, crop production, animal aquaculture, and animal production. Labour coefficients for the disaggregated agriculture sectors were estimated using information from the total payment of wages and salaries, and supplementary labour income shares by agricultural activity according to the Input-Output table for the year 2006. Table 3-7 shows the total payment of wages and salaries plus the supplementary labour income by selected agricultural sectors.

Table 3-7. Total payment of wages and salaries by selected agricultural sectors

Agriculture sector	**Wages and salaries plus supplementary labour income (million dollars)**	**Share**
Crop production	1,756	100.00%
Wheat	240	13.67%
Feed grain	84	4.78%
Oilseed	171	9.74%
Potatoes	221	12.59%
Fruits & Vegetables	520	29.61%
Other Crops	520	29.61%
Animal Production	1,505	100%
Dairy	559	37.14%
Cattle	280	18.60%
Hogs	303	20.13%
Poultry and eggs	287	19.07%
Other livestock	76	5.05%

The total number of working hours was allocated to the agriculture sectors using these shares. Labour coefficients for each sector were obtained by divide the total number of working hours by the total industrial output for that sector. The computed labour coefficients are shown in Appendix D.

3.4.3.3 Land

Land coefficients were only estimated for the agriculture activities in the model. Land as a factor of production does not play an important role in most industrial sectors, with the exceptions of agriculture, forestry, and mining. Since the analysis is focused on agriculture and food commodities, only the land coefficients for the agricultural activities were estimated. Land intensity by agricultural activity was estimated with information from the 2006 Census of Agriculture (Statistics Canada 2006). Table 3-8 gives the total area of farms in acres.

Table 3-8. Total area of farm (acres)

Total area of farm	***167,010,491***
Land in crops	88,741,106
Summer fallow land	8,662,461
Tame or Seeded pastures	14,071,138
Natural land for pastures	38,157,034
All other land	17,378,752

Source: Census of Agriculture 2006

A detailed table of land use by hay and field crops was also provided by the Census. It was used for distributing the land use in crops. The total of summer fallow land was distributed using the same proportions to the land use by hay and field crops as a part of the land use by crops. Tame or seeded pastures and natural land for pastures were summed to be distributed to the animal production activities. The “all other land” use includes all other land uses on farm. No obvious proxy was found to distribute this category and since it accounted for only slightly more than 10% of the total farm area, it was not included in the land calculation.

Table 3-9. Land coefficients by selected sectors

Agriculture sector	**Coefficients (acres per million dollar of output)**
Greenhouse, Nursery and Floriculture Production	25
Wheat	8,855
Feed grain	9,087
Oilseed	5,617
Potatoes	394
Fruits & Vegetables	435
Other Crops	5,447
Dairy	908
Cattle	6,343
Other livestock	4,003

Tame hay and seeded pastures were distribution by farm type. This information was obtained in the CFFD. This database also includes the number of animal heads by farm type. The land use by animal production was established by allocating the area of seeded pastures and tame hay by farm type to animal production activities (Dairy, Beef cattle, Sheep) based on the number of heads of animals. The share of computed seeded pastures and tame hay land used by animal production activity was used to allocate the total land use of tame or seeded pastures, and natural land for pastures from the Census of Agriculture. Land coefficients were then computed by dividing the land use of each agriculture sector by its total output in the Input-Output model. Table 3-9 shows the computed land coefficients.

Chapter 4: Results and Discussion

This chapter reports the results of testing the accuracy of the modified Canadian Input-Output model and the empirical test of the Leontief Paradox with respect to the Canadian agriculture and food processing commodity trade in 2006. In section 4.1 a comparison of the estimation from the confidential Statistics Canada Input-Output model and the modified Input-Output model are presented. This test was undertaken by shocking the two models with same final demand. Factor intensities of Canadian agriculture and processed food trade are presented in section 4.2. The factor intensity results are used to test the Leontief Paradox.

4.1 Testing the modified Input-Output model

4.1.1 Shock by the total Domestic Final Demand

The modified Canadian Input-Output model was built by using the Worksheet, Link, and Medium level tables of the published Canadian Input-Output model. The agriculture and processed food sectors were kept at the most disaggregated level, while the other sectors were kept at the Medium level. The agriculture and food commodities were kept at the Link level, while the other commodities in the model were aggregated to the Medium level. The modified model is expected to provide comparable estimates to the confidential Statistics Canada model for a change in final demand. A 10% rule will be used to determine the accuracy of the model. This rule suggests that if the total estimate of the modified Input-Output model comes within 10% of the Statistics Canada model estimate, the modified model will be deemed to be accurate. To verify this expectation, the total domestic demand for the year 2006 in Canada was computed directly from the Input-Output table. Its impact on industrial output was estimated using the confidential Statistics Canada Input-Output model at the Worksheet level and to the modified Input-Output model.

4.1.1.1 The domestic final demand vector

The total value of the domestic final demand was 1,766,238.513 million dollars. Over 15% of domestic final demand was allocated to the "government sector services" (provincial and federal level of educational, medical, defence services, etc.), which ranks the highest among 59 commodities and services at the Small level. "Retail margins and services", "Financial insurances, and real estate services", "Motor vehicle, other transportation equipment and parts", and "Imputed rent", were the second to the fifth highest shares of the total domestic final demand. The share of agriculture and food products in domestic final demand was 1% and 3.7% respectively. The commodities and services that made up the ten largest commodity values at the Small level of aggregation are listed in Table 4-1.

Table 4-1. The domestic final demand by commodities and services at the Small level of aggregation in basic price

Commodity	**Value (million dollars)**	**Share to the total domestic final demand**	**Ranking**
Government sector services	277,096	15.7%	1
Retailing margins and services	138,767	7.9%	2
Finance, insurance, and real estate services	126,579.4	7.2%	3
Motor vehicles, other transportation equipment and parts	123,061.7	7.0%	4
Gross imputed rent	109,824	6.2%	5
Non-residential construction	100,571.5	5.7%	6
Residential building construction	75,924	4.3%	7
Wholesaling margins	74,761.9	4.2%	8
Mineral fuels	62,647.1	3/6%	9
Other services	52,545.1	3.0%	10

The distribution of domestic final demand by commodities determines the structure and value of the industrial output impact. For example, the demand for "Government sector services" is satisfied by the Government sector in the Canadian Input-Output table (Make matrix). Therefore, the greater level of demand for "Government sector services" will result in higher levels of output from the Government sector. The above table shows that services, manufacturing, and construction commodities were crucial sources of domestic final demand in 2006. It is expected that the total output of industrial sectors that are related to the production of these services and commodities should be high.

4.1.1.2 The Industrial Output impacts from the domestic final demand

1) The estimation by Statistics Canada's Worksheet Level Input-Output model

The Statistics Canada Input-Output model contains all of the confidential data on the input and output relationships between commodities and industries. It is based on the Worksheet level of aggregation. The confidential Statistics Canada Input-Output model can be used as a reference to test the accuracy of the modified Input-Output model.

In this study, the total industrial output, i.e. direct plus indirect, to satisfy the domestic final demand was estimated. The total industrial output required to satisfy the domestic final demand in 2006 was estimated to be 2,766,851 million dollars. This is 1.57 times the value of the total domestic final demand. This can be interpreted as follows: total industrial output of 2,766,851 million dollars was required to satisfy the demand of 1,766,238.5 million dollars. The industrial sector with the largest industrial output was the manufacturing sector. It accounted for 26% of the total increase in total industrial output. Finance, insurance, rental and leasing sector, government sector, and constructions are the second to the fourth most impacted sectors, which accounted for 14%, 11.9%, and 7.5% of the total increase in industrial output respectively. The required output of the agriculture sector was 42,099 million dollars, accounting for 1.5% of the increased total output. It is worth noting that the manufacturing sector consists of several industrial sectors at the Medium level. Transporting equipment manufacturing, agricultural food manufacturing had the largest increase in industrial output among these manufacturing sectors. The shares of output in these two sectors out of the aggregate manufacturing sectors were 21% and 10.4% respectively. The estimate from the confidential Statistics Canada model provides a good benchmark to test the accuracy of the impacts analyzed by the modified Input-Output model.

2) The estimate using the modified Canadian Input-Output model

Using the same domestic final demand vector, the modified Input-Output model estimated the increase in total industrial output to be 2,939,476.298 million dollars. The manufacturing sector had the largest increase in industrial output accounting for 24.3% of the total increase of industrial output. Finance and leasing sector, government sector and constructions followed, with share of 13%, 11.2%, and 6.7% respectively. Similar to the industrial output impact estimated by the Statistics Canada model, transporting equipment manufacturing and agricultural food manufacturing sectors took the first and second largest increase in industrial output in the manufacturing sector. The output change in the agriculture sector was 44,707.89 million dollars. The 10 industrial sectors with the largest increase in industrial output from both the Statistics Canada model and the modified Input-Output model and their rankings are given in Table 4-2.

Table 4-2. Top 10 industrial sectors at the Small level of aggregation with the largest increase in industrial output

Statistics Canada Worksheet level model		**Modified model**	
Sector	Ranking[4]	Sector	Ranking
Manufacturing	1	Manufacturing	1
Finance, insurance, rental and leasing	2	Finance, insurance, rental and leasing	2
Government	3	Government	3
Construction	4	Construction	4
Retail trade	5	Retail trade	5
Mining and Oil and Gas extraction	6	Mining and Oil and Gas extraction	6
Wholesale Trade	7	Wholesale Trade	7
Transportation and Warehousing	8	Transportation and Warehousing	8
Professional, Scientific and Technical Services	9	Professional, Scientific and Technical Services	9
Information and Cultural Industries	10	Information and Cultural Industries	10

As can be seen from the above table, the relative ranking of the top 10 industrial sectors in terms of increases in industrial output are identical for the confidential Statistics Canada model and the modified Input-Output model. This comparison suggests that the modified model's estimation of the domestic final demand's impact on the Canadian economy in 2006 is consistent with the confidential Statistics Canada model.

4 "Ranking" is based on the value of industrial output impact brought by the domestic final demand, with a descending order.

3) Comparison of the confidential Statistics Canada model and the modified Input-Output model

The estimates from the confidential Statistics Canada model will differ from the modified Input-Output model because the modified Input-Output model is built based on the published Input-Output tables where confidential data was suppressed. However, the modified model should be accurate when used to estimate the industrial output impact (direct plus indirect) brought about by a change in final demand. The domestic final demand shock to both models provides a fair comparison on the model's accuracy in analyzing the interrelationships between industries, commodities and services, and domestic final demand.

Comparing the results of the impact on the economy, the total industrial output required to satisfy the domestic final demand estimated by the modified Input-Output model is 6.23% more than the value computed from the confidential Statistics Canada model. The total value of domestic demand and its estimated impact from both models are given in Table 4-3. This falls well within the 10% range that was used to test the accuracy of the modified Input-Output value. The estimated industrial output using the confidential Statistics Canada model is 1.57 times the original domestic final demand, while the estimated impact using the modified Input-Output model is 1.66 times the original shock. The results suggest that the modified Input-Output model's estimation of the industrial output required to satisfy the change in the final demand for the overall economy is greater than the estimates using the confidential Statistics Canada model.

Table 4-3. Comparison of total domestic demand and its impact on the industrial output

	Total domestic final demand (million dollar)	Estimated industrial output impact (million dollar)	Output impact by total domestic final demand
Confidential Statistics Canada model	1,766,238.513	2,766,851	1.57
Modified Input-Output model	1,766,238.513	2,939,476	1.66
% difference between the confidential model and the modified model[5]	0%	6.23%	6.23%

The changes in industrial output by specific sectors were also compared. The estimated industrial output vectors from both models were computed and aggregated to the same level of aggregations (Medium level). The dollar value of industrial output for each industrial sector was compared between these two estimates. The level of difference between the two estimates by industrial sector is measured by the difference in value between these two estimates for each sector divided by the industrial output impact estimated by the confidential Statistics Canada model.

At the Medium level of aggregation, the estimated results for the sector "Natural Gas Distribution, Water, Sewage and Other Systems" had the largest discrepancy between the

[5] The Percentage difference between the Worksheet model and Modified model is computed as: (value for the modified model - value for the Statistics Canada model) / value for the Statistics Canada model * 100%

models. The industrial output by the confidential Statistics Canada model was 11,495 million dollars, while the output change by the modified model was 7,176 million dollars. The estimate from the modified model was 37% less than the estimated result from the confidential Statistics Canada model. Despite the high level of discrepancy, the sector "Natural Gas Distribution, Water, Sewage and Other Systems" output share to the total industrial output was 0.4% in the confidential Statistics Canada model and 0.2% in the modified model. This suggests that the large observed discrepancy may be due to the small value of the industrial output in this sector. Consequently, the industrial output discrepancy between the two models for this sector would not affect the overall prediction by the modified Input-Output model. The next three sectors with the largest differences were the "Waste Management and Remediation Services", "Electrical Equipment, Appliance and Component Manufacturing", and "Computer and Electronic Product Manufacturing". The level of difference for sector "Waste Management and Remediation Services" between the two models is large. However, the share of industrial output of this sector to the total industrial output for the two models was quite close, i.e. 0.2% with the confidential Statistics Canada model and 0.24% with the modified Input-Output model. The same trend was observed for the two other sectors. For the comparison of industrial output impact by other sectors, it was observed that the absolute percentage differences were around 10%. If the shares of industrial output by sector were compared between the two models, a smaller difference for each sector was observed. For example, the total industrial output for "Crop and animal production" was 42,099 million dollars with the confidential Statistics Canada model and 44,707 million dollars with the modified Input-Output model; i.e. the estimate with the modified Input-Output model was 6% higher than with the confidential Statistics Canada model. The share of industrial output from this sector was 1.5215% of the total industrial output with the confidential Statistics Canada model and 1.5209% of the total industrial output with the modified Input-Output model. The difference between the shares was less than 0.001%.

At the Small level of aggregation the average difference for each industrial sector between the two models was 1.4%. Few exceptions were observed for large difference between the results from the confidential Statistics Canada model and the modified Input-Output model. However, their shares of total industrial output impacted by the domestic final demand were relatively small.

4.1.2 The Industrial Output impacts from the domestic final demand in agriculture and food commodities

The modified Input-Output model was designed to provide detail information on the agriculture and food commodities and the agriculture and processed food industries. The other commodities and industrial sectors were aggregated to a higher level of aggregation, i.e. the Medium level. This was done to (1) avoid the effects of confidential data on the overall estimates, and (2) focus on the analysis of the total output required by the agriculture and processed food sectors to satisfy a change in final demand for agriculture and food commodities. To further test the accuracy of the model, given its designs, a domestic final demand shock to only the agriculture and food commodities was given to both the models.

4.1.2.1 The vector of domestic final demand for agriculture and food commodities

The total value of domestic final demand for agriculture and food commodities was 128,573.7 million dollars in 2006. It was approximately 7.3% of total domestic final demand. The domestic final demand for agriculture and food commodities was distributed to 74 commodities and 6 margins in the shock vector. Five of the highest domestic final demands for agriculture and food commodities are listed in the Table 4-4. The share of each commodity is relatively small. This is because the final demand value for each commodity is given in its basic price. Using basic prices means that the value of each commodity is at the producer's price. The difference between the producers' price and purchasers' price were distributed to the margins listed among the commodities.

Table 4-4. The top 5 domestic final demand for agriculture and food commodities

Commodity	**Domestic final demand (million dollars)**	**Share**
Beer including coolers	7,780.08	6.1%
Beef, pork and other meat and edible offal, excluding poultry, fresh, chilled or frozen	4,458.03	3.5%
Wine including coolers	3,919.59	3.1%
Wheat, unmilled	3,624	2.8%
Miscellaneous dairy products	3,489.63	2.7%

4.1.2.2 Comparison of the estimated results from the two models

Shocking the domestic final demand for agriculture and food commodities provides an estimate of the impact of satisfying a final demand for agriculture and food commodities on industrial output in the economy. The total industrial output estimate was higher for the modified Input-Output model when compared with the confidential Statistics Canada model. Table 4-5 shows the comparison of the total industrial output from the two models. The total industrial output was estimated to be 236,205 million dollars with the confidential Statistics Canada model and 251,001 million dollars with the modified Input-Output model. They were 1.83 and 1.95 times the original domestic final demand for agriculture and processed food commodities. The difference between the two models was approximately 6.26%. The modified model predicts within 10% of the confidential Statistics Canada estimated output required to satisfy the final demand for agriculture and food commodities.

Table 4-5. The total industrial output required to satisfy the domestic final demand for agriculture and food commodities (million dollars)

	Domestic final demand	**Estimated industrial output impact**	**Output impact by domestic final demand**
The confidential Statistics Input-Output model	128,573.7	236,205.1	1.83
The modified Input-Output model	128,573.7	251,001.6	1.95
% difference between models	0%	6.26%	6.26%

For specific sectors at the modified Input-Output model level, the difference in required industrial output from the agriculture and processed food sectors between the modified Input-Output model and the confidential Statistics Canada model was 2.39%. This difference was smaller than the overall industrial output difference (6.26%) estimated by the two models. The largest differences occurred with the "Wineries" and "Potatoes" sectors, with 47% and 34% differences between the two models respectively. However, their contribution to the total industrial output by all sectors and by only the agriculture and processed food sectors was relatively small. This finding suggests that the difference found in the two models for these two sectors would not affect the estimates from the modified Input-Output model. Differences with the other agriculture and processed food sector outputs were around 10%. This suggests that on average, the modified Input-Output model fairly closely estimates the confidential Statistics Canada model. Table 4-6 shows the industrial output of the agriculture and processed food sectors required to satisfy the domestic final demand for agriculture and food commodities.

The total industrial output required by the changes in final demand of agricultural and processed food in the modified and confidential Statistics Canada model was different by 6.26%. The differences in individual industrial output estimates between the two models were more significant than the total overall estimates. It is useful if the reason of such variation can be explained. First of all, the observed differences between two models are mainly due to the suppressed confidential data in the published Input-Output model. If a sector consists of higher level of suppressed confidential data, the difference in industrial outputs between the two sectors are expected to be higher. One example os this, as seen in table 4-6, is the “Sugar and Confectionery Product Manufacturing” sector. The difference that results from the suppression of confidential data between the two models is 19.59%. From the make matrix in the modified Input-Output table, the reported output for this sector in 2006 was 4.931 billion dollars. However, if summing up the output for this sector according to the modified Input-Output table, the total output in 2006 was 3.172 billion dollars, which was 37% lower than the reported total. Moreover, as sugar is one of the main products by this industry, the level of confidential data supressed for commodity “sugar” in the Input-Output table would affect the industrial output of this sector. From the published Input-Output table, the reported total output of sugar in 2006 was 850 million dollars, while the calculated total was only 2 million dollars. The confidential problem in this industry and commodity “sugar” had a direct impact on the difference between the modified model and the confidential Statistics Canada model. Different levels of supressed confidential data can be seen in many other sectors, such as Wheat, Oilseed, Potatoes, and Wineries, etc. The difference for those sectors can be partially explained by the confidential data.

A second potential area of difference is with the leakage coefficients. If the modified model and the confidential Statistics Canada model applied different leakage coefficients, the changes in industrial output to satisfy final demand would be different. Leakage coefficients applied to the modified Input-Output model were provided directly by Statistics Canada. They can also be computed by using Make matrix and Final Demand matrix. It was found that the leakage values provided by Statistics Canada and the computed ones were not identical. For most commodities, differences of leakages between these two sets were around 5%. However, for certain sectors, the leakages value varied greatly. For example, for commodity “wine including cooler” the reported leakage value was 0.45, while the computed value was 0.34. The difference in leakage value can be amplified by including the leakage in the total impact matrix. Therefore, the changes of industrial output to satisfy final demand could differ between the two models.

A third factor that could affect the discrepancy of the reported data from the different levels of aggregated Input-Output table can be another explanation for the variance in industrial output. This problem existed in the agricultural sectors. For the extended agricultural worksheet level Input-Output table, the agriculture sectors were expanded to 13 sectors, while for the other levels of the model the agriculture sectors were aggregated to 1 sector. The summed total industrial outputs for these 13 sectors by commodity do not always match with the reported total in the one sector aggregate matrices. For example, the commodity “potatoes fresh and chilled” produced by the agriculture sectors in 2006 was 1.084 billion dollars, while the reported total was 1.092 billion dollars.

The level of variance in industrial output by sector between the two models can be affected by these different factors. Most of the time, such difference cannot be explained by only one factor. For “Potatoes”, “Oilseed”, and other sectors shown below, the differences between the two models were due to a combination of the factors discussed above.

Table 4-6. Comparison of industrial output from the agriculture and processed food sectors required to satisfy the domestic final demand for agriculture and food commodities

Sector	Modified model (million dollars)	Worksheet model (million dollars)	Differences
Total of Agricultural and agricultural food sectors	**170,499**	**174,674**	**-2.39%**
Total of crop and animal production	34,869	33,903	2.85%
Greenhouse, Nursery and Floriculture production	2,017	2,112	-4.51%
Wheat	4,450	3,994	11.42%
Feed grain	2,487	2,303	7.98%
Oilseed	3,889	3,366	15.54%
Potatoes	1,078	801	34.61%
Fruits & Vegetables	2,477	2,568	-3.55%
Other Crops	3,324	3,406	-2.39%
Animal aquaculture	801	716	11.81%
Dairy	3,925	4,020	-2.35%
Cattle	5,365	5,297	1.27%
Hogs	2,662	2,651	0.41%
Poultry and eggs	1,770	2,012	-12.02%
Other livestock	626	658	-4.95%
Total of Processed agricultural food production	67,815	70,386	-3.65%
Animal Food Manufacturing	4,155	4,076	1.92%
Sugar and Confectionery Product Manufacturing	3,336	4,149	-19.59%
Fruit and Vegetable Preserving and Specialty Food Manufacturing	6,060	6,046	0.23%
Dairy Product Manufacturing	9,873	9,833	0.42%
Meat Product Manufacturing	14,207	14,695	-3.32%
Seafood Product Preparation and Packaging	3,189	3,329	-4.20%
Miscellaneous Food Manufacturing	14,998	15,750	-4.77%
Soft Drink and Ice Manufacturing	3,364	3,255	3.35%
Breweries	4,017	3,864	3.95%
Wineries	882	1,682	-47.54%
Distilleries	747	771	-3.06%
Tobacco Manufacturing	2,985	2,934	1.73%

The average difference between the two models for non-agriculture and food related sectors was 10%, this differences was larger than the average for the agriculture and processed food sectors. This can be explained by the higher level of aggregation for the non-agricultural sectors.

4.1.3 Discussion

The results from the modified Input-Output model were compared with the results from the confidential Statistics Canada model. The average difference of 6.23% in the total industrial output required to satisfy the domestic final demand suggests that the modified Input-Output model is valid for the estimation of changes in final demand to the economy. The large difference in sectors “Waste Management and Remediation Services”, “Electrical Equipment, Appliance and Component Manufacturing”, and “Computer and Electronic Product Manufacturing”, and “Natural Gas Distribution, Water, Sewage and Other Systems” suggests that economic activities directly related to these sectors will be either under or over estimated. Two potential sources for these differences can be from (1) the suppression of data due to confidentiality within the sectors and commodities, and (2) discrepancies between the reported totals for individual sector output and values in the tables and the reported total of commodity value totals and values in the tables.

The second shock to both models was designed to test the modified Input-Output model’s estimation of a change in final demand for agriculture and food commodities. This was done to test the accuracy of the model when using the most disaggregated sectors and commodities. It was estimated that the domestic final demand in agriculture and food commodities in Canada in 2006 would require 251,001.6 million dollars of industrial output, which was 1.9 times the total value of the domestic agriculture and food final demand. The difference between the modified Input-Output model and the confidential Statistics Canada model was 6.26%. The estimates of output for the agriculture and processed food sectors were very close between the two models, with an average difference of 2.3%. From this comparison, it is concluded that the modified Input-Output model will provide accurate estimates of the total industrial output required to satisfy a change in final demand for agriculture and food commodities. The non-agriculture and food sector output estimates have a relatively higher difference, on average 10%. This is due to the higher levels of aggregation of these sectors and commodities in the model design. A 10% rule was used to test the accuracy of the model. Given the results, the modified Input-Output model passed the test and therefore can be used to estimate the impact of changes in final demand for agriculture and food commodities.

4.2 Examination of the Leontief Paradox

The investigation of the Leontief Paradox using Canadian agriculture and processed food trade was conducted using Leontief's methods of analysis and Leamer's propositions. In the following section, factor intensity and the existence of the Leontief Paradox for Canadian agriculture and food trade for the year 2006 will be tested.

4.2.1 The Canadian agriculture and food trade in 2006

According to the Input-Output final demand table, Canada exported 33,177 million dollars and imported 25,109 million dollars of agriculture and food commodities in 2006.

Canada was a net-exporter of agriculture and food products, with a net-exports value of 8,068 million dollars. Agriculture and processed food exports and imports accounted for 6.7% and 5.3% of total trade respectively in 2006. However, the net-exports of agriculture and food were greater than the total net-exports in Canada. This suggests that the large outflow of agriculture and processed food commodities from Canada contributed greatly to the Canadian trade surplus in 2006.

Canada's largest agricultural export was wheat, worth 3,624 million dollars. Pork, fish and seafood products, vegetables other than potatoes were the second to the fifth largest outflow of agriculture and food exports. In terms of agriculture and processed food imports, Canada imported 1,790 million dollars' worth of vegetables other than potatoes, which was the largest proportion of imports in agriculture and processed food. Wine, fresh fruits, fish and seafood products, and cigarettes were the second to the fifth largest inflow of commodities in 2006. Of the total agriculture and processed food commodities, the share of processed food exports and imports were over 50%. The share of agriculture products in exports was greater than the share in imports. This structural difference between Canadian agriculture and food commodities exports and imports in 2006 suggests that Canada's exports were dependent more on agriculture products, while its imports were more dependent on processed food products. The different structure of production factors used in agriculture and processed food production affects the factor intensity in Canada's agriculture and processed food exports and imports.

4.2.2 Applying Leontief's approach

As previously explained, Leontief computed the capital and labour requirements for an average one million dollars of exports and import replacements respectively. He found that the US exported more labour and imported more capital intensive products in 1947. The ratio of capital per labour between exports and import replacements was 0.77. This result suggested that the US resorted to international trade in order to economize its capital and dispose of its surplus labour.

In this study, the original Leontief's approach of computing the factor requirements in exports and import replacements was used to investigate the existence of the Leontief Paradox in Canadian agriculture and processed food trade. The total capital and labour requirements for an average one million dollars of agriculture and processed food exports and import replacements were estimated. The land requirement was also estimated in addition to the capital and labour requirement that was estimated in the original Leontief study.

4.2.2.1 Industrial output required to satisfy a million dollars of exports and import replacements of agriculture and processed food commodities

1) Exports

The total industrial output required to satisfy a 1 million dollars of exports in agriculture and processed food commodities was 2.097 million dollars, out of which 51% was from the agriculture and processed food sectors. For the agriculture and processed food sectors, the output in meat product manufacturing was 162,866 dollars, accounting for the largest share of the total industrial output. Miscellaneous food manufacturing, seafood product preparation and packaging, cattle, wheat, and oilseed production would produce the second to the fifth largest output to satisfy the 1 million dollars of exports of agriculture and processed food commodities. For non-agriculture and processed food sectors, the largest industrial output was from the margin sectors, and the "Finance, Insurance, Real Estate and Rental and Leasing" sector. The latter sector output was related to the agriculture sectors through the rental and leasing of agricultural machinery.

2) Imports

If produced domestically, the 1 million dollars' worth of imports in agriculture and processed food commodities would require a total of 1.96 million dollars of industrial output, of which 55% would come from agriculture and processed food sectors. The miscellaneous food manufacturing sector would produce the largest output among all sectors to satisfy the 1 million dollars of import replacements. This was followed by increased output from the meat products, fruit and vegetable preserving and specialty food manufacturing, fruits and vegetables, seafood product preparation and packaging, and sugar and confectionery product manufacturing sectors. Similar to exports, non-agriculture and processed food sectors such as "Finance, Insurance, Real Estate and Rental and Leasing" sector and wholesaling margins would require the most output. A complete list of the industrial output to satisfy the 1 million dollars of exports and import replacements is provided in Appendix E.

4.2.2.2 Factor requirements for exports and import replacements

The factor requirements for exports and import replacements for agriculture and processed food commodities were calculated by multiplying the industrial output vector computed in the last section with the factor coefficients for each industrial sector. The results can be found in Table 4-7.

Table 4-7. Domestic capital, labour and land requirements per million dollars of Canadian agriculture and food exports and import replacements

	Exports	**Import Replacements**
Capital (dollars)	3,542,800	2,572,600
Labour (working hours)	21,063.7	22,937.1
Land (acres)	2,210.1	994.7
Capital-labour ratio	168.2	112.2
Land-labour ratio	0.1	0.04
Land-capital ratio	0.0006	0.0003

These results show that an average million dollars' worth of Canadian agriculture and processed food exports used more capital and less labour than an equivalent amount for the import replacements. The ratios between capital and labour for exports and import replacements were 168.2 and 112.2 dollars per working hour respectively. The ratio of capital per working hour between exports and import replacements was 1.5. These results suggest that Canada used international trade in agriculture and processed food commodities to optimize labour and dispose of excess capital. By Leontief's definition, Canadian agriculture and processed food exports are relatively more capital intensive than its import replacements. As a developed economy, Canada is believed to be endowed with more capital than labour. According to the H-O theory, a country should export commodities that use its relative abundant factor and import commodities that use its relatively scarce factor. The estimates for Canadian agriculture and processed food trade are consistent with what is proposed by the H-O theory. Therefore, using the same approach as Leontief on Canadian agriculture and food trade, no Leontief Paradox was found to exist for the year 2006.

Apart from capital and labour, land as a natural resource was also included in this analysis. The results would indicate that Canada exported agriculture and processed food commodities that used more land, and imported commodities that used less land. The ratio of land use between exports and import replacements was 2.2. This means that for the equivalent amount of exports and import replacements, the land use in exports is more than double the land use in import replacements. The land-labour and capital-land ratio were also computed for both exports and import replacements. It was found that the land-labour ratios for exports and import replacements were 0.1 and 0.04 acres per working hour respectively, while the capital-land ratios for exports and import replacements were 1603 and 2586 dollars per acre respectively. The land-labour ratio in exports was 2.5 times the ratio for import replacements. This suggest that Canadian agriculture and processed food exports require more land per working hour than the imports if they would have been produced domestically. The capital land requirements were both higher in exports than import replacements. Moreover, the ratio between capital and land for exports was smaller than for import replacements, which indicates that land was the dominant factor in Canadian agriculture and food trade compared to the other two factors.

In conclusion, capital and land requirements were relatively greater in Canadian agriculture and food exports, while the labour requirements were relatively greater in Canadian agriculture and food imports in 2006. This result can be interpreted as indicating that Canadian agriculture and food exports were relatively capital and land intensive, while its imports were relatively labour intensive. As a developed economy, Canada is expected to be well endowed with capital and having a scarcity of labour. It is known that Canada is endowed with a large stock of natural resources. The computed results show that land as a natural resource played a dominant role in exports, which supports the factor endowment theory. Therefore, the result suggests that the Canadian agriculture and food trade supports the H-O-V theorem. There is no evidence of the Leontief Paradox for Canadian agriculture and processed food trade in 2006.

4.2.3 Applying Leamer's approach

4.2.3.1 Factor content in net-exports of agriculture and processed food trade

The factor content of net-exports of agriculture and processed food trade was computed. This was done by shocking the modified Input-Output model with the total value of agriculture and processed food exports and imports separately to estimate the impact, i.e. total industrial output, on the economy. These results were multiplied by the factor coefficients for each industrial sector. Table 4-8 provides detailed information on the factor requirements by Canadian agricultural and processed food trade.

Table 4-8. Factor requirements for agriculture and processed food trade

	Exports	**Imports**	**Net-exports**
Capital (thousand dollars)	117,910,000	65,601,000	52,309,000
Labour (thousand working hours)	700,494.9	584,440.5	116,054.4
Land (thousand acres)	73,677	25,704	47,973
Capital-labour ratio	168.2	112.2	450.7
Land-labour ratio	0.11	0.04	0.41
Land-capital ratio	0.0006	0.0003	0.0009

The results suggest that Canada was a net-exporter of capital, labour, and land in its agriculture and processed food trade in 2006 (Table4-8). The capital-labour ratio, land-labour ratio and land-capital ratio were 450.7, 0.41 and 0.0009 respectively. The net-exports of agricultural and processed food commodities in Canada were 8,068 million dollars. Using the capital, labour and land requirements for net-exports shown in Table 4-8 to divide the value of total net-exports of agricultural and processed food commodities would show the factor requirements by an average 1 million dollars of net-exports of agricultural and processed food commodities. An average 1 million dollars of net-exports of agricultural and processed food products requires 6.48 million dollars of total capital inputs, 14,384 working hours, and 5,946 acres. According to Leamer's proposition (1980), if a country is a net-exporter of both capital and labour, trade can be used to determine if a country is relatively endowed in capital if and only if the ratio of capital-labour embodied in net-exports is greater than the capital-labour ratio absorbed by domestic consumption.

4.2.3.2 Factor requirements for domestic consumption and production of agriculture and food commodities

According to Leamer's propositions, factor requirements in net-exports should be compared with the factor requirements in domestic consumption and production to draw any conclusion on the factor endowment for a country. It was defined in Leamer's work that production equals domestic consumption plus net exports. For the Canadian economy in 2006, the total production, domestic consumption, and the net exports for agriculture and processed food commodities were 121,872, 113,804, and 8,068 million dollars respectively. The factor requirements in these categories were estimated using equation (3-11), and are given in Table 4-9.

Table 4-9. Factor content in total agricultural production, consumption and net-exports in 2006

	Capital (thousand dollars)	**Labour (thousand working-hours)**	**Land (thousand acres)**	**Capital/ Labour ratio**	**Land/ Labour ratio**	**Land/ Capital ratio**
Net-exports	52,309,000	116,054.4	47,973	450.72	0.41	0.0009
Consumption	212,010,000	2,352,300	57,563	90.12	0.02	0.0003
Production	328,760,000	2,623,500	146,280	125.31	0.06	0.0004

The Capital-labour ratio in net-exports and production were 5 and 1.4 times that in consumption. This suggests that net-exports and production of agriculture and food commodities require relatively more capital, while consumption requires relatively more labour. Similarly, the land labour ratio in net-exports and production are higher than in consumption also suggesting that agriculture and processed food trade and production are relatively more land intensive. According to Leamer, Canada is a net-exporter of both capital and labour in agriculture and processed food trade, and capital and land embodied in net-exports are greater than the capital and land absorbed by domestic production. This would suggest that Canada's agriculture and processed food is relatively abundant in capital and land compared to labour. The land-capital ratio for net-exports is higher than both consumption and production. This suggests net-exports is comparatively more land intensive than capital intensive. Land is revealed to be relatively more abundant than capital and labour in Canada.

4.2.4 Discussion and conclusion

Factor intensities in Canadian agriculture and processed food trade were computed to investigate whether the Leontief Paradox exists in Canada. For a million dollars of exports and import replacements, the capital-labour ratio was greater in exports than imports. This estimate is consistent with approach taken by Leontief to study factor intensities. The results suggest that no evidence of the Leontief Paradox were found in Canadian agriculture and processed food trade in 2006.

The results found in this study have the same conclusion of those by Lee (1988) who investigated the Leontief Paradox for US agriculture and processed food commodities. In Lee's study, capital-labour ratio was 6.4 for imports and 10.2 for exports and land-labour ratio was 173.0 and 37.9 acres per worker year for exports and imports respectively. His computation suggested that US agriculture and processed food exports was relatively capital and land intensive compared to labour in 1982. Factor intensities in US agriculture and food trade were similar to that in Canada.

The calculation of capital and labour intensity used in this study were different from those used by Leontief (1956) and Lee (1988). In their studies they estimated capital requirements using capital flows from the US Input-Output model. This study used a stock value for capital requirements. Using a stock value for capital as oppose to a flow value is expected to give more accurate estimate of capital intensity.

Canada exported both labour and capital to the rest of the world. A comparison between factor intensities in production, domestic consumption, and net-exports were also compared. It was found that the capital-labour and land-labour ratio for net-exports and production were greater than those for domestic consumptions, which suggests that Canada was relatively abundant in capital and land as compared to labour in the international trade of agriculture and food commodities. A few studies (Naya 1967; Vanek 1963; Wahl 1961; Tatemoto 1959) suggested that the capital and land intensities were observed to change in the same direction and as a result the Leontief Paradox could be explained by the complementary relationship between capital and land in the US. In this study, even though no Leontief Paradox was observed, the results suggest that Canada is relatively more abundant in capital and land. This may also be a reflection of the complementary between capital and land. However, no conclusion of complementary between capital and land can be drawn from this study. To fully understand whether capital and land in Canada are complementary to each other, multiple years of factor intensity need to be computed and compared. If changes in capital and land were observed to be in the same direction for multiple years, the complementary between capital and land can be concluded for that period of time. This study only computed the factor intensities for trade in 2006. Even if it was observed that the Canadian agriculture exports were relatively capital and land intensive, it could not be generalized that complementary between capital and land existed because multiple years were not investigated.

Empirically, Canada as a developed country is believed to be endowed with relatively more capital than labour. The observed capital intensities in agriculture and processed food trade are consistent with this fact. Canada's exports of agricultural products such as wheat are a large proportion (8%) of Canada's agriculture and processed food trade. Land use in wheat and other crop production is large, i.e. 1 million dollars of wheat production and feed grain production requires 8,855, and 9,087 acres of land use respectively. This can explain the abundant land use in total agriculture and food trade.

From this study, it is suggested that factor intensities in Canadian agricultural and processed food trade is consistent with the factor endowments of Canada, i.e. Canada is well endowed with land and capital, while it has a scarcity of labour. Policies should be designed to promote exporting land and capital intensive goods, and therefore enhance the competitiveness of agriculture and food products in international market. Higher education and additional training should be encouraged through government funding to increase the amount of skilled labour in agriculture to compensate for its scarcity of physical labour. Industries that have a relatively intensive labour component need to find niche markets where the novelty of their product provides them with a comparative advantage. An alternative approach for these sectors would be to innovate. Innovation could include technological change that replaces labour with capital.

In conclusion, Canada was observed to export relatively capital and land intensive products as compared labour intensive products. The findings from both Leontief and Leamer's approaches did not support the Leontief Paradox for agriculture and food trade in Canada for 2006.

Chapter 5: Conclusion

The main objective of this research was to investigate whether or not the Leontief Paradox exists for Canadian agriculture and food trade for the year 2006. Factor intensities of Canadian agriculture and food trade were computed and compared with the factor endowments in Canada. A modified version of the Canadian Input-Output model was built to calculate the factor requirements in Canadian agriculture and processed food trade.

The first objective of the study was to test the accuracy of the modified Input-Output model. This was done by comparing the estimates from the modified Input-Output model with the confidential Statistics Canada Input-Output model. This was considered a valid test since the confidential Statistics Canada Input-Output model contained all of the confidential data that is suppressed in the published tables. The modified Input-Output model was constructed using Input-Output tables with different levels of aggregation for commodities and industrial sectors. This approach was taken for two reasons. First, the model could be constructed with detailed agriculture and processed food sectors and agriculture and food commodities. This allows for a better estimate of the impact of agriculture and food processing commodity exports and imports. Second, it decreases the estimation problems related to confidential data. Industrial sectors and commodities that were included at the Medium level of aggregation have less data suppressed due to confidentiality. A 10% rule was used to judge the accuracy of the modified Input-Output model.

The modified Input-Output tables for 2006 provided detailed information of the interrelationship between agriculture and processed food sectors, commodities, and final demand. Two final demand vectors were used to test the modified Input-Output model: (1) a vector of domestic final demand for all commodities and services, and (2) a vector of domestic final demand for agriculture and food commodities only.

Shocking the modified Input-Output model and the confidential Statistics Canada model with the first sector of domestic final demand, it was found that the difference in estimates was 6.23%. In this case the estimate of the modified Input-Output model was 6.23% larger than the confidential Statistics Canada model. This result suggests that the modified Input-Output model was accurate in terms of estimating the impact on industrial output for a change in domestic final demand. The difference in the estimated impact between the modified Input-Output model and the confidential Statistics Canada model for the second shock was 6.26%. The results from the second shock suggest that the modified Input-Output model can be used to estimate the impact on the economy of a change in final demand in agriculture and food commodities. The comparison of the results of the shocks to the modified Input-Output model and the confidential Statistics Canada model passed the 10% test for accuracy. As a result, the modified Input-Output model was deemed to be a good approximation of the confidential Statistics Canada estimates. The modified Input-Output model also provides detailed information on the agriculture and processed food sectors, which is needed for the analysis of the production of agriculture and food commodities. The modified Input-Output model is valid to investigate the factor intensities in Canadian agriculture and food trade.

The second objective of the study was to investigate the existence of the Leontief Paradox in Canadian agricultural trade. Three production factors, capital, land, and labour, were included in this analysis. The study used both Leontief's and Leamer's approaches to estimate the factor intensity and factor endowment revealed by agriculture and processed food trade in Canada.

The capital-labour ratio for an average 1 million dollars of agriculture and food exports and import replacements was 168.2 and 112.2 dollars per working hours respectively, and the land-labour ratio for exports and imports was 0.1 and 0.04 acres per working hours respectively. As for the factor requirements in net-exports, production, and consumptions for agriculture and food commodities, the capital-labour ratio were estimated to be 168.2, 112.2, and 450.7 dollars per working hour respectively, while the land-labour ratio were 0.11, 0.01, and 0.41 acres per working hour respectively. The results show that Canadian agricultural exports in 2006 were relatively capital and land intensive and its imports were relatively labour intensive. The capital and land intensity in net-exports was greater than that in domestic consumption, which suggests that Canada was revealed to be relatively endowed with capital and land as compared to labour. No evidence of the existence of the Leontief Paradox in Canadian agriculture and food trade for 2006 was found.

In addition, it was found that the ratio of land embodied in an average 1 million dollars' worth of net-exports to land required for an equivalent amount of domestic consumption suggested that land as a natural resource was dominant in net-exports of Canadian agriculture and food trade. This reflected the fact that Canada's major agriculture and food exports, such as wheat and other crop, use large land areas. The relative land intensive of net-exports is also in line with the fact that Canada is well endowed with natural resources compared to the rest of the world.

5.1. Recommendation for further research

Several directions can be undertaken for further research.

1) In this study, it was found that Canadian agricultural exports were capital and land intensive. As suggested by other researchers, capital and natural resources are complementary with each other. To verify this argument for the Canadian economy, a study on the factor intensities of Canadian trade on a time series is recommended.
2) Developed economies tend to have relatively rigid regulation on pollution by industrial production as compared to developing countries. It would be interesting to investigate the environmental content (GHG emissions and water pollution) in Canadian trade. Environmental concerns may be another factor in determining trade patterns in Canada. These approaches could be used to investigate pollution terms of trade between Canada and other countries and how these affect its trade and production.
3) This study concerns Canada's agriculture and food processing trade with the rest of the world. The investigation of trade patterns between Canada and a specific country or region can be studied. Canada's agriculture and food processing trade patterns with developed countries and developing countries may vary due to the differences of comparative advantages in factor endowments. As the structure of

Canadian trade by partner changes, the direction of Canadian agriculture and processed food trade overall may change as well. Therefore, a country specific study would be helpful in explaining such changes.

4) This study selected a normal year (2006) to investigate trade patterns in Canada. However, the financial crisis that took place in 2008 is expected to have an impact on Canadian's production and trade. The large degree of interdependency between the Canadian and the US economies and its impact on trade given financial crisis could be investigated. It would be interesting to see whether factor intensities in Canadian trade changed during this period of time and how such change affected patterns of trade.

5) This study integrated labour as one factor in the estimation of factor intensity in Canadian agriculture and food processing trade. Labour may be classified as skilled and unskilled labour based on various factors (education, training, or level of wages and salaries). Trade patterns for different type of labour in trade could be investigated.

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Appendix A: List of industrial sectors in the modified Input-Output model and their levels of aggregation

No.	NAICS CODE	LEVEL[6]	INDUSTRY
1	111400	W	Greenhouse, Nursery and Floriculture Production
2	111a01	W	Wheat
3	111a02	W	Feed grain
4	111a03	W	Oilseed
5	111a04	W	Potatoes
6	111a05	W	Fruits & Vegetables
7	111a06	W	Other Crops
8	112500	W	Animal Aquaculture
9	112a01	W	Dairy
10	112a02	W	Cattle
11	112a03	W	Hogs
12	112a04	W	Poultry and eggs
13	112a05	W	Other livestock
14	113	M	Forestry and Logging
15	114	M	Fishing, Hunting and Trapping
16	115	M	Support Activities for Agriculture and forestry
17	211	M	Oil and Gas Extraction
18	212	M	Mining (Except Oil and Gas Extraction)
19	213	M	Support Activities for Mining and Oil and Gas Extraction
20	22A	M	Electric Power Generation, Transmission and Distribution
21	22B	M	Natural Gas Distribution, Water, Sewage and Other Systems
22	230	M	Construction

Source: Prepared by the author

[6] "W", "L", "M" represent the correspondent "Worksheet", "Link", and "Medium" aggregation level in the Canadian Input-Output level.

Appendix A (continued)

22	230	M	Construction
23	3111	L	Animal Food Manufacturing
24	3113	L	Sugar and Confectionery Product Manufacturing
25	3114	L	Fruit and Vegetable Preserving and Specialty Food Manufacturing
26	3115	L	Dairy Product Manufacturing
27	3116	L	Meat Product Manufacturing
28	3117	L	Seafood Product Preparation and Packaging
29	311A	L	Miscellaneous Food Manufacturing
30	312A	L	Soft Drink and Ice Manufacturing
31	312B	L	Breweries
32	312C	L	Wineries
33	312D	L	Distilleries
34	3122	L	Tobacco Manufacturing
35	31A	M	Textile and Textile Product Mills
36	315	M	Clothing Manufacturing
37	316	M	Leather and Allied Product Manufacturing
38	321	M	Wood Product Manufacturing
39	322	M	Paper Manufacturing
40	323	M	Printing and Related Support Activities
41	324	M	Petroleum and Coal Products Manufacturing
42	325	M	Chemical Manufacturing
43	326	M	Plastics and Rubber Products Manufacturing
44	327	M	Non-Metallic Mineral Product Manufacturing
45	331	M	Primary Metal Manufacturing
46	332	M	Fabricated Metal Products Manufacturing
47	333	M	Machinery Manufacturing
48	334	M	Computer and Electronic Product Manufacturing
49	335	M	Electrical Equipment, Appliance and Component Manufacturing
50	336	M	Transportation Equipment Manufacturing
51	337	M	Furniture and Related Product Manufacturing
52	339	M	Miscellaneous Manufacturing
53	410	M	Wholesale Trade
54	4A0	M	Retail Trade

Source: Prepared by the author

Appendix A (continued)

55	484	M	Truck Transportation
56	485	M	Transit and Ground Passenger Transportation
57	486	M	Pipeline Transportation
58	48A	M	Other Transportation
59	49A	M	Postal Service and Couriers and Messengers
60	493	M	Warehousing and Storage
61	512	M	Motion Picture and Sound Recording Industries
62	513	M	Broadcasting and Telecommunications
63	51A	M	Publishing Industries, Information Services and Data Processing Services
64	5A0	M	Finance, Insurance, Real Estate and Rental and Leasing
65	541	M	Professional, Scientific and Technical Services
66	561	M	Administrative and Support Services
67	562	M	Waste Management and Remediation Services
68	610	M	Educational Services
69	620	M	Health Care and Social Assistance
70	710	M	Arts, Entertainment and Recreation
71	720	M	Accommodation and Food Services
72	811	M	Repair and Maintenance
73	813	M	Grant-Making, Civic, and Professional and Similar Organizations
74	81A	M	Personal and Laundry Services and Private Households
75	F10	M	Operating, Office, Cafeteria and Laboratory Supplies
76	F20	M	Travel, Entertainment, Advertising and Promotion
77	F30	M	Transportation Margins
78	NP1	M	Non-Profit Institutions Serving Households (Excluding Education)
79	NP2	M	Non-Profit Education Institutions
80	GS1	M	Hospitals and Residential Care Facilities
81	GS2	M	Universities and Government Education Services
82	GS4	M	Other Municipal Government Services
83	GS5	M	Other Provincial and Territorial Government Services
84	GS6	M	Other Federal Government Services

Source: Prepared by the author

Appendix B: List of Commodities, Services, and Primary Inputs in the modified Input-Output model and their levels of aggregation

No.	CODE	LEVEL	COMMODITY
1	1	L	Cattle and calves
2	2	L	Hogs
3	3	L	Poultry
4	4	L	Other live animals
5	5	L	Wheat, unmilled
6	6	L	Corn, barley, oats and other grains
7	7	L	Fluid milk, unprocessed
8	8	L	Eggs in the shell
9	9	L	Honey and beeswax
10	10	L	Fresh fruit, excluding tropical
11	11	L	Vegetables, fresh or chilled
12	12	L	Hay and straw
13	13	L	Seeds, excluding oil seeds
14	14	L	Nursery stock, flowers, and other horticulture products
15	15	L	Canola, soybeans and other oil seeds
16	16	L	Raw tobacco
17	17	L	Raw wool and mink skins
18	18	L	Services incidental to agriculture and forestry
19	4	M	Forestry products
20	5	M	Fish and seafood, fresh, chilled or frozen
21	6	M	Hunting and trapping products
22	7	M	Iron ores and concentrates
23	8	M	Miscellaneous metal ores and concentrates
24	9	M	Coal
25	10	M	Crude mineral oils

Source: Prepared by the author

Appendix B (continued)

26	11	M	Natural gas, excluding liquefied
27	12	M	Non-metallic minerals
28	13	M	Services incidental to mining
29	42	L	Beef, pork and other meat and edible offal, excluding poultry, fresh, chilled or frozen
30	43	L	Cured meat
31	44	L	Prepared meat products
32	45	L	Animal fat and lard
33	46	L	Margarine and shortening
34	47	L	Sausage casings
35	48	L	Feeds from animal by-products
36	49	L	Raw animal hides and skins
37	50	L	Animal by-products for industrial use
38	51	L	Custom work, meat and food
39	52	L	Poultry, fresh, chilled or frozen
40	53	L	Miscellaneous dairy products
41	54	L	Fresh cream
42	55	L	Butter
43	56	L	Cheese
44	57	L	Ice cream
45	58	L	Mayonnaise, salad dressing and mustard
46	59	L	Fish and seafood products
47	60	L	Other fruit products
48	61	L	Fruit and jam in airtight containers
49	62	L	Other preserved vegetables
50	63	L	Vegetables and vegetable juices in airtight containers
51	64 and 65[7]	L	Soups in airtight containers and Infant and junior foods in airtight containers

Source: Prepared by the author

7. Some classified commodities are combined together for the reason that one or more of the commodity's total output equal to zero. Therefore, for the convenience of inversing the matrix, they are integrated together.

Appendix B (continued)

52	66	L	Pickles, relishes and other sauces
53	67	L	Vinegar
54	68	L	Prepared meals, mineral water and pasta product excluding dry pasta
55	69	L	Feed supplements and premixes
56	70	L	Complete feeds
57	71	L	Feeds from grain by-products
58	72	L	Feeds from vegetable by-products
59	73	L	Pet feeds
60	74 and 75	L	Wheat flour and Starches
61	76	L	Breakfast cereal products
62	77	L	Biscuits
63	78	L	Bread and rolls
64	79	L	Other bakery products and food snacks
65	80	L	Cocoa and chocolate
66	81	L	Nuts
67	82	L	Confectionery
68	83	L	Sugar
69	84	L	Feeds from vegetable oil by-products
70	85	L	Crude vegetable oils
71	87	L	Other flours and processed grains
72	88	L	Maple sugar and syrup, other syrups, and molasses
73	89	L	Prepared cake and other mixes
74	90	L	Dehydrated soup mixes and bases
75	91	L	Roasted coffee
76	92	L	Tea
77	93	L	Potato chips and flakes
78	94	L	Other miscellaneous food products
79	95	L	Soft drink concentrates
80	96	L	Carbonated soft drinks
81	97	L	Distilled alcoholic beverages
82	98	L	Beer including coolers
83	99	L	Wine including coolers
84	25 and 26	M	Unmanufactured tobacco and Cigarettes, and Other tobacco products

Source: Prepared by the author

Appendix B (continued)

85	27	M	Tires and tubes
86	28	M	Other rubber products
87	29	M	Plastics products
88	30	M	Leather and leather products
89	31	M	Yarns and fibres
90	32	M	Fabrics
91	33	M	Other textile products
92	34	M	Hosiery and knitted clothing
93	35	M	Other clothing and accessories
94	36	M	Lumber and timber
95	37	M	Plywood and veneer
96	38	M	Other wood products
97	39	M	Furniture and fixtures
98	40	M	Wood pulp
99	41	M	Newsprint and other paper, excluding coated paper and paper products
100	42	M	Coated paper and paper products
101	43	M	Printed products and publishing service
102	44	M	Advertising in print media
103	45	M	Primary products of iron and steel
104	46	M	Primary products of aluminium and aluminium alloys
105	47 and 48	M	Primary products of copper/nickel and copper/nickel alloys
106	49	M	Primary products of other non-ferrous metals
107	50	M	Boilers, tanks, and plates
108	51	M	Structural and prefab. metal building prod.
109	52	M	Other fabricated metal products
110	53	M	Agricultural machinery
111	54	M	Other machinery
112	55	M	Motor vehicles, mobile homes and trailers and semi-trailers
113	56	M	Motor vehicle parts
114	57	M	Other transport equipment and repairs
115	58	M	Appliances and household equipment
116	59	M	Other electrical and electronic products
117	60	M	Cement, ready-mix concrete and concrete products
118	61	M	Other non-metallic mineral products
119	62	M	Motor gasoline and other fuel oils
120	63	M	Other petroleum and coal products
121	64	M	Industrial chemicals
122	65	M	Fertilizers

Source: Prepared by the author

Appendix B (continued)

123	66	M	Pharmaceuticals
124	67	M	Other chemical products
125	68	M	Scientific, laboratory, medical and photographic equipment and instruments and medical and ophthalmic goods
126	69	M	All other miscellaneous manufactured products
127	70	M	Residential building construction
128	71	M	Non-residential construction
129	72	M	Repair construction
130	73	M	Pipeline transportation
131	74	M	Other transportation and storage
132	75	M	Radio and television broadcasting, including cable
133	76	M	Telephone and other telecommunication services
134	77	M	Postal and courier services
135	78	M	Electric power
136	79	M	Other utilities
137	80	M	Wholesaling margins
138	81	M	Retailing margins and services
139	82	M	Gross imputed rent
140	83	M	Finance, insurance, and real estate services
141	84	M	Business and computer services
142	85	M	Education, tuition and other fees services
143	86	M	Health and social services
144	87	M	Amusement and recreation services
145	88	M	Accommodation services and meals
146	89	M	Other services
147	90	M	Transportation margins
148	91	M	Operating, office, cafeteria and laboratory supplies
149	92	M	Travel, entertainment, advertising and promotion
150	93	M	Services provided by non-profit institutions serving households, except education services
151	94	M	Education services provided by non-profit institutions serving households
152	95	M	Government funding of hospital and residential care facilities
153	96	M	Government funding of education
154	97	M	Defence services
155	98	M	Other municipal government services

Source: Prepared by the author

Appendix B (continued)

156	99	M	Other provincial government services
157	100	M	Other federal government services
158	101	M	Non-competing imports
159	102	M	Unallocated imports and exports
160	103	M	Sales of other government services
161	104	M	Indirect taxes on products
162	105	M	Subsidies on products
163	106	M	Other subsidies on production
164	107	M	Other indirect taxes on production
165	108	M	Wages and salaries
166	109	M	Supplementary labour income
167	110	M	Mixed income
168	111	M	Other operating surplus

Source: Prepared by the author

Appendix C: One million dollar shock to Canadian agriculture and processed food exports and import replacements at their basic price

Industrial Sector	Exports (CAD)	Import Replacements (CAD)
Agriculture and food commodities	***845,194***	***1,000,000***
Cattle and calves	34,180	680
Hogs	19,008	40
Poultry	1,038	1,199
Other live animals	3,220	3,557
Wheat, unmilled	66,492	200
Corn, barley, oats and other grains	12,483	12,271
Fluid milk, unprocessed	0	0
Eggs in the shell	981	1,839
Honey and beeswax	891	759
Fresh fruit, excluding tropical	6,066	60,277
Vegetables, fresh or chilled	53,795	75,506
Hay and straw	5,143	520
Seeds, excluding oil seeds	1,978	5,476
Nursery stock, flowers, and other horticulture products	10,805	15,509
Canola, soybeans and other oil seeds	57,285	10,592
Raw tobacco	589	40
Raw wool and mink skins	2,861	4,157
Fish and seafood, fresh, chilled or frozen	40,632	27,340
Beef, pork and other meat and edible offal, excluding poultry, fresh, chilled or frozen	103,260	43,129
Cured meat	3,082	3,158
Prepared meat products	6,008	16,228
Animal fat and lard	2,672	1,359
Margarine and shortening	2,685	2,358
Sausage casings	557	2,678
Feeds from animal by-products	5,919	5,436
Raw animal hides and skins	7,252	240
Animal by-products for industrial use	1,749	1,719
Custom work, meat and food	0	0
Poultry, fresh, chilled or frozen	4,424	10,472
Miscellaneous dairy products	3,882	11,112
Fresh cream	0	0
Butter	325	2,358
Cheese	2,639	10,193

Source: Calculated by the author

Appendix C (continued)

Ice cream	2,191	440
Mayonnaise, salad dressing and mustard	1,013	2,438
Fish and seafood products	80,019	60,876
Other fruit products	6,357	41,770
Fruit and jam in airtight containers	3,087	5,596
Other preserved vegetables	28,780	16,068
Vegetables and vegetable juices in airtight containers	3,505	7,515
Soups in airtight containers and Infant and junior foods in airtight containers	2,769	2,558
Pickles, relishes and other sauces	8,571	14,869
Vinegar	45	640
Prepared meals, mineral water and pasta product excluding dry pasta	12,341	17,068
Feed supplements and premixes	0	2,598
Complete feeds	6,470	999
Feeds from grain by-products	3,642	2,158
Feeds from vegetable by-products	2,518	2,118
Pet feeds	7,079	19,986
Wheat flour and Starches	1,832	2,158
Breakfast cereal products	10,770	12,911
Biscuits	20,855	12,431
Bread and rolls	234	1,919
Other bakery products and food snacks	13,826	25,941
Cocoa and chocolate	14,894	20,265
Nuts	410	17,747
Confectionery	28,168	39,332
Sugar	1,517	1,799
Feeds from vegetable oil by-products	5,935	14,190
Crude vegetable oils	13,074	5,996
Other flours and processed grains	9,963	12,031
Maple sugar and syrup, other syrups, and molasses	8,029	6,675
Prepared cake and other mixes	117	2,478
Dehydrated soup mixes and bases	0	2,198
Roasted coffee	4,748	15,589
Tea	2,731	7,674
Potato chips and flakes	498	3,517
Other miscellaneous food products	26,656	59,677
Soft drink concentrates	1,226	1,199
Carbonated soft drinks	6,183	6,595
Distilled alcoholic beverages	20,449	52,682

Source: Calculated by the author

Appendix C (continued)

Beer including coolers	15,692	42,809
Wine including coolers	2,245	66,632
Unmanufactured tobacco and Cigarettes, and Other tobacco products	4,858	37,453
Margins	***154,806***	***0***
Pipeline transportation	0	0
Other transportation and storage	13,465	0
Other utilities	81,016	0
Wholesaling margins	0	0
Retailing margins and services	56,870	0
Transportation margins	3,454	0
Total	**1,000,000**	**1,000,000**

Source: Calculated by the author

Appendix D: The Capital and Labour coefficients by industrial sector

Industrial Sector	Capital (dollar value per million dollars)	Labour (working hour per million dollars)
Greenhouse, Nursery and Floriculture Production	1,604,295	24,942
Wheat	7,245,521	10,466
Feed grain	7,247,733	3,739
Oilseed	7,251,377	6,391
Potatoes	3,304,240	25,902
Fruits & Vegetables	5,172,861	46,497
Other Crops	2,134,564	16,114
Animal Aquaculture	5,265,025	8,016
Dairy	8,784,080	25,095
Cattle	6,952,458	9,219
Hogs	2,863,942	19,801
Poultry and eggs	4,477,343	26,003
Other livestock	5,247,460	20,455
Forestry and Logging	287,300	8,577
Fishing, Hunting and Trapping	856,460	15,648
Support Activities for Agriculture and forestry	232,772	21,078
Oil and Gas Extraction	1,925,840	1,270
Mining (Except Oil and Gas Extraction)	1,444,019	3,402
Support Activities for Mining and Oil and Gas Extraction	918,427	12,327
Electric Power Generation, Transmission and Distribution	3,638,062	4,455
Natural Gas Distribution, Water, Sewage and Other Systems	1,716,012	5,815
Construction	178,073	10,692
Animal Food Manufacturing	177,796	3,411
Sugar and Confectionery Product Manufacturing	803,819	5,558
Fruit and Vegetable Preserving and Specialty Food Manufacturing	330,916	7,372

Source: Calculated by the author

Appendix D (continued)

Dairy Product Manufacturing	195,999	3,694
Meat Product Manufacturing	132,697	5,722
Seafood Product Preparation and Packaging	227,306	11,435
Miscellaneous Food Manufacturing	264,873	6,163
Soft Drink and Ice Manufacturing	312,502	5,602
Breweries	423,654	4,413
Wineries	605,517	8,142
Distilleries	644,942	6,114
Tobacco Manufacturing	285,410	2,051
Textile and Textile Product Mills	431,647	13,343
Clothing Manufacturing	254,111	20,214
Leather and Allied Product Manufacturing	874,857	25,186
Wood Product Manufacturing	390,000	7,457
Paper Manufacturing	679,798	6,799
Printing and Related Support Activities	231,708	12,831
Petroleum and Coal Products Manufacturing	296,359	739
Chemical Manufacturing	486,445	3,662
Plastics and Rubber Products Manufacturing	291,235	9,393
Non-Metallic Mineral Product Manufacturing	427,847	9,025
Primary Metal Manufacturing	430,793	2,829
Fabricated Metal Products Manufacturing	236,017	10,692
Machinery Manufacturing	298,240	8,205
Computer and Electronic Product Manufacturing	394,604	8,478
Electrical Equipment, Appliance and Component Manufacturing	293,871	8,333
Transportation Equipment Manufacturing	262,896	3,411
Furniture and Related Product Manufacturing	222,843	12,921
Miscellaneous Manufacturing	250,809	12,900
Wholesale Trade	667,512	13,247

Source: Calculated by the author

Appendix D (continued)

Retail Trade	1,028,229	26,080
Truck Transportation	228,516	14,962
Transit and Ground Passenger Transportation	3,072,738	28,016
Pipeline Transportation	3,945,666	2,342
Other Transportation	1,632,080	8,933
Postal Service and Couriers and Messengers	311,591	20,396
Warehousing and Storage	1,289,572	21,712
Motion Picture and Sound Recording Industries	585,428	7,954
Broadcasting and Telecommunications	1,042,538	6,970
Publishing Industries, Information Services and Data Processing Services	244,798	11,348
Finance, Insurance, Real Estate and Rental and Leasing	1,715,236	5,128
Professional, Scientific and Technical Services	132,551	17,552
Administrative and Support Services	97,610	28,112
Waste Management and Remediation Services	414,517	11,637
Educational Services	254,856	30,626
Health Care and Social Assistance	395,756	20,262
Arts, Entertainment and Recreation	932,183	22,869
Accommodation and Food Services	596,624	28,757
Repair and Maintenance	230,324	29,216
Grant-Making, Civic, and Professional and Similar Organizations	2,169,187	20,237
Personal and Laundry Services and Private Households	141,365	43,194
Operating, Office, Cafeteria and Laboratory Supplies	0	0
Travel, Entertainment, Advertising and Promotion	0	0
Transportation Margins	0	0
Non-Profit Institutions Serving Households (Excluding Education)	390,833	26,607

Source: Calculated by the author

Appendix D (continued)

Non-Profit Education Institutions	496,626	21,816
Hospitals and Residential Care Facilities	739,894	19,109
Universities and Government Education Services	864,980	18,580
Other Municipal Government Services	2,927,879	11,899
Other Provincial and Territorial Government Services	1,209,885	7,570
Other Federal Government Services	1,100,530	11,446

Source: Calculated by the author

Appendix E: Industrial output requirements to satisfy $1 million dollar exports and import replacements

Industrial Sector	Exports	Import replacements
Greenhouse, Nursery and Floriculture Production	29,563.35	40,890.69
Wheat	76,408.59	8,143.01
Feed grain	33,019.20	28,975.34
Oilseed	71,803.51	28,033.23
Potatoes	18,600.54	25,746.27
Fruits & Vegetables	18,113.76	75,157.65
Other Crops	45,703.63	38,615.65
Animal Aquaculture	21,595.71	15,184.45
Dairy	7,839.01	16,295.07
Cattle	81,760.04	29,965.77
Hogs	40,873.92	15,036.46
Poultry and eggs	16,444.10	14,148.84
Other livestock	9,873.03	10,686.91
Forestry and Logging	4,660.51	4,981.81
Fishing, Hunting and Trapping	43,945.45	29,914.67
Support Activities for Agriculture and forestry	10,545.98	9,692.98
Oil and Gas Extraction	34,225.00	29,191.30
Mining (Except Oil and Gas Extraction)	16,220.11	10,109.30
Support Activities for Mining and Oil and Gas Extraction	2,936.29	2,416.91
Electric Power Generation, Transmission and Distribution	19,028.96	18,159.25
Natural Gas Distribution, Water, Sewage and Other Systems	2,000.90	2,141.86
Construction	17,889.22	15,036.33
Animal Food Manufacturing	52,135.68	47,411.14
Sugar and Confectionery Product Manufacturing	42,256.88	57,487.76
Fruit and Vegetable Preserving and Specialty Food Manufacturing	54,106.52	86,625.02

Source: Calculated by the author

Appendix E (continued)

Dairy Product Manufacturing	17,178.91	39,589.14
Meat Product Manufacturing	162,865.61	113,466.64
Seafood Product Preparation and Packaging	85,387.90	63,703.10
Miscellaneous Food Manufacturing	139,520.74	217,250.89
Soft Drink and Ice Manufacturing	15,454.74	19,023.56
Breweries	8,504.31	21,738.60
Wineries	579.66	14,326.10
Distilleries	4,833.91	11,853.79
Tobacco Manufacturing	6,148.74	38,143.63
Textile and Textile Product Mills	1,409.88	1,704.31
Clothing Manufacturing	500.63	285.66
Leather and Allied Product Manufacturing	61.23	39.61
Wood Product Manufacturing	3,756.49	3,882.14
Paper Manufacturing	13,028.69	16,499.87
Printing and Related Support Activities	6,078.38	6,456.39
Petroleum and Coal Products Manufacturing	48,156.29	31,397.72
Chemical Manufacturing	40,494.14	58,042.51
Plastics and Rubber Products Manufacturing	11,066.94	12,616.96
Non-Metallic Mineral Product Manufacturing	2,921.09	3,449.38
Primary Metal Manufacturing	4,021.12	3,900.28
Fabricated Metal Products Manufacturing	8,160.30	9,521.20
Machinery Manufacturing	5,645.99	4,706.43
Computer and Electronic Product Manufacturing	2,341.58	2,082.45
Electrical Equipment, Appliance and Component Manufacturing	1,267.85	918.96
Transportation Equipment Manufacturing	4,782.75	3,563.41
Furniture and Related Product Manufacturing	780.08	704.23

Source: Calculated by the author

Appendix E (continued)

Miscellaneous Manufacturing	1,919.78	1,443.51
Wholesale Trade	154,645.48	82,175.13
Retail Trade	15,609.60	16,387.51
Truck Transportation	56,730.78	22,445.51
Transit and Ground Passenger Transportation	9,728.99	3,905.43
Pipeline Transportation	3,014.60	2,832.88
Other Transportation	55,890.20	23,638.48
Postal Service and Couriers and Messengers	4,158.67	3,569.09
Warehousing and Storage	4,000.30	1,644.63
Motion Picture and Sound Recording Industries	960.71	1,005.93
Broadcasting and Telecommunications	16,860.27	14,452.79
Publishing Industries, Information Services and Data Processing Services	10,920.98	11,734.60
Finance, Insurance, Real Estate and Rental and Leasing	89,302.51	85,829.99
Professional, Scientific and Technical Services	51,944.43	53,537.84
Administrative and Support Services	22,588.48	20,648.03
Waste Management and Remediation Services	2,079.33	2,271.93
Educational Services	269.04	267.22
Health Care and Social Assistance	1,420.71	1,037.48
Arts, Entertainment and Recreation	4,767.76	12,458.09
Accommodation and Food Services	31,102.14	108,646.03
Repair and Maintenance	6,193.25	5,684.61
Grant-Making, Civic, and Professional and Similar Organizations	1,681.83	1,557.84
Personal and Laundry Services and Private Households	8,138.88	6,926.33

Source: Calculated by the author

Appendix E (continued)

Operating, Office, Cafeteria and Laboratory Supplies	45,514.62	39,147.44
Travel, Entertainment, Advertising and Promotion	34,188.04	38,553.25
Transportation Margins	80,828.01	23,780.91
Non-Profit Institutions Serving Households (Excluding Education)	1,985.04	3,199.89
Non-Profit Education Institutions	110.34	105.77
Hospitals and Residential Care Facilities	1,448.50	947.22
Universities and Government Education Services	1,669.51	1,500.88
Other Municipal Government Services	5,225.60	4,834.92
Other Provincial and Territorial Government Services	2,929.07	2,693.73
Other Federal Government Services	2,676.50	2,465.33
Total Industrial Output	2,097,001.78	1,960,244.82

Source: Calculated by the author