University of Alberta

An Input-Output Analysis of the Economic Impacts of Chronic Wasting Disease and Bovine Spongiform Encephalopathy in Alberta and Canada

by

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Abstract

This thesis utilizes input-output analysis to calculate the economic impacts from potential prion diseases outbreaks in Alberta and Canada. Both chronic wasting disease and bovine spongiform encephalopathy have the capacity to not only affect the farmed cervid and cattle industries, but to impact all industries with direct and indirect links to these sectors. Cervid sector shocks consistently yield small spillover effects on the economy in all models. In contrast, the cattle sector generates larger multiplier effects. A worst-case scenario that reduces cervid sector output to zero yields total economic losses of $11.5 million in Alberta, and $43.7 million in Canada. A reduction of cattle sector output to zero results in total economic losses of $6.4 billion in Alberta, and $34.9 billion in Canada.

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List of Abbreviations

ABIO	Alberta input-output
BSE	Bovine spongiform encephalopathy
CANIO	Canada input-output
CGE	Computable general equilibrium
CJD	Creutzfeldt-Jakob disease
CRS	Constant returns to scale
CSNEA	Canadian System of National Economic Accounts
CWD	Chronic wasting disease
I-O	Input-output
IRIO	Interregional input-output
GNE	Gross national expenditure
GNI	Gross national income
GDP	Gross domestic product
H-S	Hawkins-Simon
L	Historical link
M	Medium
NAICS	North American Industry Classification System
OIE	Office International des Épizooties/World Organization for Animal Health
S	Small
SAM	Social accounting matrix
TSE	Transmissible spongiform encephalopathy
UNSNA	United Nations System of National Accounts
vCJD	Variant Creutzfeldt-Jakob disease
W	Worksheet
WGTA	Western Grain Transportation Act
WHO	World Health Organization

Chapter 1 Introduction

1.1 Impetus for Research

Both chronic wasting disease (CWD) and bovine spongiform encephalopathy (BSE) belong within the taxonomic family of diseases called transmissible spongiform encephalopathies (TSEs). TSEs, alternatively known as prion diseases, are degenerative neurological diseases that affect the brain and nervous systems of animals. CWD affects cervidae—namely, elk, mule deer, white-tailed deer, and moose—while BSE is endemic within cattle.

Infectious animal diseases, such as the aforementioned two, posit growing risks to human health, biodiversity, agricultural production, and economic stability (Saskatchewan Environment, 2005). The transmission of epizootic diseases from wild to domesticated animal populations presents numerous economic, social, and health concerns. In the case of CWD, various economic impacts can arise from its transmission into farmed herds. These potential impacts include: a realignment of demand schedules from changes to consumer risk perceptions towards cervid products; government regulated trade restrictions and sanctions; government expenditures for surveillance, research, and disease management; and shifts in economic activity away from CWD infected areas (Seidl & Koontz, 2004).

A BSE outbreak in farmed cattle will have similar economic implications. Moreover, recent historical circumstances add gravitas to the severity of consequences: the discovery of BSE in Alberta in 2003 led to subsequent international trade restrictions on cattle and beef exports. These embargoes caused financial upheaval for Canada's cattle and beef industries (Samarajeewa et al., 2006). The majority of Canadian production at the time of border closures was exported, and, hence, the prompt introduction of export restrictions caused market volatility and financial losses estimated in the billions (Samarajeewa et al., 2006).

1.2 Economic Impact Analysis

There is an *a priori* understanding that disease outbreaks in farmed animals, such as CWD in cervids or BSE in cattle, will induce impacts on the economy. However, the nature, extent, and breadth of the impacts are often debated, sometimes to the extent where policy discussions are polarized into opposing viewpoints. An analytic framework capable of capturing the quantitative effects from a hypothetical outbreak can usher policy dialogue into productive debate. Such a tool possesses the ability to influence the quality of both public and private decision making.

Economic impact analysis is an analytic economic framework that estimates the effects of a policy, program, impact, or project on a particular economy. These studies can provide quantitative information about the endogenous and exogenous events that shape an economy. In this thesis, the economic impacts and market disruptions resultant from a potential CWD or BSE outbreak are estimated using economic impact analysis. Government agencies, private sector firms, policy makers, and public interest groups, among others, often undertake this class of analysis.

The origins of impact studies and regional models can be traced to the growing need to forecast new economic activity within cities and regions (Schaffer, 1999). For instance, consider a project proposed to be constructed in a specified locality: the project is expected to stimulate growth in various industrial sectors, create new employment opportunities, and add value to the region's economy. Public planners and private entrepreneurs can only accommodate this new growth with an appropriate level of regional infrastructure if informational asymmetries are minimized. By implementing economic impact analyses, valuable *ex ante* forecasts of the physical changes expected to result from the proposed project can be estimated. The information yielded from these studies can then assist public planners, investors, and private-sector organizations with regional planning and development.

These forms of analysis quantify the economic effects of both positive and negative stimulus beyond the first round of expenditures (Davis, 1990). The antecedent hypothetical project can also generate secondary, or induced, effects on the economy. For example, additional household income may be generated from the region's economic growth, which in turn can increase consumer demand for commodities, thereby further stimulating the region's productive sectors. These studies are devised to consider the total economic impacts beyond the first round of expenditures: the sums of the first round through n^{th} round (Davis, 1990).

This thesis utilizes input-output (I-O) analysis—one of the constituent methods amid the family of regional economic impact models. I-O models calculate the economy-wide impacts from market shocks to any one sector. They provide static-time representations of industrial trade relations by tracing interindustry linkages throughout an economy. Transactions between industry sectors, or between industry and final demand sectors, disseminate successions of expenditure rounds throughout an economy. These expenditure rounds, triggered by an initial stimulus, bring about changes to industrial production. I-O models quantify these changes.

1.3 Research Objectives

CWD and BSE can impose extensive and diverse effects on both the Albertan and Canadian economies. Industries, communities, consumers, and government agencies will face multiple and unique consequences if either of these pathogenic diseases are transmitted into captive livestock. International market closures in response to the discovery of BSE in 2003 are chief examples of the economic ramifications that animal diseases bring about. This research project intends to shed light on the direct and indirect economic effects that can occur if a prion disease is transmitted into farmed cervid and cattle populations. The analytic results are intended to provide industry and government agencies with information that will be a boon to decision making.

Using I-O analysis, this research project aims to estimate the economic impacts on all industry sectors with direct and indirect ties to the farmed cervid and cattle industries. Two geographic spaces are of interest: Alberta's regional economy, and Canada's national economy. Separate I-O models are constructed to represent each economy. Moreover, a third economic model—also of Alberta—is constructed that accounts for interregional trade patterns with the rest of Canada. Open and closed versions of each of these three I-O models are created, rendering a total of six models—all of which calculate the output effects of every industry sector, as well as total-economic income effects, from shocks to the farmed cervid and cattle industries.[1]

Although impact studies that capture the effects of BSE have been undertaken, the modelling of CWD's economic implications in Canada has not been researched to date. The following points summarize the objectives of this thesis:

1. Develop input-output models that accurately capture interindustry dependencies within the regions of interest.
2. Estimate the direct effects on the farmed cervid and cattle industries from CWD and BSE-induced final demand shocks.
3. Estimate the indirect effects on all other industry sectors from final demand shocks to the farmed cervid and cattle industries.
4. Estimate the effects on income variables, such as gross domestic product and wages and salaries, from shocks to cattle and cervid farming.
5. Analyze the transformation of general equilibria from the aforementioned final demand suppressions.

The models constructed in this thesis will be able to answer research questions of the form: if a final demand stimulus occurs to industry A, how much will A's output change, how much will industry B and C's output change, and how will regional gross domestic product (GDP), tax collection, household income, and returns to capital change?

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[1] Precise definitions of open and closed I-O models are elaborated upon in section 3.4.5.

1.4 Thesis Structure

The remaining chapters of this thesis are organized in the following fashion. Chapter 2 discusses the background of prion diseases, the economic risks they pose, the array of impact models that can be used to quantify their effects, and concisely reviews other similar studies of recent vintage. Chapter 3 provides a detailed examination of the theoretical framework underlying input-output analysis. Chapter 4 discusses the data used for model construction, transformation algorithms, and model specifications. Chapter 5 presents the results of each model, as well as interpretations of their meaning. Finally, Chapter 6 is the conclusion, and provides a review of the thesis, discusses the limitations of the modelling approach, and outlines avenues for future research.

Chapter 2 Background

2.1 Global Disease Emergence

Since the turn of the century, the rate of disease emergence has created new challenges for societies around the world. Diseases and viruses originating in or carried by animals, such as avian influenza, severe acute respiratory syndrome (SARS), human immunodeficiency virus (HIV), acquired immune deficiency syndrome (AIDS), tuberculosis, BSE, and CWD—to name a few—have imposed serious impacts on human health, animal biodiversity, food safety, agricultural production, and regional economic stability (Saskatchewan Environment, 2005). It is believed that approximately seventy percent of new global diseases that threaten human health and regional economies are derived from wild animals (Saskatchewan Environment, 2005).

Assessments of Canada's disease response programs were undertaken by various agencies in 2003. The diseases deemed the greatest concern to human and domestic animal health were zoonotic diseases, and diseases that affect human society by impacting wild and farmed animals (Saskatchewan Environment, 2005). Within Canada, BSE has already caused significant financial and economic damage; on the other hand, CWD is still designated an emerging disease, with the potential to impose negative effects on people, economies, and the environment. The following two sections discuss both CWD and BSE.

2.1.1 Bovine Spongiform Encephalopathy

Bovine spongiform encephalopathy, colloquially known as mad cow disease, is a type of prion disease found in cattle. Prion diseases—scientifically termed transmissible spongiform encephalopathies—are degenerative neurological diseases that affect the brain and nervous system of animals. Abnormally folded prion proteins are the cause of TSEs. To date, all prion diseases are untreatable and fatal, with most animals dying within several months of onset (Centre for Research in Neurodegenerative Diseases, 2010; Belay et al., 2004). These diseases are difficult to detect because of their long incubation phase, lasting several years in cattle and deer, and even decades in humans. Furthermore, almost all detection is made postmortem.

BSE is food-borne, and is spread among cattle—typically herbivores—when fed rendered meat-and-bone meal remains of other infected cattle (Williams & Miller, 2002). Symptoms of BSE in cattle include: alterations in the animal's attitude and activity, loss of coordination and motor functioning, and decreases in body mass. The disease has an incubation period ranging from one to eight years, with a mean of four to five years (Collee, 1993). Upon completion of the incubation phase, the disease becomes fatal within weeks of onset. The prolonged incubation phase creates additional challenges for controlling transmission. For example, if a BSE-incubating cow is slaughtered and used as feedstuff prior to disease onset, the possibility of transmission still exists (Collee, 1993). Moreover, epidemiologists have linked the consumption of BSE-infected cattle products with variant Creutzfeldt-Jakob disease (vCJD) in humans (World Health Organization, 2002a).

BSE was initially discovered in West Sussex, England, in 1984, though it was not until 1986 that it was termed and recognized as a new cattle disease. By 1988, Britain legislated a ban on feeding ruminant-derived protein to ruminants (Collee, 1993). Despite efforts, infection had already permeated the global cattle farming system. Between 1986 and 2002, the United Kingdom suffered over 180,000 cases of the cattle disease, with over 4 million cattle culled in the eradication program (Le Roy & Klein, 2005; World Health Organization, 2002b). As of July 2009, a total of 25 countries reported BSE in farmed cattle, though the UK experienced the most cases (World Organization for Animal Health, 2010).

Canadian authorities banned cattle imports from the UK and the Republic of Ireland in 1990 under transmissible animal disease guidelines provided by the World Organization for Animal Health (OIE)—known formally as the Office International des Épizooties (Le Roy & Klein, 2005; Canadian Food Inspection Agency, 2003). Importation from the UK prior to federal trade restrictions was the source of Canada's first case; BSE was eventually discovered on December of 1993 in a farm near Red Deer, Alberta, in a cow that was imported from the UK in 1987. The find prompted authorities to subsequently destroy the cow, its herd mates, its offspring, and all remaining animals imported into Canada from the UK since 1982 (Le Roy & Klein, 2005).

Under OIE recommendation, the government of Canada instituted ruminant-to-ruminant feed bans in 1997 (Le Roy & Klein, 2005; Canadian Food Inspection Agency, 2003). Despite efforts to mitigate pathogenic transmission, the second discovery of BSE in

Canada took place on May 20, 2003, in Wanham, Alberta. Unlike the first case, this cow was born, fed, and raised in Canada (Le Roy & Klein, 2005). Canada's most recent confirmed BSE case, as of March 31, 2010, was in a 71-month-old Albertan beef cow discovered on February 25, 2010 (Canadian Food Inspection Agency, 2010; World Organization for Animal Health, 2010). Surveillance programs discovered the infected cow before any part of its carcass could enter the human food or animal feed system; this constituted the 18th case of BSE detection in Canada since 1993 (Centers for Disease Control and Prevention, 2010a; World Organization for Animal Health, 2010).

2.1.2 Chronic Wasting Disease

Chronic wasting disease is a prion disease that affects members of the cervidae family, namely: Rocky Mountain elk, mule deer, white-tailed deer, and moose. First recognized in 1967 at a Colorado research centre, CWD was identified in captive mule deer as a fatal wasting syndrome of unknown etiology (Williams & Miller, 2002). It was promptly discovered again in research facilities in Colorado and Wyoming, in both captive mule deer and elk. The disease became officially classified as a TSE in 1978, and was subsequently identified for the first time in a wild free-ranging elk in Colorado in 1981. However, epidemiological modelling and animal surveillance data suggest that the disease may have been infecting wild deer populations for two decades prior to being detected (Kahn et al., 2004; Williams & Miller 2002).

Clinical studies revealed that the disease manifests weight loss, behavioural changes, difficulty swallowing, excessive salivation, polyuria, and polydipsia in its victims (Belay et al., 2004). Ataxia and head tremors were also noted in certain cases (Belay et al., 2004). Controlled experimentation also found CWD to be most prominent in cervids aged 2-7 years, though incidents in cervids as young as 17 months and as old as 15 years have also been documented (Belay et al., 2004).

Subsequent clinical studies of infected elk and deer provided evidence of lateral transmission through direct animal-to-animal contact, and demonstrated that interspecies transmission is possible; interspecies transmission has been documented between mule deer to elk, mule deer to white tailed deer, and elk to both mule and white tailed deer (Centers for Disease Control and Prevention, 2010b; Williams & Miller, 2002). Despite CWD's exclusive detection in elk, mule deer, and white-tailed deer, researchers suspect that other cervids such as red deer are susceptible to transmission (Kahn et al., 2004). It is also suggested that indirect exposure to pathogenic agents in an animal's environment, such as infected feed and water sources, can induce transmission (Centers for Disease Control and Prevention, 2010b; Belay et al., 2004). Unlike BSE, CWD is not associated with rendered ruminant meat-and-bone meal (Williams & Miller, 2002). Its sources of transmission are not yet fully understood.

Williams and Miller (2002) decompose the spread of CWD into two epidemics: the first is in free-ranging cervids; the second is in farmed cervids. The regions of northern Colorado, southern Wyoming, and western Nebraska are the geographic origins of the disease, and, hence, constitute what is known as the endemic zone. In 2001, CWD was discovered in free-ranging deer in Nebraska. As of June 2010, CWD has also been identified in Utah, South Dakota, Kansas, Wisconsin, Illinois, New Mexico, New York, West Virginia, Michigan, Montana, Minnesota, Oklahoma, Missouri, the Canadian provinces of Alberta and Saskatchewan, and the Republic of Korea.

CWD's transmission is attributed to both natural movements of infected deer and elk, and commercial movements of livestock deer and elk away from the endemic zone. It is suspected that CWD was introduced into Saskatchewan during the late 1980s by infected elk imported from South Dakota (Bollinger et al., 2004). It is also confirmed that the CWD-positive elk discovered in South Korea had been exported from Saskatchewan in either 1994 or 1997 (Kahn et al., 2004).

As of February 26, 2010, a total of 75 infected wild deer have been discovered in Alberta (Alberta Sustainable Resource Development, 2010a). To date, there have been only 3 cases of the disease in farmed Albertan cervids, all of which were discovered in 2002 (Alberta Sustainable Resource Development, 2010b). Federally enacted eradication programs were implemented in 2002, following the first on-farm CWD discovery (Alberta Sustainable Resource Development, 2010b).

2.1.3 Creutzfeldt-Jakob Disease

Creutzfeldt-Jakob disease (CJD) and variant Creutzfeldt-Jakob disease are TSE strains found in humans. CJD has been diagnosed and investigated for approximately the last century, however, its variant strain, vCJD, was only classified in 1996 (World Health Organization, 2002a). As of July 2009, there have been 205 documented deaths from vCJD, 165 of which were reported in the UK and the Republic of Ireland (The National Creutzfeldt-Jakob Disease Surveillance Unit, 2009). The disproportionate number of vCJD cases in the UK, in tandem with the country's BSE epidemic, raised alarm both in the UK and around the world. Furthermore, epidemiological models suggest a link between human consumption of BSE-contaminated meat and vCJD in humans (World Health Organization, 2002a).

The hypothesized food-borne transmission of BSE to humans, coupled with an increase in detection and geographic spread of CWD, began raising concerns about CWD's zoonotic potential (Belay et al., 2004). Empirical evidence indicates that the transmission of CWD to humans, although possible, is very unlikely. Furthermore, no strong evidence exists that links human cases of prion diseases to CWD (Canadian Food Inspection Agency, 2009; Belay et al., 2004). Belay et al. (2004) does however assert that more epidemiological and laboratory research is needed to fully comprehend the risks posed to humans.

Regardless of the lack of absolute conclusiveness surrounding the microbial pathogenicity of BSE and CWD, various government agencies, including the World Health Organization (WHO), recommend that humans not consume any animal carrying a TSE (Centers for Disease Control and Prevention, 2010b; Bishop, 2004; Bollinger et al., 2004). National public health agencies, as well as food and agricultural agencies, often comply with recommendations and guidelines published by the WHO and the OIE.

Hence, soon after prion diseases are discovered in livestock, trade barriers and restrictions are often imposed.

2.2 Economic Risks of Livestock Diseases

2.2.1 Cattle Industry

Immediately following the discovery of Canada's second BSE-positive cow on May 20, 2003, the governments of 34 countries banned imports of ruminants and ruminant products originating in Canada (Le Roy & Klein, 2005). This caused subsequent financial trauma to Canada's and, more notably, Alberta's export-oriented beef industries; of all provinces, Alberta is Canada's largest cattle and beef producer, accounting for 56% of the value of production (Weerahewa, Meilke, & LeRoy, 2008; Samarajeewa et al., 2006). Table 2-1 shows the size of both the Canadian and Albertan cattle industries. Alberta contains over a third of all of Canada's cattle. Moreover, both Alberta and Canada experience a minor reduction in the number of on-farm cattle between 2006 and 2009.

Table 2-1: Size of the Cattle Industry in Canada and Alberta

	Number of Cattle on Farms	
	July 1, 2009	**July 1, 2006**
Canada	14,735,000	16,000,000
Alberta	5,830,000	6,300,000

Source: Statistics Canada, 2010.

Canada's beef industry became increasingly export driven during the 1990s. Prior to the trade-sanction-induced export collapse, Canada was the third largest beef exporter, behind only the United States and Australia (Samarajeewa et al., 2006). By 2002, annual net exports of beef and cattle reached approximately 350,000 tonnes and 1.5 million head, respectively (Weerahewa, Meilke, & LeRoy, 2008). Approximately 60% of Canadian production was exported in 2002, with the United States receiving the largest share: 80% of Canadian beef exports, and nearly 100% of Canadian cattle exports were imported by the United States in 2002 (Samarajeewa et al., 2006).

Canada's beef and cattle industries were not always export oriented. Prior to 1987, net cattle exports were either small or negative (Doan, Paddock, & Dyer, 2003). Throughout the 1980s and 1990s, Canadian legislators shrunk their regulatory involvement in cattle and beef markets, laying the groundwork for western Canadian agricultural restructuring. For example, the Western Grain Transportation Act (WGTA) was eliminated in 1995.

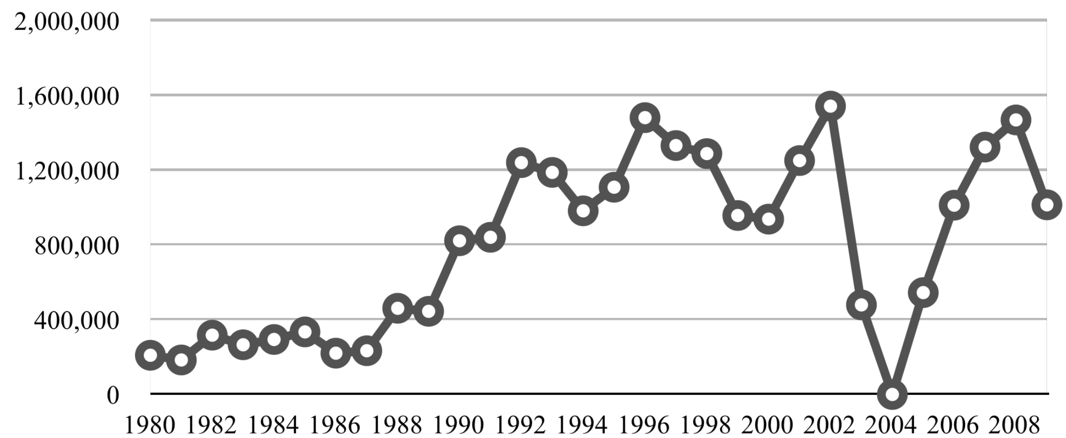
Fixing freight rates for wheat transported to eastern export facilities began in 1897 with the legislation of the Crow's Nest Pass Agreement (Doan, Paddock, & Dyer, 2003). These rates, referred to as Crow Rates, remained in effect for almost 100 years. Though, over that period, the freight rates became unable to cover costs for the railways. This led to the enactment of the WGTA in 1983, which raised existing freight rates, and institutionalized a subsidy called the Crow Benefit (Doan, Paddock, & Dyer, 2003). These agreements set out to offset handling and shipping costs, however, they inadvertently inflated feed grain prices, discouraging livestock production, diversification, and many other value-added processes (Doan, Paddock, & Dyer, 2003). They also had the effect of negatively influencing the west's agricultural production incentives (Doan, Paddock, & Dyer, 2003).

In an absence of grain transportation subsidies, farmers realigned their production decisions according to the new economic scheme. Prairie farmers began increasing the production of special crops and livestock (Doan, Paddock, & Dyer, 2003). In addition to advancing value-added agricultural production, low grain prices provided the necessary backdrop for establishing the prairie's food processing industry (Doan, Paddock, & Dyer, 2003). The elimination of the WGTA enabled cattle producers to exploit naturally occurring comparative advantages when procuring cattle feed grains (Weerahewa, Meilke, & LeRoy, 2008).

The ratification of the Canada-United States Free Trade Agreement in 1988, and later the North American Free Trade Agreement (NAFTA) in 1994, escalated the export potential for Canadian cattle and beef producers. These economic-liberalization agreements encouraged Canadian export by securing preferential market access between member countries. Figure 2-1 depicts the export growth of live Canadian cattle from 1980 to 2009. Between 1987 and 2002, live cattle exports more than quadrupled, from under 400,000 in 1987, to approximately 1.5 million in 2002. The number of exported cattle fell drastically in 2003 upon the discovery of BSE. In 2004, Canada was unable to export any live cattle.

The west's growth of value-added agricultural production, coupled with Canada's rising export potential, increased the exports of value-added agricultural commodities into the U.S.: between 1995 and 2002, value-added shipments from Canada into the U.S. increased from $7.6 billion to $16.6 billion; during that same period, value-added shipments to the rest of the world increased by only $1 billion (Doan, Paddock, & Dyer, 2003).

Figure 2-1: Number of Live Cattle Exported from Canada, 1980-2009



Source: Statistics Canada, 2010.

The culmination of policy reformations and movements toward freer trade resulted in a cattle industry that was highly vulnerable to trade disruptions. For example, immediately after BSE was confirmed in Canada, cattle price at an auction in Alberta dropped from $1.20/lb to $0.32/lb (Weerahewa, Meilke, & LeRoy, 2008). Most cattle were taken off the market soon after. The border closures resulted in net Canadian exports of cattle to the U.S. to decrease from approximately 1.5 million head in 2002 to just above 400,000 head in 2003 (Weerahewa, Meilke, & LeRoy, 2008). Similarly, Canada was a net exporter of dressed beef in 2002, with an approximate net export of 350,000 tonnes; however, by 2003, the effect of border closures resulted in Canada being a net importer by approximately 100,000 tonnes (Weerahewa, Meilke, & LeRoy, 2008).

The financial collapse of the beef sector could have been considerably more severe had the United States Department of Agriculture not re-opened borders on September 10, 2003, to beef muscle cuts from ruminants under 30 months of age (Weerahewa, Meilke, & LeRoy, 2008). Nonetheless, the scenario highlights the current risk climate and the potential impacts the industry faces.

2.2.2 Cervid Industry

Cervid farming in Canada is a relatively small industry. Meat, hides, velvet from antlers, and the live animals themselves constitute the commodities yielded from this industry. Table 2-2 shows the number of deer and elk in Alberta and Canada for census years 2001 and 2006. This table also shows the number of farms that house deer and elk for those same years. Because the largest component of cervid farming consists of elk and deer, they are used to represent the entire cervid farming industry.

Table 2-2: Size of the Cervid Industry in Canada and Alberta

	May 16, 2006		May 15, 2001	
	Farms Reporting	Number	Farms Reporting	Number
Canada				
Deer (excluding wild deer)	620	46,748	809	53,258
Elk	905	69,168	1,172	74,478
Alberta				
Deer (excluding wild deer)	108	8,965	193	8,331
Elk	352	33,783	467	31,304

Source: Statistics Canada, 2007.

In Canada, the number of deer and elk, as well as the number of deer and elk farms, decreased between 2001 and 2006 (table 2-2). In Alberta, the number of deer and deer farms also decreased over that period. Alberta's elk industry grew between 2001 and 2006, with the number of farmed elk increasing from 31,304 to 33,783; however, a concurrent decrease in the number of elk farms also took place during this time.

Although cervid farming is dwarfed in comparison to Canada's cattle industry, it nonetheless faces similar economic risks from TSEs. A CWD outbreak in farmed herds can manifest numerous economic ramifications, which are discussed below. Moreover, these economic costs to the cervid industry will impact other industries, and trickle down into households in the form of lost wages, profits, and rents (Bishop, 2004).

Regardless of whether CWD poses a real threat to human health or not, the *perceptions* of risk alone are substantial enough to alter economic equilibria. Consumer risk perceptions can induce preference changes, thereby reducing demand for deer and elk meats (Seidl et al., 2003). The period of time that consumer perceptions remain altered is uncertain, but, it can be lengthy, and a shock to consumer perceptions today can last for numerous years—well beyond the duration of an outbreak (Seidl et al., 2003). Anecdotal evidence in Colorado suggests that since 2001, consumer demand for farmed elk products has remained depressed (Seidl & Koontz, 2004).

Although a major CWD outbreak in farmed populations has yet to occur in Alberta, the financial costs of historical BSE outbreaks can act as a yardstick for any potential impacts. For example, an outbreak can initiate internationally enforced embargoes and trade sanctions (Seidl & Koontz, 2004). Domestic as well as foreign governments may ban the consumption of deer and elk products in compliance with public health regulations. Border closures have the effect of depressing consumer demand because entire markets become unable to purchase certain commodities from the producing country. For example, the Republic of Korea banned all imports of Canadian elk velvet antler in 2000 (Bishop, 2004; Seidl et al., 2003).

The existence of pathogenic animal diseases can also give rise to government expenditures on research, surveillance, and disease management (Arnot et al., 2009; Seidl et al., 2003; Williams & Miller, 2002). In the case of disease management, indemnity payments and second perimeter fencing are the avenues government policymakers are immediately considering (Arnot et al., 2009). Indemnity payments to farmers are made in the event that herds are quarantined or depopulated according to government mandate. The government of Alberta is currently undergoing an analysis of the efficacy of second perimeter fencing as a means to mitigate disease transmission from wild to farmed herds (Arnot et al., 2009). Significant human and financial resources from government agencies are also being dedicated to the understanding of TSEs in animals and humans (Seidl & Koontz, 2004).

Another potential effect of a CWD outbreak is a shift in economic activity away from CWD infected areas (Seidl & Koontz, 2004). Business interests and investors may be dissuaded from engaging in commercial activities in CWD hotbeds. In the economies of Alberta and Canada, the cervid industry presents itself as a young sector. In the case of zoonotic transmission, investment appeal may be lost in the eyes of agricultural entrepreneurs and other private-sector agents. Furthermore, all of the aforementioned potential consequences will be substantially magnified if the rate of wild animal infection continues to increase (Bishop, 2004). As an aside, it should also be noted that transmission from captive to wild populations, or additional wildlife outbreaks, can impact the tourism industry by reducing hunting rates, or by diminishing wildlife park attendance rates.

The following section briefly discusses the numerous analytic instruments that can quantify the economic impacts from a CWD or BSE outbreak. These approaches fall under the umbrella of economic impact analysis. Economic impact analyses provide information to government agencies, private-sector firms, policy makers, and public interest groups, with the ability to influence the quality of both public and private decision making.

2.3 Approaches to Economic Impact Analysis

The nomenclature within the realm of impact analysis is broad, and sometimes confusing. Various appellations exist in the literature, which, for the purposes of this research project, converge upon similar methods and meanings. Hence, economic impact analysis, regional economic impact analysis, economic impact assessment, regional impact analysis, and any other permutation, are used synonymously from hereon.

Economic impact analyses are, in essence, conditional predictive models of assessment that provide quantitative estimates to the researcher (Davis, 1990). They are predictive in that they forecast direct and latent effects on the economy from stimulus imputed into the model by the researcher, and conditional in that they are contingent upon certain theoretical assumptions. Broadly speaking, these types of studies produce counterfactual conditional statements of the form: "if, under assumption *a*, *b*, and *c*, a stimulus *x* is applied to the local economy, then impacts *y* and *z* are likely to result" (Davis, 1990, p. 5). These types of analyses are particularly useful in *ex ante* assessments; when juxtaposed with *ex post* assessments, they also provide benchmarks for the efficacy of future *ex ante* analyses.

In contrast to economic impact analysis, project evaluation analysis is a form of assessment used to quantify the economic *value* of a project or particular stimulus (Davis, 1990). These forms of assessment allow the analyst to rank projects amongst each another on the basis of the weights of their values. Some of the commonly used evaluation methods include Cost-Benefit Analysis (CBA) and Cost-Effectiveness Analysis (CEA). The project evaluation approaches do not specifically pertain to the scope of this research project and, hence, will not be mentioned hereafter. The following subsections highlight the analytic modelling techniques that can most closely service the research objectives outlined in section 1.3.

2.3.1 General Equilibrium Models

Competitive economies yield market-clearing prices when consumers and producers both maximize their respective surpluses. For example, in a bivariate analog market, equilibrium is attained when a market price between consumers and producers is reached. General equilibrium, then, is the state of all markets being in equilibrium concurrently.

Due to the interconnectedness of markets, a shock or disruption to one market will affect directly linked markets. By that same reasoning, one can see how a complex network of indirect linkages can affect numerous markets, even when only a single market is disrupted. General equilibrium analysis assesses how equilibrium configurations change as a result of changes in system parameters. The following four subsections highlight the principal general equilibrium modelling techniques used for estimating economic impacts.

2.3.1.1 Static Input-Output Models

Static I-O models are interindustry models that capture economy-wide output effects from a controlled stimulus or shock to any one sector. These models link all industries into a complex network of sales and purchase linkages, allowing both indirect and direct effects to be captured from exogenous changes in final demand. The information of sectoral linkages is contained within a symmetric matrix that accounts for the inputs and outputs of all industries. These models capture output effects from final demand changes to any one sector.

Static I-O models ignore issues of productivity and resource allocation, and are entirely demand driven. Fixed proportion technology precludes substitution possibilities in production, consumption, exports, and imports. Finally, shifts in factor input prices fail to act as market signals that can induce behavioural responses in economic agents.

Despite the drawbacks, I-O modelling is relatively cheap and effective, with the capacity to yield powerful and informative results. It is for this reason that it has become one of the chief approaches in the arsenal of regional analytic tools over the past four decades (ten Raa, 2005; Hewings & Jensen, 1988). Static I-O analysis is selected as the modelling approach utilized in this thesis. This approach services the requirements of this thesis by its ability to compute the indirect output effects on all industries, from shocks to only the cervid and cattle sectors. Chapter 3 provides a lengthy discussion of the background, theories, methods, conditions, and assumptions underlying I-O analysis.

2.3.1.2 Dynamic Input-Output Models

In contrast to static I-O models, dynamic I-O models incorporate time and investment into the analytic framework (Johnson, 1996). These models effectively trace an economy's approach towards equilibrium, without it ever being in equilibrium (Johnson, 1996). However, according to Johnson (1996), inconsistencies reside in the model's treatment of time and other assumptions, leaving most versions of these models "very unrealistic and computationally unmanageable" (p. 127).

Dynamic I-O models that do perform well provide considerable information not captured by static approaches. In addition to industry output effects, which are also calculated by static I-O models, dynamic models capture the timing of production, consumption, and investment, effectively incorporating the accelerator principle, capacity constraints, and excess capacity (Johnson, 1996). The incorporation of dynamic time into the model relaxes the static approach's embedded assumption that successive rounds of economic shocks occur instantaneously.

2.3.1.3 Social Accounting Matrices

A social accounting matrix (SAM) is another static representation of a region's economic structure. Analogous to the I-O model, SAMs are a product of double-entry bookkeeping, where sales and purchase flows—the inputs and outputs—are accounted for in a matrix. This double-entry bookkeeping method ensures that no injections or leakages occur in an economic system (Adelman & Robinson, 1986). In effect, SAMs provide a depiction of the circular flow of resources, commodities, and finances in an economy. The underlying assumptions made in the SAM framework are also identical with the static I-O approach (Adelman & Robinson, 1986).

What distinguishes SAMs from the I-O framework is their capacity to capture distributional effects in addition to economic impacts; they provide the magnitude *and* distribution of economic impacts among income groups—or any other broad aggregate of individuals (Johnson, 1996). Adelman and Robinson (1986) constructed a SAM of the United States economy, focusing on links between nonagricultural and agricultural sectors, and variations in income distribution from value-added phenomenon. They found that a one billion dollar expansion for dairy commodities distributed income unevenly over socioeconomic groups: the poorest 40% of households received an increase of $190 million, the next 40% received an increase of $173 million, and the wealthiest 20% of households received an increase of $848 million (Adelman & Robinson, 1986).

The SAM framework sets out to explore structural features of economies, such as the aforementioned distributional inequalities. The approach is cost effective and relatively quick, and is “best applied to cases where data from disparate and somewhat inconsistent sources must be sorted out” (Johnson, 1996, p. 126). SAMs allow analysts to evaluate different data by reconfiguring and unifying them into a consistent framework (Johnson, 1996). However, the methodology possesses the same drawbacks as the I-O approach: the limitations are a consequence of the assumptions made within the model.

2.3.1.4 Computable General Equilibrium Models

The SAM framework can be extrapolated upon and used as a basis for developing a computable general equilibrium (CGE) model. In these multisectoral supply and demand models, prices are endogenously calibrated to clear markets (Clarete & Roumasset, 1986). These models are based upon the same general equilibrium foundations as the static I-O and SAM frameworks, but they relax the rigidity of unresponsive price behaviour (Johnson, 1996). In the static I-O and SAM frameworks, firms are not price responsive. This means that price mechanisms play no role in the economy, leaving firms’ input combinations unchanged despite factor price changes. In contrast, CGE models incorporate price responsive consumers and producers into the interindustry analysis (Johnson, 1996).

CGE models require considerably more data than the static I-O or SAM approaches. Data for each sector is required in order to calibrate the system's parameters for supply, demand, and substitution elasticities (Johnson, 1996). The complexity of these models often limits their use to analyses of highly aggregated sectors only. CGE approaches are also costly and time consuming, and are best applied towards policy analyses that have a macroeconomic scope (Johnson, 1996).

2.3.2 Integrated Econometric Input-Output Models

Regional impact analysis can also be performed using econometric models. In contrast to general equilibrium models, econometric models apply regression analysis to a multilinear system of equations. They can also utilize time series data, as opposed to only single-period data. These models employ the interindustry structure of the I-O framework, with the flexibility of the econometric approach (Glennon & Lane, 1990).

Econometric models are also able to endogenize many sources of growth, as opposed to relegating all sources as external to the economic system (Pleeter, 1980). Prices and wages, for example, can be determined within the econometric system. Moreover, changes in macroeconomic variables are also able to influence these models. These characteristic differences render econometric impact models more suitable for forecasting, and other dynamic analyses (Glennon & Lane, 1990). According to Johnson (1996), these types of models are most often used for a one-time-only policy analysis—for example, in determining the likely response of the private sector to specific changes in tax policy.

Standard I-O models are demand driven and output oriented. The integration of the I-O and econometric approaches first requires a method for converting output linkages into employment linkages (Glennon & Lane, 1990). An overview of these procedures is outlined in Glennon and Lane (1990). Econometric approaches also require more data than the static I-O approach, and have a higher level of complexity.

2.3.3 Mathematical Programming Models

A variety of mathematical programming models can also be used for impact analysis, namely: linear models, nonlinear models, chance-constrained models, stochastic programming models, dynamic programming models, and optimal control models (Johnson, 1996). Mathematical programming methods maximize or minimize an objective function over a specified solution space (Johnson, 1996). According to Johnson (1996), they are most effective in the specific circumstance where policy makers face the precise alternatives captured by the model. In these rare circumstances, the models can be maximized or minimized subject to any conditions or constraints, providing the best possible solution for the decision maker.

The following section offers a concise discussion of some recent studies that estimated economic impacts from BSE and CWD. All of the studies were conducted on the Canadian and U.S economies, and they all employed a form of economic impact model.

2.4 Review of Similar Studies

To date, only a few studies have been conducted on the economic impacts of CWD. One of the more salient studies was conducted by Anderson, Frosch, and Outlaw (2007). They employed an I-O model to estimate the cervid farming industry's economic impact on the U.S. economy. Anderson, Frosch, and Outlaw (2007) estimated that cervid operations generate $893.5 million in direct expenditures within the U.S. economy each year. The indirect effects caused by ripples throughout the economy were estimated to be $2.3 billion. This effect is the total industry output of all sectors that supply the cervid farming industry. In addition, the study also revealed that cervid farming in the U.S supports 29,199 jobs, all of which face greater danger if additional CWD outbreaks occur.

Wigle et al. (2007) constructed a CGE model of the Canadian economy to estimate the impacts of BSE-related trade restrictions. The analysis aimed to determine the interindustry spillover effects from an embargo. As expected, the model predicted that cattle producers would face significant losses from border closures. However, the model also determined other general equilibrium considerations in the event of a border closure, such as gains to processors and consumers under certain circumstances. Nonetheless, in scenarios where all export markets to Canadian beef and cattle producers are closed, Canada undergoes welfare losses of approximately $1 billion dollars.

Yeboah et al. (2007) conducted an input-output analysis of a consumer demand reduction for U.S beef products. The justification for their analysis hinged upon various consumer perception surveys conducted in Europe and the U.S. that indicated consumers would shift consumption away from beef under BSE outbreak scenarios. Yeboah et al. (2007) estimated output and income effects from a 20% decline in beef demand. Their findings revealed declines in total industry output from $54 billion to $43 billion, declines in meat processing from $22 billion to $18 billion, and declines in food processing from $8.6 billion to $6.9 billion.

Samarajeewa et al. (2006) also conducted an I-O analysis of BSE impacts, but for the Canadian economy. Economic effects from $10 million of reduced beef and cattle exports were calculated. Export reductions for beef and cattle in Alberta resulted in GDP losses of $8.5 and $8.9 million, respectively. Alberta's beef and cattle output multipliers were also estimated at 3.01 and 2.44, respectively. These multipliers indicate that a $1.00 increase in final demand for beef generates $3.01 of total output from all industry sectors, and a $1.00 increase in final demand for cattle generates $2.44 of total output from all industry sectors.

2.5 Chapter Summary

The beef and cattle industry is a large source of revenue in both Alberta and Canada. The farmed cervid industry on the other hand is young and considerably smaller. Regardless of this disparity, they both face similar economic risks from prion diseases. Prion diseases—BSE in cattle and CWD in cervids—have the potential to induce a variety of impacts on the farmed cervid and cattle industries. Outbreaks can result in herd depopulations, export market closures, reductions in consumer demand, and other economic outcomes; the unifying theme among these scenarios is their proclivity to reduce final demand for cattle and cervid output, either directly or indirectly.

The interconnectedness of markets within an economy renders most if not all sectors vulnerable to disruptions, even when only a single industry is impacted. In the event of a CWD or BSE outbreak, the shocks to the farmed cervid and cattle sectors will impact numerous other sectors. An economic impact analysis that captures economy-wide effects from changes to final demand for a single industry will best service the objectives of this thesis. A variety of impact models were discussed in section 2.3. Of these models, the static I-O model is utilized for this impact analysis. The following chapter discusses in depth the theoretical basis for I-O analysis.

Chapter 3 Input-Output Analysis

3.1 Introduction

Input-Output analysis is the chief modelling method within the family of general equilibrium models (ten Raa, 2005). Professor Wassily Leontief developed this technique in the 1930s, which earned him a Nobel Memorial Prize in Economic Sciences in 1973 (The Nobel Foundation, 2010; Miller & Blair, 1985). Leontief's accomplishments for the United States' National Bureau of Economic Research pioneered the I-O framework. His initial work was in modelling interdependencies between industrial sectors in the United States, and hence, alternative monikers such as interindustry analysis are commonly used to describe this form of analysis.

Even though Leontief's modelling approach was the first to analyze quantitative interrelationships between industrial sectors, many economists, including Leontief, attribute the original conceptualization to French Economist François Quesnay of the Physiocratic School (Miller & Blair, 1985; Oser, 1963; Leontief, 1951). Leontief (1951) accredits Quesnay in the opening paragraph of *The Structure of American Economy, 1919-1939* as follows: "The statistical study presented in the following pages may be best defined as an attempt to construct, on the basis of available statistical materials, a *Tableau Économique* of the United States for 1919 and 1929" (p. 9). Quesnay constructed his *Tableau Économique* for the King of France in 1758; the table's subsequent revision in 1766 provided a diagrammatic depiction of expenditure linkages throughout the economy (Miller & Blair, 1985; Oser, 1963). Furthermore, Quesnay's table initiated the concept of economy wide equilibria, recognizing that if one interdependent variable were to change, others would inevitably change (Oser, 1963). This precursor to the macroeconomic school of thought was paid tribute by economists such as Adam Smith, Karl Marx, and John Maynard Keynes who, among others, favored the examination of economic functioning from the viewpoint of aggregates (Oser, 1963).

Modern I-O analysis lies within the realm of mesoeconomics, a paradigm that bridges the two primary micro and macro foundations of economic analysis. The mesoeconomic perspective provides a macroeconomic overtone, while maintaining a theoretical grounding in microeconomic theory—namely, in consumption and production (ten Raa, 2005). I-O models attempt to capture interdependencies between industries within a specified geographic space, linking industry sectors with one another, and with final demand sectors. By tracing the linear interdependencies between sectors, these models enable analysts to observe the state of economy-wide general equilibrium after individual sectors have been exogenously shocked. The partial equilibrium approach, in contrast, reduces these economic effects to the simple mechanics of bilateral markets that involve only consumers and firms. Although the I-O approach does not guarantee absolute accuracy, it nonetheless delivers important results of economic disturbances.

The structural underpinnings that differentiate I-O models from partial equilibrium models are the interdependencies accounted for between all productive sectors, where production from one industry sector variably influences all remaining sectors. This model integrates successive chains of interactions at the industrial level: in order for one industry to manufacture commodity outputs, it will require commodity inputs generated by other industries, whom in turn demand their factor input mix from other industries, and so on; each industry's inputs are the outputs of other sectors. This network of linkages spawns a complex series of interindustry interactions (United Nations, 1999). These ongoing expenditure rounds are the basis for the multiplier effect, and the *tour de force* of the I-O model.

The most salient criticisms of the I-O approach are as follows: first, the fixed Leontief technology function, implicit within every producing sector, eliminates the possibility of factor input substitution; second, the approach assumes fixed prices within the economy, failing to incorporate consumer and producer behavioural responses to price changes; finally, the approach places no constraints on supplies of factor inputs (Alavalapati, Adamowicz, & White, 1998; Miller & Blair, 1985; Leontief, 1951). The third criticism suggests the possibility that firms are interdependent due to competition over scarce factors of production, even when they are not connected by commodity flows (Alavalapati, Adamowicz, & White, 1998). The first two criticisms are discussed with added detail in section 3.2.3.

Despite some of the limitations of the I-O framework, it continues to be among the chief modelling approach for policy analysis, planning, general equilibrium analysis, and economic impact analysis (ten Raa, 2005; Hewings & Jensen, 1988). This is largely due to the relative ease of its construction, its cost effectiveness, and its provision of expeditious results. The approach has also seen widespread adoption throughout the world (Hewings & Jensen, 1987). Before analyzing the structure and relationships of the input-output system, a brief survey of the method's underlying foundations and assumptions is undertaken

3.2 Theoretical Foundations

3.2.1 Intensive Production Function

Production functions specify the technology that combines all factor inputs to produce outputs. The inputs, or factors of production, can be as few as one, or as many as required; the number is contingent upon the characteristics of the commodity or service being produced. The standard neoclassical assumptions are in effect: production functions are technologically efficient, that is, it is not possible to increase any factor input without increasing output; production isoquants are convex to the origin and, hence, exhibit diminishing marginal rates of technical substitution; and finally, the functions are complete, reflexive, and transitive (Binger & Hoffman, 1998).

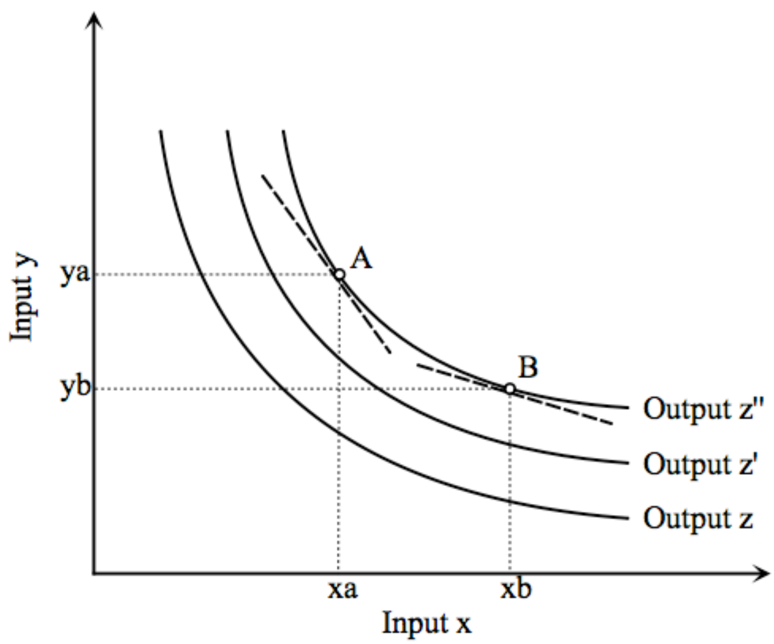
Consider an objective production function with two inputs, say *x* and *y*, that are combined to produce one output, called *z*:

$$z = f(x,y) = x^{1/2}y^{1/2} \tag{3.1}$$

A diagrammatic representation of (3.1) is a three-dimensional mound-shaped function in the non-negative octant of the Cartesian three-dimensional coordinate system. For the sake of comprehensibility, three of the level surfaces of the *z* function are projected onto the *xy* plane. The function is a rectangular hyperbola with horizontal and vertical asymptotes. Figure 3-1 illustrates the level surfaces of the production function in *xy* space: these are the production isoquants representing all combinations of inputs to produce output, where each isoquant represents a fixed level of output. Furthermore, as isoquants increase in geometric distance from the origin, they represent higher levels of output.

Diminishing marginal rates of technical substitution in figure 3-1 implies that as more *x* and less *y* is used along an isoquant, the marginal product of *x* must decline relative to the marginal product of *y*. This is illustrated in the move from point *A* to point *B*. Marginal productivity is the ratio of an infinitesimal increment of total output, divided by the corresponding infinitesimal increment of any factor (Leontief, 1951).

Figure 3-1: Production Isoquants



Market price ratios of factor inputs are illustrated as downward sloping linear functions that intersect both the *x* and *y* axes; these are illustrated as the two lines tangent to points

A and *B*, which are also the concomitant optimal production solutions when output is held fixed at z''. Theory dictates that firms optimize their production by adjusting their factor input combinations when facing changes in factor price ratios. In figure 3-1, when the factor price ratio changed, the firm altered its productive factor combination from point *A* to *B*, keeping output fixed at z''. However, the case of Leontief technology precludes this form of market behaviour.

3.2.2 Leontief Production Function

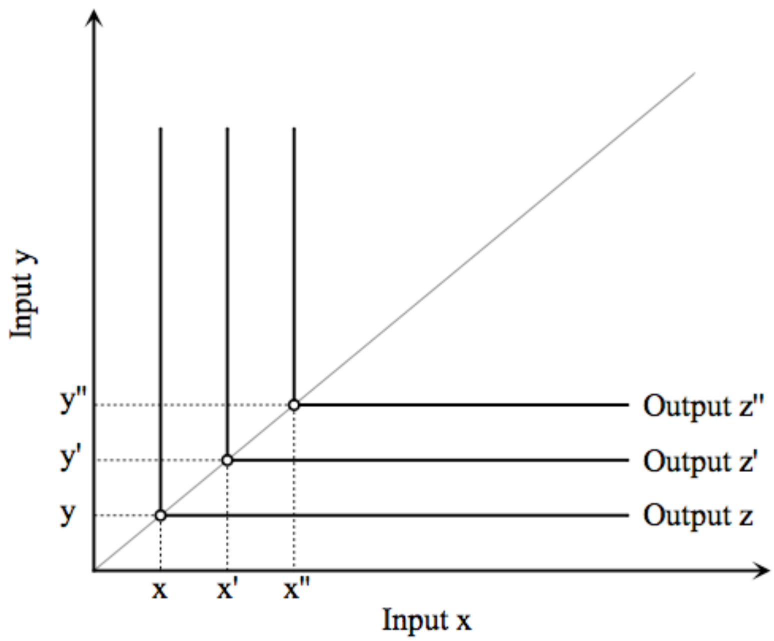
Nonstrict-convex Leontief production functions exhibit a constant elasticity of substitution equalling zero (Chiang & Wainwright, 2005; Binger & Hoffman, 1998). As a consequence, the production isoquants are square with the implication that all input factors must be used in fixed proportions. The fixed proportion technology production function, with inputs x and y, output z, and factor prices q and w for inputs x and y, respectively, reads:

$$z = f(x, y) = \min(x/q, y/w) \tag{3.2}$$

This function maintains that a single combination of factor inputs exists for each level of output; hence the synonymous designations: fixed proportion technology and no substitution technology.

Figure 3-2 illustrates an optimal input combination of x and y used to produce each level of z. For each level of output, there is one requisite input mix: x and y are used to optimally produce z, x' and y' to produce z', and x'' and y'' to produce z''. By increasing one input, *ceteris paribus*, no change in output will result. In effect, the marginal productivity of any factor of production is zero (Leontief, 1951). In order to move to a higher isoquant, the input combination must increase in fixed proportions.

Figure 3-2: Leontief Technology Isoquants



3.2.3 Assumptions Underlying Input-Output Analysis

Input-output models utilize production principles embodied in the Leontief technology function. The resultant assumptions that underlie analog I-O economies, then, are as follows:

1. Each industry sector produces a single homogeneous output;
2. Each industry sector produces with no substitution technology using fixed input ratios, which implies
3. Constant returns to scale (CRS) throughout the economy;
4. Firms and industry sectors are not price responsive in their behaviour.

In terms of the first assumption, real-world firms can produce numerous goods and services, but in the analog I-O economy, industry sectors can produce only one homogeneous commodity. The second assumption highlights how industry sectors use fixed proportions of inputs, which are purchased from other industry sectors, to produce their homogenous output. This assumption implies that disproportionate changes in output relative to inputs cannot exist, and hence, constant returns to scale.

Mathematically, the CRS condition holds when production functions are homogenous of degree one. For instance, the production function

$$f(\alpha x, \alpha y) = \alpha^m f(x, y) \ \forall \ \alpha \geq 0 \tag{3.3}$$

exhibits CRS if $m = 1$, which denotes that doubling all inputs exactly doubles all output. This condition ignores economies of scale in production (Miller & Blair, 1985). The fourth assumption connotes that price mechanisms play no role in the economy, with firms unresponsive in their input combination when prompted by changes in factor prices.

Input-output models impose these four characteristics onto all industrial production. Productive sectors must utilize their factor inputs—the intermediate outputs of other industry sectors—using fixed proportion technology: an industry's n-dimensional input mix will always utilize its n inputs in constant proportions. Since price responsiveness is precluded by this technology function, this effectively makes the I-O model a static depiction of the economy.

3.3 Fundamental Relationships

In this section, the input-output transactions table and its underlying structural relationships are elaborated upon. This table forms the starting point for I-O analysis, and an intuitive understanding of the table's sectoral interactions is imperative before any analysis can ensue. In this table, industry sectors and primary factors are listed along rows, while industry sectors and final demand categories are listed along columns. The table's entries are generally in monetary units that vary in currency according to the nation being depicted.

A transactions table itemizes the forward (sales) and backward (purchases) linkages throughout an economic system. Each row indicates the sales to, or receipts from, all other sectors. At the same time, each column indicates the purchases from, or expenditures to, every other sector. In this capacity, all sectors become interconnected within a system of double-entry accounting, and each transaction is both a receipt to one sector and an expenditure to another—hence the name, input-output (ten Raa, 2005; Davis, 1990; Hewings, 1985).

The I-O transactions table provides a macroscopic depiction of an economy's accounting flows by collapsing both sets of transactions into one matrix. If no linkage exists between two industry sectors, a zero entry is observed at the intersection of their respective vectors. It is also a distinct possibility that processing sector *A* purchases inputs from *B*, but *B* does not purchase inputs from *A*.

For demonstrative purposes, a small five-industry-sector I-O transactions table is illustrated in figure 3-3. The table is decomposed into four principle quadrants. Quadrant I, top left, illustrates interindustry transactions. Each industry sector sells their produced output to, and purchases their inputs from, many other industry sectors; they are effectively both consumers and producers, and are thus listed along rows *and* columns. The transactions made here are of raw materials and intermediate goods—those sold to other firms to undergo further processing (Schaffer, 1999; Davis, 1990; Hewings, 1985). An example of an intermediate transaction is the sale of steel to the automobile sector for the production of vehicles.

The productive sectors listed along the rows and columns of this quadrant are identical, forming a square, symmetric table. This double-entry accounting feature allows each industry to be a seller along the rows, and a purchaser along the columns. In order to produce output, an industry must purchase its factor inputs from other sectors, whom in turn must purchase their inputs from various other sectors, and so forth. The culmination of these subsequent rounds of spending is known as the multiplier effect, and is elaborated upon in greater detail later in this chapter (Schaffer, 1999). This quadrant is the foundation for I-O analysis, and provides the necessary production relationships needed for developing analytic I-O models.

Quadrant II, top right, is the final demand quadrant. This quadrant illustrates the linkages between end users in the economy and productive sectors. Transactions are deemed for final use when the good or service is either exported, or is purchased for final consumption (Statistics Canada, 2009a). This contrasts with intermediate purchases made

Figure 3-3: Input-Output Transactions Table

			PURCHASING									
			Industries					Final Demand				
			[1] A	[2] B	[3] C	[4] D	[5] E	[6] Household Consumption	[7] Gross Private Capital Formation	[8] Government Expenditures	[9] Exports	[10] Total Gross Output
PRODUCING	Industries	[1] A			I				II			
		[2] B										
		[3] C										
		[4] D										
		[5] E										
	Primary Factors	[6] Wages and Salaries			III				IV			
		[7] Operating Income										
		[8] Indirect Taxes										
		[9] Imports										
		[10] Total Gross Inputs										

by industry sectors, because final demanders do not purchase commodities with the express purpose of manufacturing goods for the market. Examples of final uses include: households purchasing clothing, government agencies purchasing automobiles, and foreign regions purchasing electronic goods. Again, the rows disclose the forward linkages, while the columns disclose the backward linkages. The final demand sectors listed in figure 3-3 are household consumption, gross private capital formation, government expenditures, and exports.

Quadrant III, bottom left, is known as the primary commodity, primary factor, primary input, or value-added quadrant. The primary factors in quadrant III of figure 3-3 are wages and salaries, operating income, and indirect taxes. This quadrant also includes purchases of raw and intermediate goods from outside the economy: imports. Despite the inclusion of imports in this quadrant, it is not a value-adding input; rather, its inclusion is merely due to convention and structural organization. If, for example, quadrant II indexes *net* exports (exports less imports) instead of exports, no imports row vector will exist in quadrant III; this is equivalent with subtracting imports from quadrant III, and subtracting the transposed imports row from exports in quadrant II.

Since the productive sectors of quadrant I will require various primary inputs to produce their output—for example, labour, and capital—this quadrant accounts for the receipts to all primary factors, and expenditures from all industry sectors. In figure 3-3, the payments to value-added sectors from processing sectors leave the industrial system of quadrant I, flowing to households as labour income, to resource and capital owners as revenue, and to external regions in exchange for imported goods. Hence, these transactions are designated as final payments (Schaffer, 1999).

The fourth and final quadrant, IV, bottom right, reveals the purchases and sales between final demand columns and value-added rows. Schaffer (1999) identifies this quadrant as either nonmarket transfers or social transfers: "[h]ere we see gifts, savings, and taxes of households; we see the surpluses and deficits of governments and their payments to households and intergovernmental transfers" (p. 16). This quadrant also contains household and government purchases of domestic labour, government purchases of imported commodities, and imported commodities that are reexported (Miller & Blair, 1985).

The final demand sectors listed in figure 3-3 are by no means exhaustive. Final demand can be disaggregated into many sectors, however the parent components are always consumption (*C*), investments (*I*), government purchases (*G*), and exports (*E*). Consumption represents consumer, or household, purchases. Investments are purchases made by the private sector for investment purposes. Government purchases encompass transactions made by federal, state, and city governments. Exports are simply sales abroad. Total final demand (*Y*) for any selling sector, then, can be calculated as follows:

$$Y_i = C_i + I_i + G_i + E_i \tag{3.4}$$

where subscript *i* denotes the selling sector. Final demand can also be grouped into domestic final demand ($C + I + G$), and foreign final demand (*E*).

The primary factors listed in figure 3-3 are also only for demonstrative purposes. Actual input-output transactions tables can include many primary inputs. The sum of components in the primary commodities quadrant equals the differences between total intermediate outlays and total final outlays. Value-added inputs provide economic service to the economy, giving rise to the difference in final price and intermediate price of a commodity (Mankiw & Scarth, 2004). Examples of value-added inputs include: employment wages for labour services, government services that are paid by tax revenue, entrepreneurial and investment income, interest payments, and returns to capital and land.

The value-added inputs included in figure 3-3 are wages and salaries (*W*), operating income (*P*), and indirect taxes (*T*). Total value added (*V*) generated by any purchasing sector in figure 3-3 is calculated as:

$$V_j = W_j + P_j + T_j \tag{3.5}$$

where subscript *j* denotes the industry sector purchasing the primary commodity. Keep in mind, though, that imports are also included in this quadrant, despite not being a primary input. Total expenditures in the primary factors quadrant (*N*) can be calculated by adding purchases of imported inputs (*M*) to equation (3.5):

$$N_j = V_j + M_j \tag{3.6}$$

which can be expanded into

$$N_j = W_j + P_j + T_j + M_j \tag{3.7}$$

Table 3-1 expands upon the purchases and sales flows depicted in figure 3-3 by organizing the linkages into a matrix.

Table 3-1: Five-Industry-Sector Input-Output Flow Matrix

	1	2	3	4	5	C	I	G	E	X
1	z_{11}	z_{12}	z_{13}	z_{14}	z_{15}	C_1	I_1	G_1	E_1	X_1
2	z_{21}	z_{22}	z_{23}	z_{24}	z_{25}	C_2	I_2	G_2	E_2	X_2
3	z_{31}	z_{32}	z_{33}	z_{34}	z_{35}	C_3	I_3	G_3	E_3	X_3
4	z_{41}	z_{42}	z_{43}	z_{44}	z_{45}	C_4	I_4	G_4	E_4	X_4
5	z_{51}	z_{52}	z_{53}	z_{54}	z_{55}	C_5	I_5	G_5	E_5	X_5
W	W_1	W_2	W_3	W_4	W_5	W_C	W_I	W_G	W_E	W
P	P_1	P_2	P_3	P_4	P_5	P_C	P_I	P_G	P_E	P
T	T_1	T_2	T_3	T_4	T_5	T_C	T_I	T_G	T_E	T
M	M_1	M_2	M_3	M_4	M_5	M_C	M_I	M_G	M_E	M
X	X_1	X_2	X_3	X_4	X_5	C	I	G	E	X

Equations (3.4) and (3.7) represent the components presented in quadrants II and III of table 3-1. The elements of quadrant I (z_{ij}) represent both the interindustry sales from sector i, and concurrent purchases by sector j. If column sums are taken for each industry sector, including purchases of primary commodities and imports, total gross inputs can be calculated:

$$X_j = \sum_{i=1}^{n} z_{ij} + W_j + P_j + T_j + M_j \tag{3.8}$$

Similarly, if row sums are taken for each industry sector, including sales to final demand sectors, total gross output can be attained:

$$X_i = \sum_{j=1}^{n} z_{ij} + C_i + I_i + G_i + E_i \tag{3.9}$$

A fundamental axiom of I-O analysis is that total inputs, or outlays, will always equal total output (Hewings, 1985; Miernyk, 1965). Thus, both the total outputs column and total inputs row are denoted by the same variable: X. This equality is preserved by the double-entry accounting methodology used in compiling the data, where a credit to one sector corresponds with a debit to another sector, and vice versa (Gibbins, 2003). Hence, the sum of an industry's row vector elements will equal the sum of its column vector elements—always.

Examining quadrants I and II—the first five rows of table 3-1—reveals all intermediate and final sales from industries 1 through 5. Each industry's total output—its intermediate *and* final sales—is acquired by summing all of its row elements. Equation (3.10) represents sector *i*'s distribution of output:

$$X_i = z_{i1} + z_{i2} + \cdots + z_{ii} + \cdots + z_{in} + C_i + I_i + G_i + E_i \tag{3.10}$$

where X_i is total output, C_i, I_i, G_i, and E_i are the components of final demand, and z_{ij} are the sales to industry *j*. Note that industry *i* also purchases its own intermediate output: z_{ii}.

Following Miller and Blair (1985), equation (3.10) is expanded upon into a system of linear equations that reflect the total output, or sales, of all *n* sectors:

$$\begin{aligned}
X_1 &= z_{11} + z_{12} + \cdots + z_{1i} + \cdots + z_{1n} + Y_1 \\
X_2 &= z_{21} + z_{22} + \cdots + z_{2i} + \cdots + z_{2n} + Y_2 \\
&\vdots \\
X_i &= z_{i1} + z_{i2} + \cdots + z_{ii} + \cdots + z_{in} + Y_i \\
&\vdots \\
X_n &= z_{n1} + z_{n2} + \cdots + z_{ni} + \cdots + z_{nn} + Y_n
\end{aligned} \tag{3.11}$$

where the components of final demand are truncated into total final demand, *Y*. Isolating the i^{th} column on the right-hand side of (3.11) reveals each industry's sales to sector *i*, or *i*'s purchases from the various producing sectors:

$$\begin{pmatrix} z_{1i} \\ z_{2i} \\ \vdots \\ z_{ii} \\ \vdots \\ z_{ni} \end{pmatrix} \tag{3.12}$$

In addition to detailing the purchase and sales linkages throughout the economy, table 3-1 shows how symmetric I-O transactions tables allow for easy tabulation of aggregate economic activity.

3.3.1 Links with National Income Accounts

Aggregate economic performance is routinely measured and updated by macroeconomists. Gross domestic product is principle among these measures. GDP is the total market value of all goods produced and services provided within a regional or national economy during a specified period of time. It can be calculated using one of three alternative approaches: the expenditure approach, the income approach, or the product approach (Abel et al., 2006).

The expenditure approach adds the amount spent by all final users of output; the income approach adds all income received, including after-tax profits, wages, salaries, and taxes—the government's income; the product approach adds the market values of goods and services produced, less the goods and services used as intermediate inputs (Abel et al., 2006; Mankiw & Scarth, 2004). The product approach makes use of the value-added concept, hence, is also referred to as the value-added approach. All three approaches yield equivalent GDP measures, thus:

$$\textit{Total Expenditure} = \textit{Total Income} = \textit{Total Production} \tag{3.13}$$

Equation (3.13) is the fundamental identity of national accounting, which forms the basis for national income accounting (Abel et al., 2006). The I-O transactions table, provided in figure 3-1, allows for easy tabulation of GDP using both the expenditure and income approaches.

In table 3-1's five-industry-sector economy, total gross output is calculated as

$$\sum_{i=1}^{5} X_i = \sum_{i=1}^{5}\sum_{j=1}^{5} z_{ij} + \sum_{i=1}^{5}\left(C_i + I_i + G_i + E_i\right) \tag{3.14}$$

whereas total gross input is calculated as

$$\sum_{j=1}^{5} X_j = \sum_{j=1}^{5}\sum_{i=1}^{5} z_{ij} + \sum_{j=1}^{5}\left(W_j + P_j + T_j + M_j\right) \tag{3.15}$$

Because total input must equal total output, expressions (3.14) and (3.15) can be equated, leaving

$$\sum_{i=1}^{5}\sum_{j=1}^{5} z_{ij} + \sum_{i=1}^{5}\left(C_i + I_i + G_i + E_i\right) = \sum_{j=1}^{5}\sum_{i=1}^{5} z_{ij} + \sum_{j=1}^{5}\left(W_j + P_j + T_j + M_j\right) \tag{3.16}$$

The interindustry transactions (z_{ij}) are contained on both sides of (3.16); they are equivalent, and can be dropped from the expression. If the remaining row and column sums are regarded as the variables indicated in the "totals" row and column of table 3-1, (3.16) can be written

$$C + I + G + E = W + P + T + M \tag{3.17}$$

The left-hand side represents the sum of all final demands in the economy, while the right-hand side represents the sum of all primary factors plus imports in the economy. Rearranging terms to account for net exports ($E - M$) leaves

$$C + I + G + (E - M) = W + P + T \tag{3.18}$$

Over any given period, double-entry bookkeeping procedures ensure that every dollar spent equals every dollar earned, and thus the two sides of (3.18) must equilibrate. The left-hand side represents total expenditure, as determined by the expenditure approach, while the right-hand side represents total income, as determined by the income approach. As per (3.13), these two quantities are always equivalent.

Assume for a moment that (3.18) represents a national economy, in which case the left-hand side equals gross national expenditure (GNE), while the right-hand side equals gross national income (GNI). Again examining (3.13), both GNE and GNI are equivalent with one another, and with GDP:

$$GNE = GNI = GDP \tag{3.19}$$

GNE measures the dollar value expended on goods and services in a nation during a specified period, while GNI measures the dollar value earned by all of the national economy's productive factors. This equality is not only existent when national boundaries are in consideration. On the contrary, gross expenditure and gross income are also equivalent at the regional level—for example, at the provincial level.

Now that the flows, transactions, and accounting relationships of the transactions table have been presented, I-O modelling methodologies can be introduced. The construction of an analytic I-O model first requires the data contained within the transactions table to be manipulated. These procedures are detailed in the following subsection.

3.4 Input-Output Model

In the production process, the industrial flow from *i* to *j* depends entirely upon the total output of sector *j*. There is no source of debate within this relationship. Few would contest that as more output is generated, additional input is required. Where contention lies is over the precise nature of this relationship in the I-O framework (Miller & Blair, 1985).

Recalling sections 3.2.2 and 3.2.3, the underlying result of no substitution technology in the Leontief production function is constant returns to scale. CRS is ascribed to the I-O system by the following equation:

$$a_{ij} = \frac{z_{ij}}{X_j} \tag{3.20}$$

Here, the interindustry flows from table 3-1 (z_{ij}) are divided by respective industry input totals to calculate technical coefficients (a_{ij}). Again, recall that input totals and output totals are equivalent. Technical coefficients are also called input-output coefficients and direct input coefficients in the literature (Leontief, 1986; Miller & Blair, 1985). If, for example, z_{24} = \$100 and X_4 = \$1,000, then a_{24} = 0.10. Because this is equivalent with \$0.10/\$1.00, and because industry input equals industry output, the 0.10 is interpreted as the cost of inputs required from industry 2 to generate one dollar's worth of output by industry 4.

Direct input coefficients are derived from observed values in the transactions table, and once these ratios are calculated, they are assumed fixed. Regardless of how much output industry 4 produces, it will always require the same input ratio from industry 2; if X_4 = \$2000, then z_{24} = \$200, if X_4 = \$50,000, z_{24} = \$5,000, and so forth. This system of production disregards economies of scale, thus operating under constant returns to scale (Chiang & Wainwright, 2005; Leontief, 1986; Miller & Blair, 1985; Miernyk, 1965; Leontief, 1951).

The I-O framework also requires that industries use inputs in fixed proportions (Miller & Blair, 1985). Extending the above example, if industry 4 also purchases input from sector 1, it would use inputs from sectors 1 and 2 in the proportion $Q_{12} = z_{14}/z_{24}$. If industry 4 increases output, the inputs from both sectors will increase by exact magnitudes that ensure technical coefficients remain fixed, and Q_{12} remains constant.

Again examining table 3-1, one can derive a general production function for industry *j* with *n* productive sectors:

$$X_j = f_j\left(z_{1j}, \dots, z_{nj}, W_j, P_j, T_j, M_j\right) \tag{3.21}$$

By embedding the direct input coefficient ratio from equation (3.20) into (3.21), we arrive at:

$$X_j = \frac{z_{1j}}{a_{1j}} = \cdots = \frac{z_{nj}}{a_{nj}} = \frac{W_j}{a_{Wj}} = \frac{P_j}{a_{Pj}} = \frac{T_j}{a_{Tj}} = \frac{M_j}{a_{Mj}} \tag{3.22}$$

The above formula becomes problematic if industry *j* does not absorb inputs from *i*, since a_{ij} will then equal zero, making (3.22) undefined (Miller & Blair, 1985). Taking this into consideration, the key specification for the Leontief production function, ignoring contributions from primary factors, becomes (Miller & Blair, 1985; Parmenter, 1982; de Boer, 1976):

$$X_j = \min\left(\frac{z_{1j}}{a_{1j}}, \cdots, \frac{z_{nj}}{a_{nj}}\right) \tag{3.23}$$

Equation (3.23) denotes that fixed minimum amounts of all inputs are required to produce a unit of industry j's output. This assumption eliminates the possibility for producers to economize on one input, by using less of another—hence, no substitution (Parmenter, 1982). For a_{ij} coefficients equaling zero, the ratio z_{ij}/a_{ij} is infinitely large, and is thus disregarded in the process of selecting the smallest ratio within the function (Miller & Blair, 1985). The assumption of CRS is further substantiated here, as multiplying z_{ij} by any scalar will invariably multiply X_j by that same scalar.

A complete set of technical coefficients that correspond with transactions table 3-1 is presented below in table 3-2. This table is commonly referred to as the technical coefficients matrix, or direct requirements table. Here, technical coefficients (a_{ij}) are shown in lieu of the transactions table's sales and purchase flows (z_{ij}). In addition, total final payments (N) is divided by X_j, where N_j/X_j denotes the value of all final payments required to generate one dollar of output for sector j. The components of value added need not be aggregated into one vector, as demonstrated in table 3-2; this is performed simply for purposes of brevity. Summing the total industry purchases row vector with the total final payments row vector produces unity (Allen, 1963).

Table 3-2: Technical Coefficients Input-Output Flow Table

	1	2	3	4	5
1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}
2	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}
3	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}
4	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}
5	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}
Total Industry Purchases	$\sum a_{i1}$	$\sum a_{i2}$	$\sum a_{i3}$	$\sum a_{i4}$	$\sum a_{i5}$
Total Final Payments	N_1/X_1	N_2/X_2	N_3/X_3	N_4/X_4	N_5/X_5
Total Inputs	1.00	1.00	1.00	1.00	1.00

Given (3.20), linear system (3.11) can now be rewritten by replacing all z_{ij} with $a_{ij}X_j$:

$$
\begin{aligned}
X_1 &= a_{11}X_1 + a_{12}X_2 + \cdots + a_{1i}X_i + \cdots + a_{1n}X_n + Y_1 \\
X_2 &= a_{21}X_1 + a_{22}X_2 + \cdots + a_{2i}X_i + \cdots + a_{2n}X_n + Y_2 \\
&\vdots \\
X_i &= a_{i1}X_1 + a_{i2}X_2 + \cdots + a_{ii}X_i + \cdots + a_{in}X_n + Y_i \\
&\vdots \\
X_n &= a_{n1}X_1 + a_{n2}X_2 + \cdots + a_{ni}X_i + \cdots + a_{nn}X_n + Y_n
\end{aligned} \tag{3.24}
$$

Equation (3.24) explicates how sales from sector *i* to *j* are contingent upon sector *j*'s total output. This moves the linear system one step closer to the operational form required for I-O analysis. Rearranging all components to isolate total final demand on the right hand side yields:

$$
\begin{aligned}
X_1 - a_{11}X_1 - a_{12}X_2 - \cdots - a_{1i}X_i - \cdots - a_{1n}X_n &= Y_1 \\
X_2 - a_{21}X_1 - a_{22}X_2 - \cdots - a_{2i}X_i - \cdots - a_{2n}X_n &= Y_2 \\
&\vdots \\
X_i - a_{i1}X_1 - a_{i2}X_2 - \cdots - a_{ii}X_i - \cdots - a_{in}X_n &= Y_i \\
&\vdots \\
X_n - a_{n1}X_1 - a_{n2}X_2 - \cdots - a_{ni}X_i - \cdots - a_{nn}X_n &= Y_n
\end{aligned} \tag{3.25}
$$

Grouping X_1s together in the first equations, X_2s in the second, X_3s in the third, and so forth, produces:

$$\begin{aligned}
(1-a_{11})X_1 - a_{12}X_2 - \cdots - a_{1i}X_i - \cdots - a_{1n}X_n &= Y_1 \\
-a_{21}X_1 + (1-a_{22})X_2 - \cdots - a_{2i}X_i - \cdots - a_{2n}X_n &= Y_2 \\
\vdots \\
-a_{i1}X_1 - a_{i2}X_2 - \cdots + (1-a_{ii})X_i - \cdots - a_{in}X_n &= Y_i \\
\vdots \\
-a_{n1}X_1 - a_{n2}X_2 - \cdots - a_{ni}X_i - \cdots + (1-a_{nn})X_n &= Y_n
\end{aligned} \tag{3.26}$$

Reorganizing the system to isolate Y on the right-hand side leaves n general equilibrium relationships between the total output of all industrial sectors, and the final transactions absorbed by households, government, and other final users (Leontief, 1986). At this point, the Y_1, Y_2,..., Y_n are known numbers, the a_{ij} are known coefficients, and the X_1, X_2,..., X_n are to be found (Miller & Blair, 1985).

This format allows for the following types of inquiry: under the schema of current production technology, how much production is necessitated from each industry sector to satisfy a certain level of final demand? Alternatively, the question can be portrayed from the perspective of impact analysis: given a specified technology matrix, how much will industries' output change if final demand is altered, or shocked, by a determined quantity?

The mathematical manipulations required for the construction of analytic I-O models can be made lucid if the procedures are interpreted in matrix notation. In matrix form, linear system (3.26) becomes

$$(I - A)x = y \tag{3.27}$$

where

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1i} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2i} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{ni} & \cdots & a_{nn} \end{pmatrix}, \quad x = \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{pmatrix}, \quad y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix} \tag{3.28}$$

and where I is the identity matrix of size n:

$$I_n = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{pmatrix} \tag{3.29}$$

An identity matrix of size n is an $n \times n$-dimensional square matrix, with ones on the principal diagonal and zeros everywhere else. Thus, the matrix (I–A) will have ($1-a_{11}$), ($1-a_{22}$),..., ($1-a_{nn}$) on its principal diagonal, and $-a_{ij}$ everywhere else.

Matrix algebra notation is elected as the choice operational form for I-O analysis, as it succinctly and conveniently makes lucid the mathematical procedures required for model construction. For readers without background in this notational form, matrices are rectangular arrays of expressions, while any single-dimensional array is referred to as a vector—namely, rows and columns. The typographical format used throughout this thesis denotes matrices with uppercase letters, and vectors with lowercase letters.

The values contained within a matrix, referred to as either entries or elements, are differentiated from one another using two subscript indices that indicate their position:

the first subscript indicates the row, and the second subscript the column. For example, the elements in matrix B are labelled b_{ij}, belonging to the i^{th} row and j^{th} column of the matrix. A matrix's size is codified as being $m\times n$-dimensional, where m corresponds with the number of rows, and n the number of columns:

$$B = \begin{pmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{m1} & \cdots & b_{mn} \end{pmatrix} \tag{3.30}$$

Matrix B can also be written in compact notation as

$$B = [b_{ij}]_{m\times n} = [b_{ij}] \tag{3.31}$$

The technical coefficients from the fictitious five-industry-sector economy of table 3-2 can also be expressed as a matrix:

$$A = \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{pmatrix} \tag{3.32}$$

In general, technical coefficient matrices, $[a_{ij}]$, are nonnegative $n\times n$-dimensional square matrices. A nonnegative matrix is one such that $A \geq 0$, where all its elements are nonnegative: $a_{ij} \geq 0 \; \forall \; i, j$.

The existence of a unique solution for (3.27) is contingent upon the nonsingularity of $(I–A)$; that is, the multiplicative inverse of $(I–A)$ must exist. In general, if two matrices of identical dimension exist such that $BC = CB = I$, then B is invertible, or nonsingular, and C is called the inverse of B. If no such matrix C exists with this property, then B is said to be singular. Matrix B is nonsingular if and only if its determinant does not equal zero: $\det(B) \neq 0$. If $|I–A| \neq 0$, the inverse of $(I–A)$ exists, and the unique solution is represented as

$$x = (I - A)^{-1} y \tag{3.33}$$

where $(I–A)^{-1}$ is known as the Leontief inverse (ten Raa, 2005; Schaffer, 1999; United Nations, 1999; Hewings, 1985; Miernyk, 1965).

Because the $(I–A)$ matrix is nonsingular, $(I–A)^{-1} = [\delta_{ij}]$, and solution values for x in equation (3.33) must exist. The linear system resulting from $x = (I–A)^{-1}y = [\delta_{ij}]\ y$ is expressed as:

$$\begin{aligned}
X_1 &= \delta_{11}Y_1 + \delta_{12}Y_2 + \cdots + \delta_{1j}Y_j + \cdots + \delta_{1n}Y_n \\
X_2 &= \delta_{21}Y_1 + \delta_{22}Y_2 + \cdots + \delta_{2j}Y_j + \cdots + \delta_{2n}Y_n \\
&\vdots \\
X_i &= \delta_{i1}Y_1 + \delta_{i2}Y_2 + \cdots + \delta_{ij}Y_j + \cdots + \delta_{in}Y_n \\
&\vdots \\
X_n &= \delta_{n1}Y_1 + \delta_{n2}Y_2 + \cdots + \delta_{nj}Y_j + \cdots + \delta_{nn}Y_n
\end{aligned} \tag{3.34}$$

Equation (3.34) elucidates the dependence of industries' gross outputs on the values of all final demands. Furthermore, the linearity of this system can easily be observed, because

$$\partial X_i / \partial Y_j = \delta_{ij} \tag{3.35}$$

and in linear functions, the partial derivates are simply each variable's coefficient.

Economic rationale dictates that the system of (3.34) must have a solution that consists of only nonnegative values (Chiang & Wainwright, 2005; Takayama, 1985). A negative coefficient interacting with a final demand variable in the determination of an industry's output is not theoretically sound. Thus, in addition to existence, the Leontief inverse must also comprise of only nonnegative values: for any given $y \geq 0$ in $(I–A)\,x = y$, the existence of a unique $x \geq 0$ is only guaranteed if the matrix $(I–A)$ is nonsingular, and if $(I–A)^{-1} \geq 0$ (Takayama, 1985). This nonnegativity requirement, known as the Hawkins-Simon (H-S) condition, is only attainable when the $(I–A)$ matrix possesses certain properties.

3.4.1 Hawkins-Simon Condition

In order for the Leontief inverse to have all nonnegative entries, the $n \times n$ matrix $(I–A)$ must have all positive principal minors (Chiang & Wainwright, 2005; ten Raa, 2005; Takayama, 1985; Hawkins & Simon, 1949). This specification, developed by David Hawkins and Herbert A. Simon, is known as the Hawkins-Simon condition (1949). A brief digression into the concepts of principal minors is first required in order to fully comprehend the H-S condition.

The geometric definition of a matrix determinant is the area of a parallelogram in $\mathbb{R}^2$, or, in general, the volume of 3-or-more-dimensional parallelepiped in Euclidean space. It is a number that acts as a spatial scale factor when the matrix is regarded as a linear transformation. The determinant of matrix B is written $\det(B)$ or $|B|$, and a minor is simply a subdeterminant obtained by deleting the i^{th} row and j^{th} column of $|B|$, where i and j are not necessarily equal. If the restriction $i = j$ is imposed, then the resulting minor, or subdeterminant, is termed the principal minor. They are termed *principal* because, when imposing $i = j$, the principal-diagonal elements of all remaining subdeterminants consist exclusively of the principal-diagonal elements of B. Furthermore, multiple rows and columns can be simultaneously removed to calculate determinants of various-order principal minors.

The H-S condition depends only upon the positivity of a particular subset of the principal minors; these are referred to as leading or successive principal minors. For example, if B is a 3×3 matrix, these leading principal minors—the first, second, and third-order principal minors, are

$$|B_1| \equiv |b_{11}| \quad |B_2| \equiv \begin{vmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{vmatrix} \quad |B_3| \equiv \begin{vmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{vmatrix} \tag{3.36}$$

The subscript m in $|B|$ indicates that the leading principal minor is of dimension $m \times m$. Higher-dimensional determinants, say, $n \times n$, will of course consist of a greater number of principal minors. In general, a k^{th} order principal minor is obtained by removing any $n - k$ rows and the same-numbered columns from $|B|$ (Chiang & Wainwright, 2005).

With these new concepts, the H-S condition can now be exemplified on an $n \times n$ matrix $B = [b_{ij}]$:

$$b_{11} > 0, \quad \begin{vmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{vmatrix} > 0, \dots, \quad \begin{vmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{n1} & b_{n2} & \cdots & b_{nn} \end{vmatrix} > 0 \tag{3.37}$$

This condition states in matrix notation that all successive principal minors of B are positive. In the case of a two-industry I-O system

$$I - A = \begin{pmatrix} 1 - a_{11} & -a_{12} \\ -a_{21} & 1 - a_{22} \end{pmatrix} \tag{3.38}$$

the H-S condition requires that

$$1 - a_{11} > 0, \quad \text{and} \quad \begin{vmatrix} 1 - a_{11} & -a_{12} \\ -a_{21} & 1 - a_{22} \end{vmatrix} > 0 \tag{3.39}$$

The second-order principal minor condition can also be written

$$(1 - a_{11})(1 - a_{22}) - a_{12}a_{21} > 0 \tag{3.40}$$

which is equivalent to

$$a_{11} + a_{12}a_{21} + (1 - a_{11})a_{22} < 1 \tag{3.41}$$

The economic interpretation of the H-S condition is that industry *j*'s use of its own commodity in the production of one dollar's worth of its final output must be less than one dollar (Chiang & Wainwright, 2005). In (3.41), a_{11} measures the *direct* use of industry 1's own commodity to generate its output, while $a_{12}a_{21}$ measures the *indirect* use—the amount of the first commodity needed in production of the second commodity, that goes into the production of a dollar's worth of the first commodity (Chiang &

Wainwright, 2005). The H-S stipulations effectively ensure that industry 1's direct and indirect use of its own commodity in the production of one dollar's worth of output is less than one dollar. No industry would operate if the cost of total requirements exceeded the value of output.

It is now evident that a unique and positive solution for $(I–A)\,x = y$ exists if and only if all the successive principal minors of $(I–A)$ are positive (Chiang & Wainwright, 2005; Takayama, 1985; Hawkins & Simon, 1949). A concise and useful theorem presented by Chiang and Wainwright (2005) is as follows:

> Given (*a*) an $n{\times}n$ matrix B, with $b_{ij} \leq 0$ $(i \neq j)$ (i.e., with all off-diagonal elements nonpositive), and (*b*) an $n{\times}1$ vector $d \geq 0$ (all elements nonnegative), there exists an $n{\times}1$ vector $x^* \geq 0$ such that $Bx^* = d$, if and only if $|B_m| > 0$ $(m = 1, 2,..., n)$ i.e., if and only if the leading principal minors of B are all positive. (p. 118)

3.4.2 Direct & Indirect Effects

In contrast to the partial equilibrium approach, which relies heavily upon *ceteris paribus* assumptions, the I-O framework seeks to capture mutual interdependencies within an economy (Leontief, 1951). An impact to one economic sector generates a series of ripple effects that induce a long chain of interindustry interactions. This closed-loop effect continues until the economy returns to equilibrium (Schaffer, 1999; United Nations, 1999). Two effects are derived from these spending rounds: direct effects and indirect effects.

Direct effects are those associated with the initial industry expanding output to meet the new demand. It must purchase its factor inputs from other sectors in order to manufacture its commodity. Indirect effects are those associated with the "other" sectors: as they expand output to meet the requirements of the principal industry's demand, they must too purchase inputs from other sectors. This chain of interactions continues until infinity (United Nations, 1999).

The values in the technical coefficients matrix, *A*, describe the input proportions required to generate one dollar's worth of output for each industry. Each column vector is effectively a linear fixed-coefficient production function that constitutes the direct effect. Direct-input coefficient matrices fail to describe, however, the indirect effects resultant from production. Fortunately, the Leontief inverse is able to calculate both direct and indirect effects. Before this is illustrated, the Leontief inverse must be written in the form of an infinite series:

$$(I - A)^{-1} = \sum_{k=0}^{\infty} A^k = I + A + A^2 + A^3 + A^4 \ldots \tag{3.42}$$

Proof that this is in fact the Leontief inverse is demonstrated by premultiplication with (*I*–*A*):

$$(I - A)\sum_{k=0}^{\infty} A^k = \sum_{k=0}^{\infty} A^k - \sum_{k=1}^{\infty} A^k = A^0 = I \tag{3.43}$$

which yields the identity matrix, which is operationally equivalent to unity in ordinary algebra.

Although the Leontief inverse calculates a solution to the infinite series—which is a matrix of partial output multipliers—simply stating the solution fails to provide the reader with an intuitive understanding of the rounds of spending. A solution by iterations approach is thus adopted to explain this concept (Schaffer, 1999; United Nations, 1999; Hewings, 1985). Consider the infinite series

$$X = (I - A)^{-1} S = \sum_{k=0}^{\infty} A^k S = S + AS + A^2 S + \ldots A^k S \tag{3.44}$$

where X is the solution, S is the shock, or new demand, on the economy, and k is the number of expenditure rounds required to generate results approximating those obtained when k approaches infinity (Schaffer, 1999). Because the identity matrix, I, is equivalent with the number one, the first variable on the right hand side equals the magnitude of the exogenous shock, S. This can be construed as round zero—the initial expenditures to be traced, which takes effect before the long chain of interactions ensues.

Round one is AS, which calculates the outputs required from each industry to produce the commodity demanded in the initial shock, S. Round two is A^2S, which calculates the outputs required from each industry to produce the goods and services purchased in round one. The third round is the incremental output needed to meet the input requirements of the second round's output. This succession of expenditures repeats until A^kS. Round zero, the initial purchase, is the direct effect on the economy, rounds one through k are the indirect effects, and the solution simply sums both effects over an infinite series. Schaffer (1999) maintains that the number of expenditure rounds need not approach infinity to yield useful results; on the contrary, he asserts that in most cases k=6 captures over 97 percent of flows, and k=8 captures over 99 percent.

The solutions to these infinite series are always larger than the size of the initial shocks. Because the exogenous shocks *are* the direct effects, this implies that the indirect effects are larger than zero. Furthermore, the magnitude of indirect effects varies from sector to sector according to the complex set of linear dependencies underlying the analog economy. These proportions of added income, generated by increases in economic activity, are referred to as multiplier effects (Miernyk, 1965). They are discussed in further detail in subsection 3.4.4. However, a digression into the topic of infinite series convergence is first required before continuing on to multiplier analysis.

3.4.3 Convergence

The question now emerges as to how an I-O system can generate a solution if there exists a seemingly endless succession of expenditures. If the system's rounds of spending continue until infinity, as in (3.42), how can the elements of the Leontief inverse matrix not be infinitely large? Furthermore, how is an infinitely large multiplier conducive to economic theory?

The succinct answer to these questions is that the infinite series converges to something finite if, and only if, the column sums of matrix A are less than one (ten Raa, 2005). In the demonstration of this principle, two unit vectors are utilized:

$$e = \begin{pmatrix} 1 \\ \vdots \\ 1 \end{pmatrix} \tag{3.45}$$

and

$$e^T = (1 \; \ldots \; 1) \tag{3.46}$$

Throughout this thesis, row vectors are written as column vectors with superscript "*T*" to denote transposition.

Both vectors consist only of ones, and serve a particular purpose: for any given n-dimensional square matrix, B, postmultiplication by an appropriately sized e yields an $n\times1$-dimensional vector consisting of matrix B's row totals, and premultiplication by e^T yields a $1\times n$-dimensional vector consisting of B's column totals. It can be seen, then, that the requirement for the technical coefficient matrix, A, is

$$e^T A < e^T \tag{3.47}$$

The economic rationale behind this condition is intuitive: an industry's generation of \$1.00 worth of output must use less than \$1.00 of material costs. If A fulfills this requirement, the column sums of A^k are geometrically declining, which permits summation over k and the existence of a finite Leontief inverse (ten Raa, 2005).

This requirement is demonstrated by following the work of ten Raa (2005). First, the condition of (3.47) is rewritten as the weak inequality

$$e^T A \le \alpha e^T, \; 0 \le \alpha \le 1 \tag{3.48}$$

where α is the maximum column total, or maximum absolute column sum norm, of A:

$$\alpha = \|A\|_1 = \max \sum_{i=1}^{n} |a_{ij}| \tag{3.49}$$

Converting a_{ij} into absolute values is of little consequence, as it is reasonable to assume the technology coefficients of matrix A are all nonnegative values. The second step is to acknowledge that inequality (3.48) implies:

$$e^T A^2 = e^T AA \leq \alpha e^T A \leq \alpha^2 e^T \tag{3.50}$$

Postmultiplying (3.50) by A arbitrarily many times yields:

$$e^T A^k \leq \alpha^k e^T \tag{3.51}$$

which implies:

$$0 \leq e^T \sum_{k=0}^{N} A^k = \sum_{k=0}^{N} e^T A^k \leq \sum_{k=0}^{N} \alpha^k e^T = \frac{1-\alpha^{N+1}}{1-\alpha} e^T \leq \frac{e^T}{1-\alpha} \tag{3.52}$$

It is a mathematical principle that bounded sequences of real numbers are convergent. Inequality (3.52) demonstrates that the column totals $\sum A^k$ are bounded as N increases, which connotes the $(i, j)^{th}$ elements to be bounded as N increases (ten Raa, 2005). Therefore, the $(i, j)^{th}$ elements have a limit, and $\sum A^k$ converges to something finite (ten Raa, 2005).

3.4.4 Multiplier Effects

I-O models are designed to trace economy-wide effects from controlled stimulus. These effects include flows of monies throughout an economy, and changes to value added accruing to capital and resource owners (Schaffer, 1999). Two forms of stimuli can affect the economic model: structural changes, and final demand changes (Schaffer, 1999). Structural changes are essentially modifications to firms' technology coefficients. This thesis concerns itself only with final demand changes.

I-O models borrow an important notion from economic-base theory: final demand is the motivating force in an economy (Schaffer, 1999). Hence, the effect on output from changing final demand remains the cornerstone of impact analysis. As previously discussed, the difference between total gross output and total intermediate use is final demand. In order for firms to increase output, they must also require more intermediate inputs. This induces a feedback effect of interindustry sales and purchases, disproportionately influencing output. Hence, final demand shocks elicit what is known as a multiplier effect on output (ten Raa, 2005).

3.4.4.1 Shocking the Model: Demand-Pull Analysis

In equation (3.33), matrix A signifies production technology, which has already been determined, y is a final demand vector, and x is a total output vector, which is of particular interest to the analyst. Given A, the researcher can fabricate a final demand vector (y) such that impact analysis is performed according to specifications.

In order to understand the mathematical computations required to impute I-O models with exogenous final demand shocks, an additional unit vector is required:

$$e_i = \begin{pmatrix} 0 \\ \vdots \\ 0 \\ 1 \\ 0 \\ \vdots \\ 0 \end{pmatrix} \tag{3.53}$$

In this vector, the i^{th} entry equals one, and all other entries are zero. The I-O model is shocked by replacing the final demand vector (y) in $x = (I–A)^{-1}y = \sum A^k y$ with (3.53), where unity corresponds with the industry sector that is shocked.

Postmultiplication of the Leontief inverse by a specified unit vector of final demand yields an $n\times1$ vector of output multipliers corresponding with all n industries in the I-O model. This $n\times1$ vector, the model's solution set, concisely captures the multiple rounds of spending and money flows throughout the economy; this solution vector is the total outputs vector x of equation (3.33). Recall that every entry in this vector lists, in whatever monetary numeraire the analyst specified, the total output of each industry as a result of y. Once the economic disturbance has made its multiple rounds throughout the economy, the analyst can easily determine how much each sector has outputted as a result of one sector satisfying a final demand. For example, if final demand increased for industry j by \$1.00, a one would occupy the j^{th} row of (3.53), and output vector x would capture the total effects of this demand stimulus for each industry.

Because of the linearity embedded within the I-O model, any numerical value can replace the i^{th} entry of (3.53), but the disproportional effects on multipliers will be linear. For example, if a \$1.00 increase in demand to industry j has a total output effect of \$1.38, a \$1,000 increase will generate \$1,380 of total output. Moreover, a negative exogenous shock to final demand, modelled in the form of diminished demand, will yield a reduction in total output of –\$1.38 per –\$1.00. For this reason, the economic effects of final demand changes are almost always recorded as a multiplier coefficient, relative to \$1.00 worth of exogenous demand. As per the preceding example, the total effects would simply be stated as having a total demand-pull output multiplier effect of 1.38.

The benefit of utilizing the demand-pull approach is that numerous industries can be simultaneously shocked. In this case, the unit vector (3.53) will require augmentation, where ones will replace all entries corresponding to sectors experiencing final demand pulls. The additive nature of the linear model ensures that output multipliers are summed appropriately.

3.4.4.2 Equilibrium Conditions

The analog I-O economy begins in a state of equilibrium, and returns to a state of equilibrium once the demand stimulus's circular multiplier effect has taken its course. The model's state of general equilibrium is determined by the mathematical relationships created according to data in the transactions table. Behavioural responses in respect to price change are not captured within the model, however, changes in industries' supply and demand schedules do occur as a result of linear linkage dependencies. In addition, the model does not account for the temporal length required to move the analog economy out of equilibrium, perform expenditure rounds, and again return to equilibrium. This process is treated as instantaneous, or, at least, it takes as long as computational processing power enables, which is virtually instantaneous given today's computing technology.

3.4.4.3 Output Multipliers

The aforementioned demand-pull method of shocking the model yields output multipliers. However, the Leontief inverse provides another approach for examining output multipliers. If all conditions are met, the Leontief inverse $(I–A)^{-1}$ yields a symmetric impact matrix that is equidimensional with the technical coefficients matrix, A. This impact matrix, also termed the total requirements table, consists of elements that show the total purchases from the industries along each row, for each dollar of delivery to final demanders by the industries along each column (Schaffer, 1999). This matrix effectively details all economy-wide purchases due to one sector's delivery to final demanders.

Table 3-3: Five-Industry-Sector Impact Matrix

	1	2	3	4	5
1	δ_{11}	δ_{12}	δ_{13}	δ_{14}	δ_{15}
2	δ_{21}	δ_{22}	δ_{23}	δ_{24}	δ_{25}
3	δ_{31}	δ_{32}	δ_{33}	δ_{34}	δ_{35}
4	δ_{41}	δ_{42}	δ_{43}	δ_{44}	δ_{45}
5	δ_{51}	δ_{52}	δ_{53}	δ_{54}	δ_{55}
Total Industry Outputs	$\sum\delta_{i1}$	$\sum\delta_{i2}$	$\sum\delta_{i3}$	$\sum\delta_{i4}$	$\sum\delta_{i5}$

Table 3-3 shows the total requirements matrix for a five-industry-sector economy. In this table, δ_{ij}—the partial output multipliers for each respective industry, denotes the entries in the $(I–A)^{-1}$ matrix. Linear system (3.34) relates δ_{ij} to all final demands (Y_j), for a given industry output (X_i). These partial output multipliers account for both direct and indirect effects. The sum of all industries' outputs required for each column industry to deliver one dollar's worth of output to final demanders, known as the total multiplier effect, is also included in this table along the bottommost row.

As an example, if there was a $1.00 increase in export demand for the manufacturing sector, and if $\sum\delta_{iMANUF}$, the total multiplier effect, was equal 1.45, it could be said that by exporting $1.00 worth of output, the manufacturing sector would cause production by all industrial sectors to be $1.45. Extrapolating on this, it can be seen that $1,000 worth of export would amount to $1,450 worth of production by all industries. This is the source of the term multiplier effect: one unit of exogenous demand on the economy does not impose a one-to-one output effect on industrial production; on the contrary, the total economic effect is a multiple of the initial shock—hence, multiplier.

3.4.4.4 Income Multipliers

In addition to output increases from final demand stimuli, new economic activity can generate a multiplier effect on primary factors. Many authors of I-O literature cite the multiplier effects on primary inputs to be among the most salient of results generated by I-O models. These multipliers are referred to as income multipliers.

First, recall that, like technical coefficients, primary inputs are also calculated on a per-dollar-of-industry-output basis: N_j/X_j (table 3-2), where N is total expenditures in the primary factors quadrant, X is total output, and the ratio is effectively a coefficient analogous to technical coefficients. An income multiplier per $1.00 increase in final demand to industry j is obtained by the product of the $1\times n$ primary-input coefficients vector (N_j/X_j, $\forall$ j), and industry j's $n \times 1$ vector of partial output multipliers from the Leontief matrix $(I–A)^{-1}$. This algorithm can be used on any individual primary factor (see equations (3.5) - (3.7)); multipliers for industry GDP, labour income, and taxes collected by governments can all be calculated.

An alternative procedure is to premultiply the Leontief inverse with a primary factor row vector. If, for example, the income multipliers for taxes collected by government are to be calculated, the tax coefficients vector, t^T, premultiplies the Leontief inverse:

$$t^T \sum_{k=0}^{\infty} A^k = t + tA + tA^2 + tA^3 + \cdots \tag{3.54}$$

The product of (3.54) is a row vector, where the j^{th} entry is the income multiplier for taxes collected by government from a \$1.00 increase in final demand to the j^{th} industry. Each entry in this product vector corresponds with a \$1.00 increase in the respective Leontief inverse column, from industry 1 until industry n. The first term in (3.54), t, is the direct tax effect of alternative commodity increases, the second term, tA, is the tax collected from the production of the direct material input requirements, and the remaining terms, tA^k, are the taxes collected during the production of the indirect requirements (ten Raa, 2005).

3.4.5 Closing the Model

The I-O model introduced thus far operates with an exogenous final demand sector that is disconnected from the technologically linked producing sectors. The four broad components of final demand, as outlined in (3.4), are consumption, investment, government purchases, and exports. In reality, these components can be further disaggregated into many parts, but, for purposes of concision, they remain clustered into four groups. The consumption component plays an important role with respect to the households sector.

Economic theory dictates that households both earn income in the form of wages and salaries, and make consumption expenditures on goods and services. The model discussed until this point, referred to as the *open* model, only accounts for interindustry sales and purchase linkages in the model economy. However, by endogenizing the household final demand sector, and linking its sales (labour) and purchases (consumption) with the interindustry system, it enables the domestic sector to function like a productive sector. This augmentation allows households' consumption to vary according to changes in their income, as opposed to relegating it to exogenous specification. For example, a final demand pull on industry *j* would elicit households to sell additional labour throughout the multiple rounds of direct and indirect production; this additional income accruing to households would then induce more spending from consumers. This endogenous households model is referred to as the *closed* model.

It is tacit that closed models generate larger output multipliers. In fact, closed models not only capture direct and indirect effects, but they also capture additional *induced* effects; induced effects are a result of extending the successive spending rounds to households in the closed system (Schaffer, 1999; Davis, 1990; Miller & Blair, 1985). Because of the importance of induced impacts, the closed model is preferred in the literature over the open model (Schaffer, 1999; Davis, 1990). This thesis includes both *type I* (open model) and *type II* (closed model) multipliers in the results chapter.

Closing the model is performed by relocating the household consumption final demand column vector from quadrant II into quadrant I of the transactions table (figure 3-3), and by bringing the personal income value-added row vector from quadrant III into quadrant I (Davis, 1990). The augmented interindustry transactions quadrant is now an n+1-dimensional square matrix, where the endogenous household sector occupies the $n+1^{\text{th}}$ column and row. Wages and salaries flow *to* households from each of n industry sectors in the $n+1^{\text{th}}$ row

$$\begin{pmatrix} z_{n+1,1} & z_{n+1,2} & \cdots & z_{n+1,n} \end{pmatrix} \tag{3.55}$$

and expenditures flow *from* households as consumption purchases in the $n+1^{\text{th}}$ column

$$\begin{pmatrix} z_{1,n+1} \\ z_{2,n+1} \\ \vdots \\ z_{n,n+1} \end{pmatrix} \tag{3.56}$$

The element at the intersection of the $n+1^{\text{th}}$ row and $n+1^{\text{th}}$ column represents household purchases of labour services (Miller & Blair, 1985). The augmented model now modifies the i^{th} equation of linear system (3.11) with

$$X_i = z_{i1} + z_{i2} + \cdots + z_{ii} + \cdots + z_{in} + z_{i,n+1} + Y_i^* \tag{3.57}$$

where Y_i^* represents the exogenous final demand components, less household consumption.

The augmented technical coefficients matrix is represented as

$$\overline{A} = \left(\begin{array}{c|c} A & h_C \\ \hline h_R & h \end{array} \right) \tag{3.58}$$

where h_C, h_R, and h represent the households column vector, row vector, and intersection element, respectively. From here, the methodologies required to calculate the Leontief inverse and to perform a demand-pull shock on the system are identical with those employed in the open model.

3.4.6 Interregional Models

Until this point, only single-region models have been considered. The linkages in these models are contained within the spatial boundaries of the regional or national economy being analyzed. Exports and imports are the only interactions these regions have with the outside world. These transboundary interactions are, however, exogenous to the industrial production cycle; these forms of sales and purchases do not augment the indirect production requirements underlying output creation. In contrast, interregional input-output (IRIO) models—set out by Ronald E. Miller (1963), employ an operational form that accounts for interconnections *between* regional industries.

For demonstrative purposes, consider a fictitious country consisting of five states. A single-region I-O model of the first state captures the economic ripple effects of a new chemicals refinery in that state. However, because the system lacks interconnectedness, the multipliers understate total impacts. On the other hand, an IRIO system that connects industrial activity between all five states accounts for cross-boundary linkages: the manufacturing sector in state one purchases inputs from state three's steel industry, which purchases inputs from state four's construction industry, and so forth. By capturing interregional linkages, the model enables multipliers to capture total economic effects, and relaxes the assumption that interregional transactions are autarkic.

In this research project, two-region interregional models are employed. A hypothetical two region IRIO model is outlined in table 3-4 to delineate the system's schematics: this table of interregional interindustry sales and purchases proxies for quadrant I of the transactions table. Both regions' transactions tables need not be of identical dimensions to perform this integration.

Table 3-4: Two-Region Interregional Interindustry Flow Matrix

			Purchasing Sectors				
			Region N			Region P	
			1	2	3	1	2
Producing Sectors	Region N	1	z_{11}^{NN}	z_{12}^{NN}	z_{13}^{NN}	z_{11}^{NP}	z_{12}^{NP}
		2	z_{21}^{NN}	z_{22}^{NN}	z_{23}^{NN}	z_{21}^{NP}	z_{22}^{NP}
		3	z_{31}^{NN}	z_{32}^{NN}	z_{33}^{NN}	z_{31}^{NP}	z_{32}^{NP}
	Region P	1	z_{11}^{PN}	z_{12}^{PN}	z_{13}^{PN}	z_{11}^{PP}	z_{12}^{PP}
		2	z_{21}^{PN}	z_{22}^{PN}	z_{23}^{PN}	z_{21}^{PP}	z_{22}^{PP}

This table exhibits the recirculation of monies between both regions' producing sectors. Region N consists of three industry sectors, while Region P consists of two. The top left 3×3 and bottom right 2×2 submatrices represent sales and purchases within Regions N and P, respectively. The top right matrix indicates interregional sales from Region N's three industries to Region P's two industries. Similarly, the bottom left matrix indicates interregional purchases by Region N's three industries from Region P's two industries. The subscripts follow the conventions consistent throughout this thesis, denoting selling and purchasing sectors. The first superscript denotes the selling region, while the second superscript the purchasing region. The matrix of interregional interindustry transactions is written as

$$Z = \left(\begin{array}{c|c} Z^{NN} & Z^{NP} \\ \hline Z^{PN} & Z^{PP} \end{array} \right) \tag{3.59}$$

where each Z represents a submatrix of recirculated monies.

The linear equation describing total output of industry 1 in region P is

$$X_1^P = z_{11}^{PN} + z_{12}^{PN} + z_{13}^{PN} + z_{11}^{PP} + z_{12}^{PP} + Y_1^P \tag{3.60}$$

where the first three terms on the right-hand side represent sales, or trade, to region N, the following two terms represent sales within region P, and the final term represents sales of industry 1's output to final demand in region P (Miller & Blair, 1985). Similar equations exist for X_i^P and X_i^N.

Technical coefficients for own-region sales are calculated in the consistent manner:

$$a_{ij}^{NN} = \frac{z_{ij}^{NN}}{X_j^N}, \quad a_{ij}^{PP} = \frac{z_{ij}^{PP}}{X_j^P} \tag{3.61}$$

Interregional trade coefficients are calculated as

$$a_{ij}^{NP} = \frac{z_{ij}^{NP}}{X_j^P}, \quad a_{ij}^{PN} = \frac{z_{ij}^{PN}}{X_j^N} \tag{3.62}$$

A complete technical coefficients matrix encompassing all regional and interregional transactions consists of the following four submatrices:

$$A = \left(\begin{array}{c|c} A^{NN} & A^{NP} \\ \hline A^{PN} & A^{PP} \end{array} \right) \tag{3.63}$$

Extending the existing I-O framework, the IRIO system from table 3-4 becomes (Round, 2001; Miller, 1966; Miller, 1963):

$$\left[\left(\begin{array}{c|c} I & 0 \\ \hline 0 & I \end{array} \right) - \left(\begin{array}{c|c} A^{NN} & A^{NP} \\ \hline A^{PN} & A^{PP} \end{array} \right) \right] \left(\begin{array}{c} X^{N} \\ \hline X^{P} \end{array} \right) = \left(\begin{array}{c} Y^{N} \\ \hline Y^{P} \end{array} \right) \tag{3.64}$$

As a system of linear equations, (3.64) is written (Round, 2001; Miller, 1966; Miller, 1963):

$$\begin{aligned} (1 - A^{NN})X^{N} - A^{NP}X^{P} = Y^{N} \\ -A^{PN}X^{N} + (1 - A^{PP})X^{P} = Y^{P} \end{aligned} \tag{3.65}$$

As with the single-region models, the IRIO models assume stable and unvarying trade coefficients. Apart from dimensionality differences, the impact analysis of an IRIO model follows the same guidelines as the single-region approach. However, this type of model accounts for spillover effects due to interregional trade; region P may accrue a positive impact from economic activity that is undertaken in region N. In addition to the *intra*regional multiplier effects of single-region models, IRIO models compound an additional *inter*regional spillover effect resultant from cross-boundary industrial trade (Round, 2001).

Because of the additional feedback effects associated with IRIO models, single-region models have been theorized to understate the *true* output multipliers of a regional or national economy (Miller & Blair, 1985). However, experimentation and analysis has revealed that the actual additional feedbacks are, on average, small (Round, 2001; Miller & Blair, 1985; Miller, 1966). Miller's (1966) analysis revealed that the average multiplier understatement between single-region and two-region interregional models was less than one percent. Furthermore, Brown (1972) later surmised that interregional spillovers are estimated to add at most an additional 0.01 multiplier effect to a regional model. Miller and Blair's (1985) cross-examination of eight IRIO models revealed that when interregional feedbacks were ignored, average errors in output multipliers ranged from 0.42 percent to 14.4 percent. This thesis incorporates IRIO models in addition to single-region models for juxtapositional purposes.

3.5 Chapter Summary

An in-depth analysis of the I-O framework is presented in sections 3.1 through 3.4. In these sections the model's theoretical underpinnings and mathematical foundations are outlined in detail. Furthermore, variations on the modelling approach are also elaborated upon—namely: open versus closed models, single-region versus interregional models, and the calculation of income multipliers in addition to output multipliers.

In theory, the IRIO approach is expected to produce larger multiplier effects, as it accounts for interregional trade. The exclusion of interregional trade—a scenario of autarky, is expected to underestimate the size of the *real* multiplier effect. However, some studies have revealed that the discrepancy in multiplier value between single and multiregion models is marginal. Nonetheless, in addition to single-region models, this thesis will also utilize the IRIO approach.

Closed models—models that endogenize households into the productive economy—are also expected to generate larger multiplier effects. This is due to the household sector's involvement in production (sales of labour) and consumption (purchases of industry output). In addition to open models, closed models are also created in this thesis, yielding *type II* multipliers. Schaffer (1999) suggests that *type II* multipliers are more theoretically relevant because, in the real world, households are involved in the productive economy; hence, they are included in this research project. By constructing both open and closed versions of models, the endogenous household sector's contribution to the multiplier effect can be compared to scenarios where it is not endogenized.

Finally, in addition to output multipliers, income multipliers for industry GDP, labour income, returns to capital, and taxes collected by government are also calculated. In addition to the standard industry output multipliers that are typically calculated, income multipliers provide results that are more macroeconomic in flavour. Moreover, the effect on these income variables from shocks to the cervid and cattle industries is of great importance to policy makers.

The I-O modelling methods detailed in this chapter assumes that the analyst is already in possession of a symmetric transactions table (figure 3-3). In many instances, data provided by statistical agencies do not conform to the layout of the symmetric I-O transactions table. The following chapter discusses the I-O data available in Canada, and details how these data can be manipulated to construct the transactions tables that are necessary for producing analytic I-O models.

Chapter 4 Data, Data Modifications, & Model Modifications

4.1 Introduction

Leontief input-output models are constructed using observed economic data. These data are most often published at national and subnational levels. The literature often refers to subnational geographic spaces as regions, which are classified into two groups: homogenous regions and nodal regions. Homogenous regions bind adjoining geographic spaces that are alike in characteristic (Davis, 1990). The Maritime provinces and Prairies of Canada are both homogenous regions. A nodal region, in contrast, lacks homogeneity, but consists of "functionally integrated areas" (Davis, 1990, p. 4). Administrative divisions such as provinces, states, cities, and municipalities are nodal regions.

Input-output data in Canada are published at national, provincial, and territorial levels. The two latter nodal regions, as well as the national level, are routine sources of I-O model construction in Canada. Modelling economic interrelationships at a further subregional level—for example, a geographic fragment of a province—is possible if the requisite data is available. This process is often referred to as regionalization, and requires the employment of additional matrix manipulations (Jackson, 1998).

This chapter is broken into sections according to three overarching themes. The first theme discusses in section 4.2 Statistics Canada's published I-O data tables, along with their format, layouts, and economic interpretations. Because the published I-O data are not consistent with the formats required to construct analytic I-O models—symmetric transactions tables (figure 3-3)—the data tables must be modified in order to make them useful. The second broad theme, covered in sections 4.3 and 4.4, elaborates on how the data tables and models are augmented to make them useable for this research project. First, the published data are modified to create a symmetric I-O transactions table, which is necessary for conducting I-O analysis (section 4.3). Second, the agricultural industry sector in the I-O models are disaggregated into subsectors, such that industry sectors for cervid and cattle farming are created (section 4.4). The third and final theme, covered in section 4.5, discusses additional data and model modifications that are necessary before the results can be calculated.

4.2 Data

The I-O models constructed in this thesis utilize information from Statistics Canada's 2006 provincial and national input-output tables. All values are in 2006 Canadian dollars, at modified basic price. The following subsections discuss the data in further detail.

4.2.1 National Accounting

National accounts are most often compiled by national statistical offices, with the express purpose of delivering a consistent and comprehensive catalogue of a country's economic performance. Canada's statistical agency, Statistics Canada, provides a variety of national accounts that enable government researchers and private stakeholders to examine economic phenomena from behind the lens of macroeconomic analysis, policy analysis, economic monitoring, and strategic decision making. These accounts are classified under the Canadian System of National Economic Accounts (CSNEA), and are published in the form of statistical statements. An important caveat should be stated at this time: despite the moniker *national* used in national accounting, Statistics Canada also publishes data at the provincial and territorial level.

The principal accounts released within the CSNEA are the income and expenditure accounts, the financial and wealth accounts, the balance of payment accounts, and the input-output accounts. These traditional accounting frameworks offer comprehensive and unique vantage points for analyzing the Canadian economy; albeit, they do fail to measure *all* forms of economic activity. For this reason, additional satellite accounts, productivity accounts, and government financial statistics are also tabulated and published by Statistics Canada (Statistics Canada, 2009e).

Harmonization of national accounts between countries is advocated in the United Nations System of National Accounts (UNSNA). First published in 1953, and later revised in 1968, 1993, and 2008, the document details the international guidelines for reporting national accounts that conform to "standards, internationally accepted concepts, definitions, and classifications" for the betterment of cross-country comparability (United Nations, 2008, chapter I, part C, section 1.33). The importance for universalizing national accounting procedures is highlighted in the UNSNA:

> The basic concepts and definitions of the [accounting] System depend upon economic reasoning and principles which should be universally valid and invariant to the particular economic circumstances in which they are applied. Similarly, the classifications and accounting rules are meant to be universally applicable. (United Nations, 1993, chapter I, part F, section 1.29)

This reasoning is further reinforced in chapter I, part F, section 1.30. of the UNSNA:

> The fact that data needs and priorities, and also statistical capabilities, may vary considerably between different kinds of countries does not justify the construction of different systems with different concepts, definitions, classifications or accounting rules. Some countries may be able, at least initially, to calculate only a small number of accounts and tables for the total economy with little or no disaggregation into sectors, but a reduced set of accounts or tables does not constitute an alternative system. (United Nations, 1993)

In an effort to encourage comparable statistical data between nations, the CSNEA adheres to the international guidelines delineated in the UNSNA (Statistics Canada, 2009e; Lal, 2002).

4.2.2 Input-Output Accounts

This research project utilizes data from the CSNEA's input-output accounts. These accounts provide a detailed depiction of the origins of supply and demand within Canada's national and provincial economies (Statistics Canada, 2009d). Canada's input-output accounts are published in a series of three data tables: the supply table, the use table, and the final demand table.

The three primary data tables are published at two levels: the Canada-wide national level, and the provincial and territorial regional level. Updated tables are published annually, however, due to the magnitude of information involved, yearly publications are lagged by 28 months from the reference year (Lal, 2000). The use of 2006 I-O tables in this research project is a consequence of the unavailability of more up-to-date published data. Even so, the lagged information provides sufficient information for a static-time depiction of economic activity.

The supply and use tables are commodity-by-industry tables, and the final demand table is a commodity-by-final-demand table. Due to the immense number of Canadian industries producing diverse arrays of goods and services, both industries and commodities are aggregated into groups for purposes of comprehensibility and organization. Similarly, final demand is agglomerated into categories.

National tables are available at four different data aggregation levels: worksheet (W), historical link (L), medium (M), and small (S). The worksheet level is the least aggregated, containing the greatest number of industry sectors, commodities, and final demand categories. The small level is the most aggregated, containing the fewest industry sectors, commodities, and final demand categories. The national tables are published at all four aggregation levels, while the provincial and territorial tables are only available at the highly aggregated S level of detail. The analytic I-O models constructed in this thesis utilize the W and S level national tables, and the S level tables for the province of Alberta.

The various data aggregation levels are determined by the North American Industry Classification System (NAICS). NAICS was collaboratively developed by Canada, the United States, and Mexico, with the purpose of harmonizing business activity classification systems within the three countries. NAICS codes can be as detailed as 6-digits, where, up to and including, the 5-digit level is congruent between countries as per the international NAICS agreement. The 6-digit level accommodates government and industry needs on a nation-specific basis, and, hence, is not uniform throughout the three countries. Table 4-1 outlines the hierarchical structure of the NAICS coding system.

Table 4-1: NAICS Hierarchical Structure

Number of Digits	Level of Detail
2	Industry Sector
3	Industry Subsector
4	Industry Group
5	Industry
6	Industry (U.S., Canada, and Mexico nation specific)

The S level of aggregation—the most aggregated—is represented by 2-digit NAICS codes. On the other end of the spectrum, the least aggregated and most detailed W level is represented by highly specialized 6-digit NAICS codes. In order to further illustrate this coding system, the agriculture industry is exemplified with associated NAICS codes in parenthesis: at the S level, all primary agricultural production is amalgamated into one category titled crop and animal production (1A); at the W level, this category is decomposed into four specialized constituent groups—greenhouse, nursery and floriculture production (111400), crop production (except greenhouse, nursery and floriculture production) (111A00), animal aquaculture (112500), and animal production (except animal aquaculture) (112A00) (Statistics Canada, 2009b). The input and output totals for the agriculture industry, irrespective of data aggregation level, are always equal.

The input-output accounts are first balanced and prepared at the highly disaggregated worksheet level (Statistics Canada, 2009a). The data are then aggregated to construct the

L, M, and S level tables, which contain increasingly fewer industry groups, commodity groups, and final demand categories (Statistics Canada, 2009a).

Table 4-2 details the four aggregation levels, along with their respective numbers of commodities, industry sectors, and final demand categories. For the sake of brevity and convention, the term commodities is used in lieu of goods, services, and primary factors; these commodities, listed along the rows of the use, supply, and final demand tables, consist of an assortment of goods, services, and primary factors. The commodity-by-industry tables, then, are *actually* goods-services-and-primary-factors-by-industry tables. The latter is too verbose however, hence the continued use of the abridged form.

Table 4-2: Data Aggregation Levels: Statistics Canada's Primary I-O Tables

Data Aggregation Level	No. of Goods, Services, and Primary Factors	No. of Industry Sectors	No. of Final Demand Categories
Worksheet (W)	713	285	168
Historical Link (L)	469	117	123
Medium (M)	111	62	39
Small (S)	59	25	18

Due to the inequality between the number of commodities and industry sectors, and the number of commodities and final demand categories, the supply, use, and final demand tables are effectively rectangular. At the W level, the supply and use tables are 713×285-dimensional. The final demand table at this level is 713×168-dimensional. At the S level of aggregation, the tables are respectively 59×25 and 59×18-dimensional. The entire array of industry groups, commodity groups, and final demand categories, for both the S and W aggregation levels, are presented in appendices 1 through 6.

The rationale for the rectangular commodity-by-industry I-O format is because real-world industry sectors—classified groupings of firms—consume and produce numerous inputs and outputs. All tables, irrespective of aggregation levels, contain more commodities than either industries or final demand categories. This asymmetric format allows industries to produce more than one commodity as output, and purchase more than one commodity as input. Subsections 4.2.2.1 through 4.2.2.3 discuss in detail the schematics of the rectangular supply, use, and final demand arrays.

4.2.2.1 Supply Table

The supply table, alternatively termed the output table, is a commodity-by-industry table that details the commodities produced as output by each industry sector. Each column vector lists the commodities manufactured by that unique industry sector; essentially, this table discloses *who* produces *what* within the region being examined. Certain statistical agencies publish a substitute *make* table in lieu of the supply table, which is simply an industry-by-commodity table fabricated by transposing the supply table.

In general, industrial output is confined to a small number of commodities, or, in certain cases, even a single commodity (Northwest Territories Bureau of Statistics, 2006). For example, the communication engineering construction industry's only output is railway and telecommunications construction, while the forestry and logging industry produces a few outputs, including: logs, pulpwood, and wood chips (Statistics Canada, 2009b).

Despite the communication engineering construction industry's single output, it is uncommon for highly specialized production sectors to produce only one commodity. But as a general rule, no more than a few commodities are produced by any industry sector. Chapter 11 of Eurostat (2008) substantiates this phenomenon:

> This matrix is strongly diagonal because the overwhelming proportion of the output of most industries consists of the own characteristic products (primary production). However, the matrix is not strictly diagonal, because many industries have a certain amount of secondary production. (p. 346)

The rectangular format permits single-output production, as well as any combination of primary and subsidiary production.

Figure 4-1: Supply Table

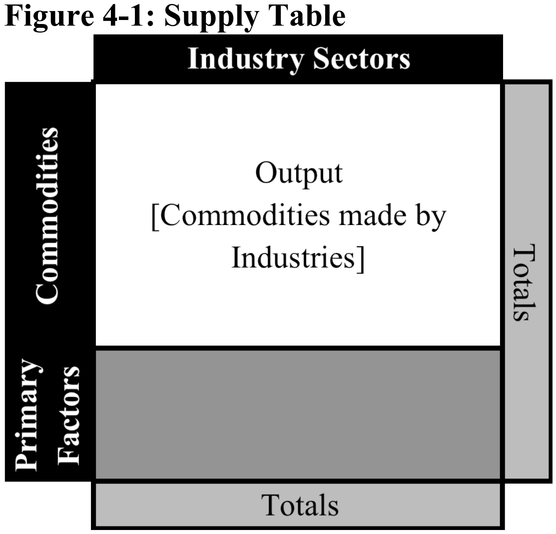


Figure 4-1 offers a diagrammatic representation of the supply table. The majority of row vectors enumerate commodities: the goods and services produced throughout the economy. The final rows are reserved for value-adding primary factors. However, the supply table's primary factors are all zero, as no industry produces any primary factor as output—for example, wages, salaries, or operating income. With *n* industry sectors and *k* primary factors, the $k \times n$-dimensional submatrix's elements consist entirely of zeros.

4.2.2.2 Use Table

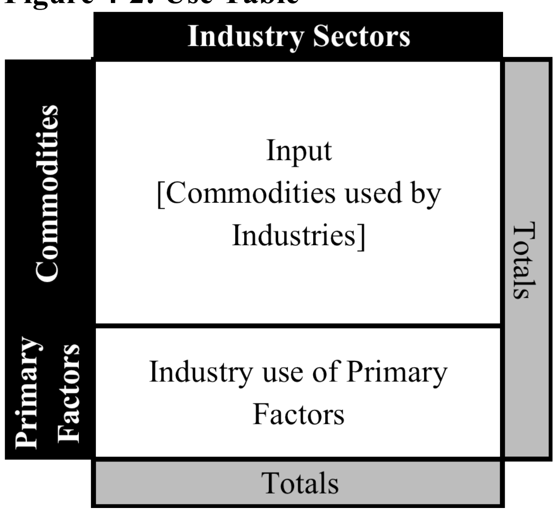
The use table is also a commodity-by-industry table that specifies the commodities used as inputs by industries. The literature alternatively denominates this table the input table, the intermediate use table, and the absorption matrix. This table reveals *who* purchases *what* in the national or regional economy. The commodities listed along the rows and the industry sectors listed along the columns are uniform with the supply table.

Despite being structurally identical to the supply table, the use table differs significantly: each column vector specifies which commodities that industry group uses as inputs. These inputs, or factor inputs, are used by industries to generate output—the same output that is revealed in the corresponding supply table.

In further contrast to the supply table, the use table's columns contain many entries. That is, each industry group uses numerous commodities as factor inputs when creating output. Highlighting the communication engineering construction industry reveals that 91 various commodities are utilized to produce its only output: railway and telecommunications construction (Statistics Canada, 2009b).

Another important distinction with the use table is its employment of primary factors as inputs. Figure 4-2 depicts a representation of the use table. Note the bottommost rows are reserved for primary factors. If there are k primary factors, the bottom of the use table will be a $k \times n$-dimensional submatrix, with n industry sectors along the columns. This submatrix of primary factors, shown as the lower white rectangle in figure 4-2, is equivocal with the value-added quadrant of the symmetric transactions table illustrated in figure 3-3, and discussed in section 3.3.

Figure 4-2: Use Table



Production processes necessitate the use of primary factors to generate output, hence their inclusion in the use table. These primary inputs are reported by businesses on the expense side of their income statements (Statistics Canada, 2009a). By again exemplifying the communication engineering construction industry, one observes that its output is only producible with the use of labour, which is paid out as wages and salaries (Statistics Canada, 2009b). A final distinctive characteristic of the use table is that GDP can be calculated from the $k \times n$-dimensional primary factors matrix. This characteristic is extrapolated upon in section 4.2.2.9.

4.2.2.3 Final Demand Table

The third and final primary data table of Statistic Canada's input-output accounts is the final demand table. This is a commodity-by-final-demand matrix indicating what commodities are purchased by which final demand sectors. Final demand sectors only purchase goods and services for final consumption. Numerous final demand categories are listed along the columns, which vary according to data aggregation level. Regardless of the level of detail being examined, the parent components are generally consumption, investments, government purchases, and exports, as demonstrated in equation (3.4). However, Statistics Canada's input-output accounts also contain an additional broad category of final demand: additions to or withdrawals from inventory (Statistics Canada, 2009a).

Figure 4-3: Final Demand Table

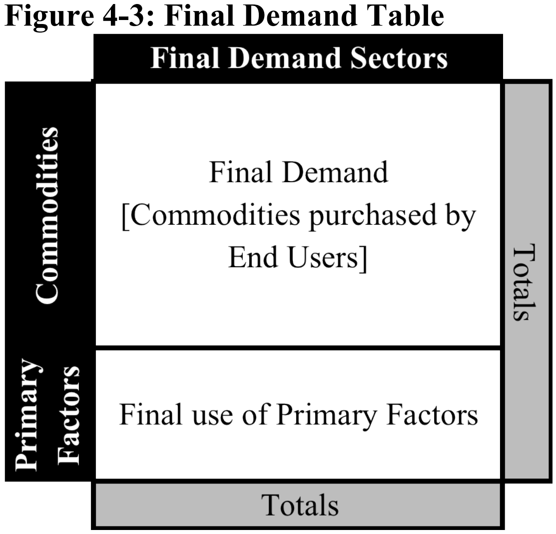


Figure 4-3 depicts the final demand table. The primary factors are all equal to zero, with the exception of indirect taxes on products (Statistics Canada, 2009a). This is because, unlike business sectors, final demanders are not consuming any value-added components such as wages and salaries, but, like business sectors, they do pay indirect taxes on products. The commodities listed along the rows are identical to the ones listed along the rows of both the supply and use tables. Thus, all three tables have an equivalent vertical dimensionality.

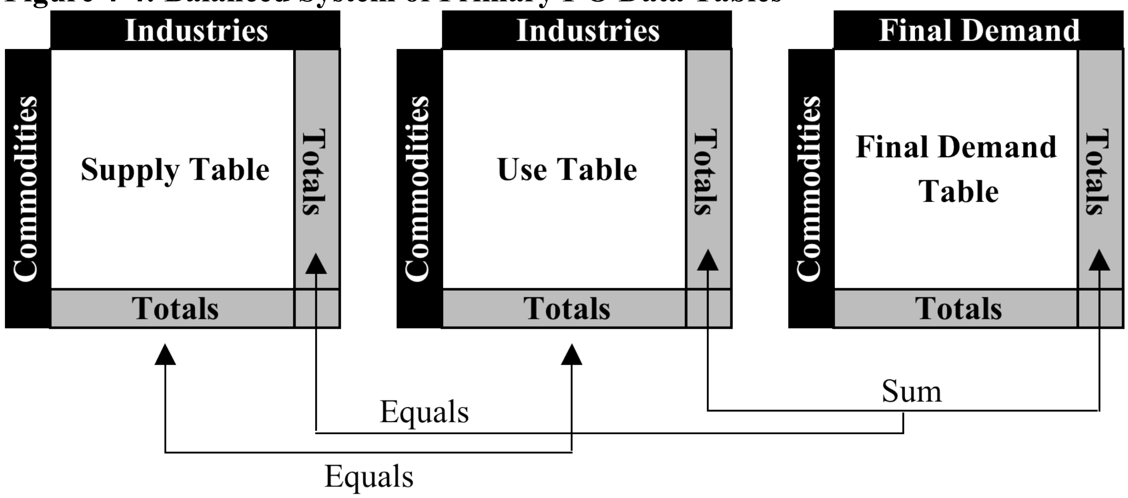
4.2.2.4 Industry Versus Commodity Accounts

Because the input-output accounts detail the interrelationships between both industry accounts and commodity accounts, the tables can be examined either along columns, or along rows. If a specific commodity group, rather than an industry sector, is of chief interest, the three tables can be examined from behind the lens of commodity use and production. Each row vector in the supply table details which industries are producing that commodity. In the use table, the row vectors reveal the industries that consume each commodity. Similarly, the final demand table's row vectors specify how each commodity is consumed as final demand.

4.2.2.5 Balancing the System

The double-entry bookkeeping system adhered to by statistical compilers ensures that the three input-output accounts are balanced. The "totals" row vector in figure 4-1, which sums down columns, is always equal to the "totals" row vector in figure 4-2: total industry input must always equal total industry output. Alternatively, summing across rows to attain commodity totals also balances: the "totals" column in the supply table (figure 4-1) must equal the sum of "totals" columns in the use (figure 4-2) *and* final demand tables (figure 4-3). The sum of total commodities for intermediate and final uses must always equal the total commodities produced. The system is balanced if total inputs and outputs of industries are equal, and total inputs and outputs of commodities are equal (Eurostat, 2008). Figure 4-4 illustrates a balanced system of primary input-output tables.

Figure 4-4: Balanced System of Primary I-O Data Tables



4.2.2.6 Primary Factors

The primary factors, also termed primary inputs and primary commodities, are uniform across all tables, regardless of aggregation level. Even though a submatrix of primary factors is included on all three tables, the supply table's primary factors contain all zero entries. Similarly, the final demand table's primary factors are all zero, with the exception of indirect taxes on products. Again, this is because primary inputs are not produced as output by industry, nor do final demanders purchase them.

The number of primary factors in I-O tables varies from country to country according to domestic statistical procedures. Statistics Canada's I-O accounts include eight primary commodities on all tables. If the supply and use tables are $m \times n$-dimensional, with m rows of commodities and n columns of industry sectors, and the final demand table is $m \times p$-dimensional, with p columns of final demand categories, the final eight of m commodities on all tables are always primary factors; that is, the m–7th to m^{th} commodities are primary commodities. These eight primary inputs are listed in table 4-3.

Table 4-3: List of Primary Factors

Number	Primary Factor
1	Indirect taxes on products
2	Subsidies on products (–)
3	Subsidies on production (–)
4	Indirect taxes on production
5	Wages and salaries
6	Supplementary labour income
7	Mixed income
8	Other operating surplus

Subsidies on both products and production are negative quantities. They effectively reduce the total input cost for the firms receiving them, and thus lower the market price of the output generated by that industry sector (Statistics Canada, 2009a). Hence, where applicable, they are subtracted from the industry sector's input cost. Indirect taxes, on the other hand, are a cost to firms, and are reflected in the market price of the goods or services it produces (Statistics Canada, 2009a).

The returns to the factors of production are calculated by summing numbers five through eight: wages and salaries, supplementary labour income, mixed income, and other operating surplus. Summing wages and salaries and supplementary labour income attains the costs of labour. Finally, the capital inputs are determined by summing mixed income and other operating surplus. Other operating surplus is the income, or loss, that is residual after accounting for the cost of all intermediate inputs and other primary inputs. "This ensures that the subtotal of inputs for a given industry is equal to its 'outputs' and an accounting identity is maintained between inputs and outputs of industries" (Statistics Canada, 2009a, p. 10).

4.2.2.7 Secondary Production

To reiterate, the rectangular format of the supply table enables industries to produce more than one commodity as output. This format permits the existence of non-homogeneous production units that can produce secondary and ancillary output in addition to their characteristic primary output. An ancillary activity is a "supporting activity undertaken within an enterprise in order to create the conditions within which the principle or secondary activities can be carried out" (United Nations, 1993, chapter V, part B, section 5.9). These activities include warehousing, communications, transportation of goods, and servicing of machinery and equipment (United Nations, 1993).

Secondary production is the activity of generating output in addition to the industry's principle activity. A distinguishing characteristic of secondary output is that its value added is always less than primary output's value added (United Nations, 1993). There are three types of secondary products: subsidiary products, byproducts, and joint products. Subsidiary products are those that are technologically unrelated to the principle product (Eurostat, 2008). Byproducts are produced simultaneously with primary output, but are regarded as secondary to that product (Eurostat, 2008). Joint products are produced simultaneously with the principle product, but cannot be entirely regarded as secondary—for example, beef and hide (Eurostat, 2008).

Byproducts can create complications in the accounting system's network of supply and demand relationships (Eurostat, 2008). For example, if firm A's secondary output is a byproduct, and that secondary output is identical to firm B's primary output, additional demand for that output should induce firm B to increase production, rather than firm A. The distortionary effects of byproducts will consequently induce both firms to increase output. This issue has been extensively discussed in the literature; however, no satisfactory solution has been found (Eurostat, 2008). Further reading on byproducts can be found in chapter 11 of Eurostat (2008). Methods for treating byproducts in certain situations can also be found in Stone (1984).

4.2.2.8 Modified Basic Price

A firm's factor inputs and outputs are often conceived of as tangible commodities; for example, an automotive firm uses steel as an input to produce automobiles. This leaves little room for cross sector juxtaposition. From an analyst's perspective, a more practical approach is to quantify all inputs and outputs in terms of their dollar values. Thus, for purposes of cross-industry and cross-commodity comprehensibility, the primary input-output tables are all tabulated using a common monetary numeraire.

In accordance with the conventions advocated by the United Nations, Canada's I-O data is published at basic price (Statistics Canada, 2009a). Basic Price is the internationally preferred method for valuing factor input costs in industrial production (Statistics Canada, 2009a). The United Nations (1993) System of National Accounts defines basic price as follows:

> The basic price is the amount receivable by the producer from the purchaser for a unit of a good or service produced as output minus any tax payable, and plus any subsidy receivable, on that unit as a consequence of its production or sale. It excludes any transport charges invoiced separately by the producer[.] (chapter III, part F, section 3.82)

Basic price is equivalent with producers' price, which is the sales price at the factory gate where the good or service is produced, and which includes any subsidy received by the producer (Northwest Territories Bureau of Statistics, 2006). Basic price does not include any wholesale, retail, or transportation margins, nor does it include taxation.

Figure 4-5: Commodity Price Outline

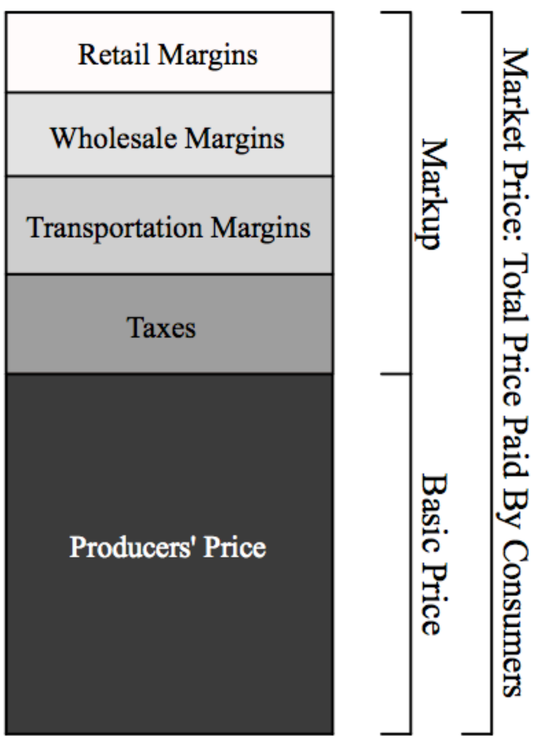


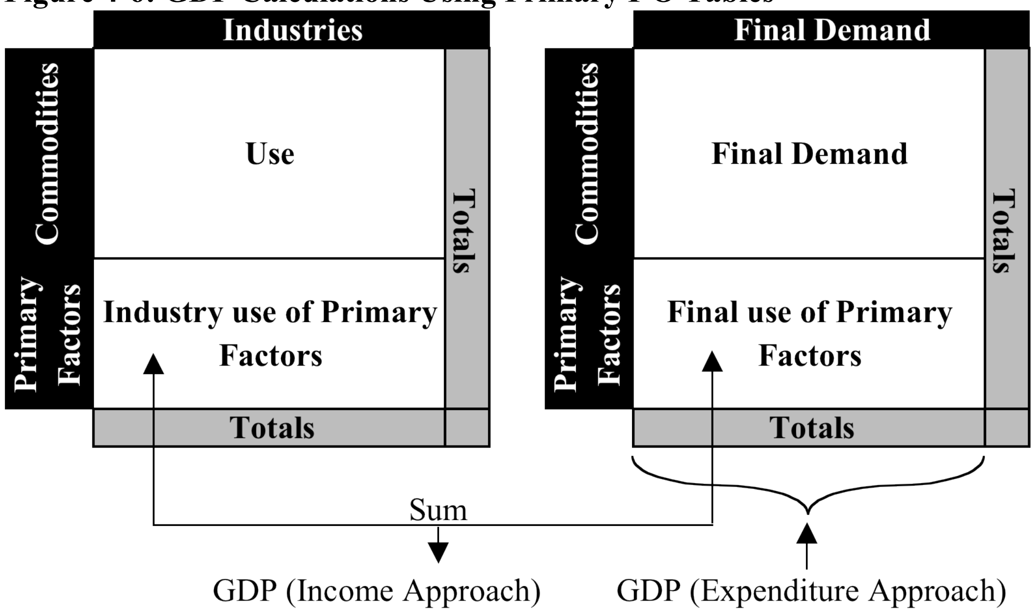
Figure 4-5 demonstrates how consecutive gradations of a commodity's movement through the economy add to its price. Between the price that producers charge upon manufacturing, and the market price consumers pay, there are retail margins, wholesale margins, transportation margins, and taxes that successively add to a commodity's price (Northwest Territories Bureau of Statistics, 2006). Statistics Canada's I-O accounts are cited as being at modified basic price. Despite this variation in terminology, it is congruent with the UNSNA criteria, and equivalent with producers' price.

4.2.2.9 Valuation of Gross Domestic Product

The primary factors submatrix in the use table (figure 4-2) can be used to calculate industry's share of GDP at either basic price or market price. To calculate an industry's GDP at market price, sum all eight primary factors for the industry sector in question. To calculate an industry's GDP at basic price, sum all primary factors except indirect taxes on products and subsidies on products. Indirect taxes on products are a cost to industries, and elevate the market price of output. Subsidies on products reduce input costs, and thus lower the market price of output. For these reasons, taxes and subsidies on products are excluded from basic price GDP.

Section 3.3.1 and equation (3.18) demonstrate how GDP is calculated from the I-O transactions table using either the expenditure or income approach, and how both approaches yield equivalent quantities. The final demand and use tables can also be used to calculate GDP using both approaches. GDP by means of the expenditure approach is simply the sum of all elements in the final demand table. GDP by means of the income approach is the sum of all elements in the use and final demand tables' primary factors submatrices. Figure 4-6 illustrates how both approaches are executed.

Figure 4-6: GDP Calculations Using Primary I-O Tables



4.3 Deriving a Symmetric Input-Output Transactions Table

For the analyst solely interested in industries' use and production of commodities, the aforementioned commodity-by-industry tables are adequate. If the analyst's intention is to develop analytic I-O models, the rectangular arrays are insufficient. Symmetric, or square, industry-by-industry tables are requisite for developing the analytic I-O models detailed in chapter 3. Shown as quadrant I of figure 3-3, this symmetric interindustry transactions component of the transactions table is seldom provided by statistical agencies. It can, however, be constructed by manipulating data contained within the three rectangular primary input-output data tables: the supply, use, and final demand tables.

The compilation and publication of I-O tables varies in format across countries. Survey results revealed that approximately half of all countries that publish I-O tables compile symmetric ones, while the other half compile tables commensurate with the approach developed under the UNSNA (Guo, Lawson, & Planting, 2002). The symmetric tables are referred to as the Leontief model, where each industry produces one primary commodity, and each commodity is produced by only one industry (Guo, Lawson, & Planting, 2002). The alternative UNSNA data compilation approach expands upon the Leontief model, allowing industries to produce multiple secondary outputs (Guo, Lawson, & Planting, 2002; United Nations, 1993; United Nations, 1968).

The UNSNA replaces the Leontief model with the make and use tables, or supply and use tables in certain countries. Again, the make table is simply a transposed supply table. The make-use format was adopted because it accommodates the growing diversity of industrial production by allowing industries to produce more than one output. By relaxing the assumption of bilateral relationships between industries and commodities, the UNSNA method enables statisticians and national accountants to more easily compile I-O accounts using industrial production data. This format is consistent with how industrial output is tabulated: "as the sum of secondary and primary product outputs of all establishments in the industry" (Guo, Lawson, & Planting, 2002, p. 3).

The inherent asymmetry embedded within the supply and use tables, caused by secondary production, has given rise to various discussions regarding the best approach to transform the make-use system into symmetric tables (Guo, Lawson, & Planting, 2002). Despite the make-use format's provision of added detail in industrial production and consumption, the symmetric Leontief format allows for further economic analysis. As demonstrated in chapter 3, the transactions table forms the foundation that all I-O analysis hinges upon.

4.3.1 The Four Basic Transformation Methods

Eurostat (2008) and United Nations (1968) both highlight four standard methods to derive symmetric I-O tables from supply and use tables. There are two types of square tables producible from these four methods: product-by-product tables and industry-by-industry tables (Eurostat, 2008; Guo, Lawson, & Planting, 2002; United Nations, 1993; United Nations, 1968). Product-by-product tables describe the intermediate consumption of products used in the manufacturing of other products. Industry-by-industry tables detail the intermediate consumption of industries' homogeneous output by other industry sectors, for use in the latter's own output.

There have been ongoing discussions in the literature regarding model superiority. Despite extensive research, debate, and discussion, no definitive consensus has emerged. On one hand, industry-by-industry tables are closer to statistical sources and real observations (Eurostat, 2008). On the other hand, product-by-product tables are theorized to be more homogeneous in their description of industry transactions than industry-by-industry tables, since the latter can have commodities that are characteristic in multiple industries (Eurostat, 2008).

It is believed that product-by-product tables are better suited for productivity analysis, or the analysis of new technologies in the economy, while industry-by-industry tables are thought to better serve purposes of economic impact analysis (Eurostat, 2008). The analyst's objectives will ultimately determine which table is selected.

The main distinction between the two symmetric table types lies in their underlying assumptions. Product-by-product I-O tables are derived under technology assumptions, whereas industry-by-industry I-O tables hinge on fixed sales structure assumptions (Eurostat, 2008; Guo, Lawson, & Planting, 2002). Technology assumptions consign production processes to have fixed input structures. Fixed sales structure assumptions entail that commodities sold to intermediate and final users have a fixed output structure. Each assumption is further subdivided by product and industry. Table 4-4 follows from Eurostat (2008), and classifies the four transformation methods according to assumptions and table type.

Table 4-4: Basic Transformation Methods

		Product-by-Product I-O Tables	Industry-by-Industry I-O Tables
Technology	Product Technology	Method A	
	Industry Technology	Method B	
Sales Structure	Fixed Industry Sales Structure		Method C
	Fixed Product Sales Structure		Method D

1. Method A: The product technology assumption results in a product-by-product I-O table, where each product is produced in a unique fashion, irrespective of the industry that produces it. Negative values are a potential consequence of this methodology.
2. Method B: The industry technology assumption results in a product-by-product I-O table, where each industry has a unique method of production, irrespective of its product mix. This methodology yields no negative values.
3. Method C: The fixed industry sales structure assumption results in an industry-by-industry I-O table, where each industry has a unique sales structure, irrespective of its product mix. Negative values are a potential consequence of this methodology.
4. Method D: The fixed product sales structure assumption results in an industry-by-industry I-O table, where each product has a unique sales structure, irrespective of the industry that produces it. This methodology yields no negative values.

This research project requires a symmetric industry-by-industry I-O table, such that economic impact analyses can be performed. Method D best serves the purpose of this thesis, and will be elaborated upon. Methods A through C can be further investigated in Eurostat (2008). Two alternative mathematical transformation methods—the hybrid technology assumption and the Almon procedure—are also expanded upon in Eurostat (2008).

The fixed product sales structure assumption, or method D, is widely used by statistical offices (Eurostat, 2008). The moniker "sales structure" refers to the proportions of commodity output that are sold to intermediate and final users (Eurostat, 2008). A fixed product sales structure in a two-industry-sector economy, for example, would necessitate that manufacturing products produced by the agriculture industry be sold in the same proportions to industries for intermediate consumption and final demanders for final consumption, as the manufacturing products produced by the manufacturing industry.

This method does not require any procedures to adjust for negative values. Another advantage of this method is that symmetric I-O tables can be derived directly from rectangular supply and use tables; method A, for example, requires all rectangular tables be made square by aggregation prior to symmetric I-O table construction (Eurostat, 2008). As a benefit, this method does not require the analyst to make formal distinctions between primary and secondary production, thereby reducing the aggregation loss of information (Eurostat, 2008).

4.3.2 Mathematical Transformation Algorithm

The supply table from section 4.2.2.1 is broken down into its constituent arrays below. The same matrix notation rules from chapter 3 apply here, where matrices are written in capital letters, column vectors in lower case letters, and row vectors as transposed column vectors. The primary factors submatrix in the supply table is a zero matrix, and is deliberately left vacant.

Table 4-5: Supply Table Framework

		Industries 1…n	Supply
Commodities	1 ⋮ m	S	q
Primary Factors	1 ⋮ k		
Output		g^T	

Similarly, table 4-6 outlines the various arrays of the use and final demand frameworks (see sections 4.2.2.2 and 4.2.2.3).

Table 4-6: Use and Final Demand Tables Framework

		Industries 1…n	Final Demand 1…p	Use
Commodities	1 ⋮ m	U	F	q
Primary Factors	1 ⋮ k	V		b
Output		g^T	e^T	

Transposing the commodity-by-industry supply matrix (S) produces the industry-by-commodity make matrix (M):

$$[S_{ij}]^T = [M_{ij}] \tag{4.1}$$

Again, because industries' production of commodities overwhelmingly encompasses characteristic primary products, the matrix is *strongly* diagonal. However, due to the production of secondary products, however few, and because the matrix is rectangular, it is not *strictly* diagonal. Table 4-7 integrates the above supply, use, and final demand frameworks into a comprehensive schematic.

Table 4-7: Integrated Accounting Framework of Primary I-O Tables

		Commodities	Industries	Final Demand	Total
		1…m	1…n	1…p	
Commodities	1 ⋮ m		U	F	q
Industries	1 ⋮ n	M			g
Primary Factors	1 ⋮ k		V		b
Total		q^T	g^T	e^T	

Definition of Matrices and Vectors:

M	Matrix of industries' output of commodities.
U	Matrix of industries' use, or input, of commodities.
V	Matrix of industries' use of primary factors.
F	Matrix of final demand categories' use of commodities.
q	Column vector of total commodity outputs.
g	Column vector of total industry outputs.
b	Column vector of total primary inputs.

q^T Row vector of total commodity outputs.

g^T Row vector of total industry outputs.

e^T Row vector of total final demand

Before a square industry-by-industry array can be constructed, a transformation matrix must be created (Eurostat, 2008). Under the fixed product sales structure assumption, the requisite transformation matrix is called the domestic market shares matrix, *D*. The market shares matrix is calculated by dividing each element of *M* by its respective commodity, or column, total (Fullerton, 1996; Lal, 1982). This industry-output-proportion matrix indicates the contribution of each industry to the output of a commodity (Guo, Lawson, & Planting, 2002). This market share matrix of commodity output proportions embodies the assumption of fixed product sales structure.

Before *D* can be created, the vector of total commodity outputs, *q*, must first be transformed into a diagonal matrix. This vector of length *m* is transformed into an $m \times m$-dimensional diagonal matrix as follows:

$$diag(q_1, \ldots, q_m) = diag(q) = \begin{pmatrix} q_{11} & 0 & \cdots & 0 \\ 0 & q_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & q_{mm} \end{pmatrix} \quad (4.2)$$

Diagonal matrices are square, with all entries outside the main diagonal equaling zero. These matrices are invertible, provided that all diagonal entries are nonzero. Computing the inverse using the Gaussian elimination algorithm yields:

$$(diag(q))^{-1} = \begin{pmatrix} 1/q_{11} & 0 & \cdots & 0 \\ 0 & 1/q_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1/q_{mm} \end{pmatrix} \tag{4.3}$$

The domestic market shares matrix is calculated by postmultiplying the make matrix with the inverted diagonal matrix of vector *q*:

$$D = M((diag(q))^{-1}) \tag{4.4}$$

Postmultiplication of any matrix by a diagonal matrix rescales the initial matrix's column entries by the corresponding elements of the diagonal matrix. Premultiplication by a diagonal matrix rescales the initial matrix's row entries by the corresponding elements of the diagonal matrix. Because of matrix multiplication's noncommutative quality, AB and BA need not produce equal matrices. In general, it is said that $AB \neq BA$, however, in some specific cases they can commute.

Two additional matrix operations remain before the symmetric I-O table can be constructed: 1) the matrix of industries' use of commodities must be premultiplied by the domestic market shares matrix

$$T_{n\times n} = D_{n\times m} U_{m\times n} \tag{4.5}$$

and 2) the domestic market shares matrix must premultiply the matrix of final demand categories' use of commodities

$$Y_{n\times p} = D_{n\times m} F_{m\times p} \tag{4.6}$$

The subscripts in (4.5) and (4.6) indicate the various matrices' dimensions. For example, matrix products T and Y are $n \times n$ *and* $n \times p$-dimensional, respectively. Table 4-8 places these newly constructed arrays within the symmetric industry-by-industry input-output framework. By inspection, one can see that this new framework is effectively the transactions table of figure 3-3.

Table 4-8: Symmetric Industry-by-Industry I-O Table

		Industries	Final Demand	Output
		1…n	1…p	
Industries	1 ⋮ n	T	Y	g
Primary Factors	1 ⋮ k	V		b
Input		g^T	e^T	

Definition of Matrices:

T Industry-by-industry square matrix of intermediate transactions.

Y Industry-by-final-demand matrix of final transactions.

The primary factors array, V, is identical to the array in table 4-6. This submatrix is simply duplicated into table 4-8 without any mathematical manipulation. The new framework consists of three submatrices: 1) an industry-by-industry matrix, 2) an industry-by-final-demand matrix, and 3) a primary-factors-by-industry matrix.

Transforming the three rectangular primary arrays into a symmetric industry-by-industry table enables construction of the analytic I-O model outlined in chapter 3. However, a consequence of this necessary procedure is a loss of secondary and ancillary production detail. The symmetric table reduces all industrial activity into homogenous production units, where each industry yields only a single homogenous output. This type of production is among the assumptions underlying I-O analysis (section 3.2.3), and is regarded as a limitation of the model.

4.4 Industry Sector Disaggregation

Statistics Canada's I-O accounts are the most detailed source of interindustry flow data in Canada. Even so, these data tables may not provide adequate detail for certain analyses. This research project aims to determine the multiplier effects resultant from shocks to both the farmed cervid and cattle sectors, but the I-O data tables—even at the 285-industry worksheet level, do not include industry groups corresponding with these sectors. For this reason, the broader industry group containing these two sectors must be disaggregated to reflect both the farmed cervid and cattle industries.

Table 4-9 details how industry groups are broken down into additional components. At the S level of detail, the broad industry group "crop and animal production" is decomposed into "cervid production," "cattle production," and "remaining crop and animal production." At the W level of detail, the industry group "animal production (except animal aquaculture)" is decomposed into "cervid production," "cattle production," and "remaining animal production (except animal aquaculture)." At the S level of detail, one agricultural industry group is effectively transformed into three groups, and at the W level, four agricultural industry groups are decomposed into six groups.

Table 4-9: Industry Disaggregation

<table>
<tr><th>NAICS Code</th><th>S-Level Industry Group</th><th>W-Level Industry Groups</th><th>Modified Industry Groups</th></tr>
<tr><td rowspan="3">1A</td><td rowspan="3">Crop and Animal Production</td><td rowspan="3"></td><td>Cervid Production</td></tr>
<tr><td>Cattle Production</td></tr>
<tr><td>Remaining Crop and Animal Production</td></tr>
<tr><td>111400</td><td></td><td>Greenhouse, Nursery and Floriculture Production</td><td></td></tr>
<tr><td>111A00</td><td></td><td>Crop Production (Except Greenhouse, Nursery and Floriculture Production)</td><td></td></tr>
<tr><td>112500</td><td></td><td>Animal Aquaculture</td><td></td></tr>
<tr><td rowspan="3">112A00</td><td rowspan="3"></td><td rowspan="3">Animal Production (Except Animal Aquaculture)</td><td>Cervid Production</td></tr>
<tr><td>Cattle Production</td></tr>
<tr><td>Remaining Animal Production (Except Animal Aquaculture)</td></tr>
</table>

Disaggregation procedures can be complex and, while numerous approaches exist, they vary considerably from one another. When selecting methodologies, researchers face a tradeoff between accuracy and cost, where the most detailed and accurate disaggregations require ample expenditures, resources, and time. At one extreme, industry data is collected and compiled to amend the existing make-use framework (Lindberg & Hansson, 2009). At the other end of the spectrum, approximations are made that deliver fast and expedient results, but sacrifice the richness of data quality. For purposes of efficiency, this research project opts for the latter route, and the purity of data is relinquished for a labour, time, and cost saving approach.

The method utilized in this thesis disaggregates the impact matrix by duplicating and rescaling rows and columns of industry groups. For example, with a three sector impact matrix

$$(I - A)^{-1} = \begin{pmatrix} \delta_{11} & \delta_{12} & \delta_{13} \\ \delta_{21} & \delta_{22} & \delta_{23} \\ \delta_{31} & \delta_{32} & \delta_{33} \end{pmatrix} \tag{4.7}$$

if sector 1 is to be disaggregated into two subsectors, with known weights w_1 and w_2, and where $w_1 + w_2 = 1$, the new expanded impact matrix becomes:

$$\begin{pmatrix} w_1 w_1(\delta_{11} - 1) + 1 & w_1 w_2(\delta_{11} - 1) & w_1\delta_{12} & w_1\delta_{13} \\ w_1 w_2(\delta_{11} - 1) & w_2 w_2(\delta_{11} - 1) + 1 & w_2\delta_{12} & w_2\delta_{13} \\ w_1\delta_{21} & w_2\delta_{21} & \delta_{22} & \delta_{23} \\ w_1\delta_{31} & w_2\delta_{31} & \delta_{32} & \delta_{33} \end{pmatrix} \tag{4.8}$$

Before the array is rescaled, all diagonal elements comprise of unity in addition to the partial output multiplier value. To reiterate, the value of unity corresponds with the direct effect of a dollar's worth of additional final demand for that sector. In order to not confound the procedure, the direct effect is first subtracted from δ_{11}. This ensures that only the partial output multiplier is decomposed according to w_1 and w_2. Moreover, multiplier (δ_{11} – 1) fills all four elements in the top left corner of matrix (4.8). It is rescaled appropriately to ensure that the sum of all four elements equals the original δ_{11}, and that no multiplier effect is double counted. Once sector 1 has been duplicated and rescaled, ones are added back onto the two modified diagonal elements. This approach is a loose approximation of Wolsky's (1984) approach, except performed with minimal data.

The total output multiplier effects less unity—the column sums less the direct effect—of both new subsectors of industry 1 will sum up to equal the total output multiplier effect less unity of the original industry 1 in (4.7). Successful disaggregation requires that the expanded impact matrix does not overstate or understate the economic effects of an output shock. Impact matrices of any size can have their industry sectors disaggregated. Furthermore, one industry sector can be disaggregated into multiple subsectors using this approach. The analyst simply requires the necessary weights to perform this manipulation.

The I-O models constructed in this thesis disaggregate crop and animal production, and animal production (except animal aquaculture) to yield subsectors for cervid and cattle industries. The rescaling weights used to determine these new industry sectors are derived from Alberta Agriculture and Rural Development's farm cash receipt data, as well as from the 2006 Census of Agriculture (Statistics Canada, 2007; Agriculture and Rural Development, 2006). Farm cash receipts are the sum of revenues from agricultural commodity sales, government program payments, and payments from agricultural insurance programs.

Because of the difficulty obtaining data for small-scale alternative livestock production, elk and deer production data was used as proxy for cervid production; the production of elk and deer constitutes the largest share of cervid production, and, hence, is a reasonable substitute. In the Alberta models, the ratio of total farm cash receipts of elk and deer farms to total farm cash receipts is calculated as the cervid sector weight. Similarly, the ratio of total farm cash receipts of cattle production—cattle and calves, as well as dairy production—relative to total farm cash receipts is computed for the cattle sector. The remaining crop and animal production sector weight is calculated as one subtract the cervid and cattle sector weights, ensuring that $w_1 + w_2 + w_3 = 1$.

In the Canada models, elk and deer cash receipt data was not available, so per-head elk and deer receipts were calculated from the Alberta data, and then multiplied with the total number of elk and deer in Canada. This estimated value of national farm cash receipts for elk and deer farms was divided by the value of Canada's total livestock farm cash receipt to obtain the cervid sector weight. Similarly, the cattle proxy was obtained by dividing cattle, calves, and dairy production cash receipts by total livestock farm cash receipts. The remaining animal production (except animal aquaculture) sector weight is simply one subtract the cervid and cattle sector weights, so that $w_1 + w_2 + w_3 = 1$. The scaling weights, or proxies, used for disaggregation are presented in appendices 7 through 9.

4.5 Additional Data & Model Modifications

4.5.1 Imports & Other Operating Surplus

Two basic data manipulations must be undertaken in order for the I-O transactions table to become balanced. Statistics Canada's I-O tables have imports entered as nonpositive column vectors in the final demand table. This format allows for easy tabulation of net exports by a mere examination of the final demand table. However, in the process of constructing a transactions matrix, the imports vectors must be multiplied by negative one, then transposed, then added to the primary factors quadrant.

At this point, total output and total input are approaching equivalency, but, because of certain suppressions of confidential data, they differ slightly (Statistics Canada, 2009a). In order to ensure that the table is balanced, other operating surplus must be tweaked so that total input is precisely equivalent with total output. Other operating surplus is located in the primary factors quadrant (table 4-3) and, as discussed, is the income, or loss, that is residual after accounting for the cost of all intermediate inputs and primary inputs. It is thus appropriate to alter this residual—usually by very small additions or subtractions—to effect equivalency between total outputs and total inputs.

4.5.2 Income Multipliers

Again revisiting table 4-3, we see the list of primary commodities that are included in all primary I-O data tables, and which comprise the value-added components in all transactions tables and technical coefficients matrices. In I-O analysis, these primary inputs alone are of little interest, however, recalling section 3.4.4.4, income multipliers can be generated from them. By summing certain primary inputs, relevant income categories are created, namely: industry GDP at basic price, labour income, returns to capital, and taxes collected by government.

Industry's GDP at basic price is the sum of all primary factors except indirect taxes on products and subsidies on products. Labour income is the sum of wages and salaries and supplementary labour income. Returns to capital is the sum of mixed income and other operating surplus. Finally, taxes collected by government is the sum of indirect taxes on products and other indirect taxes on production. Income multipliers for all four categories are included in the results chapter for each type of industry shock under the single-sector Alberta and Canada models.

4.5.3 Closed Model

Section 3.4.5 outlines the theoretical underpinnings for closing I-O models in respect to households. In order to actually perform this operation with Statistics Canada's data tables, the following procedures must be conducted. At the S aggregation level, all four personal expenditures final demand categories are summed and relocated into the industry transactions portion of the transactions table (see appendix 3). Wages and salaries and supplementary labour income are also summed and relocated into the industry transactions array as a new industry sales row vector.

The new column and new row effectively become the endogenized household sector. At the W level of detail, an identical process is conducted, however, instead of four personal expenditures final demand categories, there are fifty (see appendix 6). The standard methods are applied from this point onward, with the model now able to yield *type II* multipliers.

4.5.4 Two-Region Interregional Model

Section 3.4.6 details the foundations and schematics of an interregional I-O system. This thesis constructs a two-region IRIO model, where region one is Alberta, and region two is the rest of Canada. The rest of Canada corresponds with the remaining twelve provinces and territories—or, alternatively, all of Canada less Alberta. This model utilizes the S aggregation level data tables for Alberta and Canada.

First, a transactions table was constructed for Canada at the S level of detail. It was then transformed into a transactions table representing the rest of Canada by calculating the difference between the elements of Canada's transactions table and elements of Alberta's transaction table. Once this table was obtained, a technical coefficients matrix for the rest of Canada was constructed.

Equation (4.9) illustrates the interactions between regions.

$$A = \left(\begin{array}{c|c} A^{LL} & A^{LR} \\ \hline A^{RL} & A^{RR} \end{array} \right) \tag{4.9}$$

Superscript *L* denotes Alberta, and superscript *R* denotes the rest of Canada. Matrices A^{LL} and A^{RR} are the technical coefficients matrices for Alberta and the rest of Canada, respectively. In these two arrays, interindustry trade takes place within each region's boundaries. Matrix A^{LR} details the industrial trade flows from Alberta to the rest of Canada, and A^{RL} denotes the trade flows from the rest of Canada into Alberta.

Interprovincial exports divided by total output was calculated for each industry in the Alberta transactions table. This new column vector was then constructed into a diagonal matrix, which premultiplied the Alberta technical coefficients matrix, A^{LL}. The new matrix, A^{LR}, is the trade flows from Alberta into the rest of Canada. For the rest of Canada, the transposed interprovincial imports row vector in the Alberta transactions table was used as substitute for exports; the rest of Canada's exports into Alberta are equal to Alberta's interprovincial imports, hence it was an appropriate substitute. Performing similar calculations on the rest of Canada's technical coefficients matrix yielded A^{RL}: the trade flows from the rest of Canada into Alberta. The standard procedures and manipulations are then carried out to construct the IRIO model. The results chapter includes both an open IRIO model and closed IRIO model.

4.6 Chapter Summary

The layouts, schematics, and principles of Statistics Canada's three primary I-O data tables are discussed in section 4.2; these are the use, supply, and final demand tables. These three tables contain the necessary information required for I-O analysis, however, the information is presented in a format that is incongruent with the symmetric I-O transactions table shown in figure 3-3. As discussed, the transactions table is required at the outset of I-O model construction. The methods for transforming the three primary data tables into a symmetric I-O transactions table are presented in section 4.3.

Once the data are transformed into a transactions table, I-O models can be constructed. The methods for model construction are detailed throughout section 3.4. At this point, an additional step is required to make the models useful for this research project. Because the level of industry aggregation is too broad—even at the W level—certain agricultural sectors must be disaggregated such that farmed cervid and farmed cattle sectors are individually accounted for. The methods for disaggregating industry sectors are elaborated upon in section 4.4.

Finally, section 4.5 discusses a few final modifications that must be made to the data and models before I-O analysis can be employed. These modifications are of a disparate nature, and affect different aspects of the data and models. Nonetheless, the steps are necessary. In essence, these final modifications and procedures are lumped into one section, with the sole unifying property being that they must be performed before results can be attained. Chapter 5, as follows, outlines the results of the various I-O models.

Chapter 5 Results

A total of six input-output models were constructed using Statistics Canada's 2006 I-O data. These I-O models estimate the output effects on all industry sectors from a controlled final demand stimulus to any one sector; they capture the multiple rounds of spending and money flows throughout the economy in the form of a multiplier effect. I-O multipliers signify the change in output of each industry sector, or change in magnitude of any value-added income component, from a one-dollar change in final demand to the affected industry.

The linearity of the model ensures that the magnitude of multiplier effect from an increase in demand is identical to the magnitude of multiplier effect from an equivalently sized reduction in demand, except with an opposite sign; for example, a 0.21 multiplier effect from a $1.00 increase in demand means a $1.00 decrease in demand creates a -0.21 multiplier effect. Because it is theorized that CWD and BSE outbreaks induce reductions in final demand for cervid and cattle products, the multipliers can be interpreted as output and income changes from one dollar of reduced final demand by multiplying the results by negative one.

Open and closed models were constructed for both of the single-region frameworks—Alberta and Canada—as well as for the interregional framework. Open models yield *type I* multipliers, while closed models yield *type II* multipliers. Closed models endogenize households into the interindustry feedback process, allowing households to earn income as wages, and spend additional income on new consumption. Because of this, the feedback effects from the spending rounds are expected to be consistently higher in all closed models.

All of the models' shock results are presented in the forthcoming results tables in a uniform fashion. Due to the extensive number of industry groups—particularly in the Canada model, and because a majority of industries' multiplier effects are marginal, only the most impacted industries are listed. First, at the top of each table, the own-industry partial output multiplier effect is listed. This multiplier is the sum of direct and indirect effects of the demand stimulus on the industry being shocked. The direct effect is equivalent to the magnitude of shock, which always equals one, and the indirect effect to the own industry is simply any value the multiplier holds in addition to one.

Second, listed below the own-industry effects are the ten most impacted industries, with the partial output multiplier effects listed from largest to smallest. These multipliers are the indirect effects to other industries. Third, below the ten industries, the remaining industries' partial output multiplier effects are summed into one number and listed. Most of the total multiplier effect is captured by the own and top ten industries, hence, it is unnecessary to list every industry's effect individually. Finally, the sum of all partial output multipliers is listed on the bottommost row of each table. This constitutes the total output multiplier effect on the entire economy, capturing the direct and indirect effects of the industry that is shocked, and the indirect effects on all other industries. In instances of the closed model, additional induced effects are added to these results.

For the single-region models, value-adding income components' multiplier effects are also calculated. The multiplier effects on industry GDP at basic price, labour income, returns to capital, and taxes collected by government are included for both the Alberta and Canada models. Because of certain methods used in creating the IRIO models, they are unable to calculate income multipliers.

5.1 Single-Region Models

Two single-region I-O models were constructed: The Alberta input-output (ABIO) model, and the Canada input-output (CANIO) model. After disaggregation, the latter consists of 287 industry groups, while the former consists of 27 industry groups. When the model is closed, the household industry acts as an additional industry, leaving the ABIO model with 28 industry groups, and the CANIO model with 288 industry groups. All four models—the open and closed Alberta models, and open and closed Canada models—are imputed with two separate shocks: the farmed cervid industry is shocked, then the farmed cattle industry is shocked. The demand-pull-analyses' results for all four models are presented below.

5.1.1 Alberta Input-Output (ABIO) Model

5.1.1.1 Cervid Industry Impact Analysis

The results of a shock to the cervid sector in the open Alberta model are presented in table 5-1. The total output multiplier effect sums all *type I* multipliers, and represents the total economy-wide output effects from a final demand stimulus to the cervid sector. A \$1.00 decrease in final demand for cervid production will yield total economic output to decrease by $1.001815. The effect on the cervid industry is a reduction in output by $1.00000071, where the direct effect is a loss of $1.00, and the indirect effect is a loss of $0.00000071. The two most indirectly impacted industries are the manufacturing industry and the remaining crop and animal production industry, with respective losses of $0.000495 and $0.000271. The remaining 16 industry groups—aggregated into one sector—experience production losses of $0.000232.

Table 5-1: Open ABIO Model - Direct and Indirect Effects from a $1.00 Final Demand Shock to Cervid Production

Output Multipliers	
Industry Group	**Type I Multiplier**
Cervid Production	1.00000071
Manufacturing	0.00049519
Remaining Crop and Animal Production	0.00027121
Cattle Production	0.00021032
Finance, Insurance, Real Estate and Rental and Leasing	0.00012226
Mining and Oil and Gas Extraction	0.00011939
Wholesale Trade	0.00011388
Transportation and Warehousing	0.00008022
Professional, Scientific and Technical Services	0.00007305
Operating, Office, Cafeteria and Laboratory Supplies	0.00006076
Construction	0.00003536
Remaining 16 Industry Groups	0.00023289
Total Output Multiplier Effect	**1.00181524**

Table 5-2 details the results of a $1.00 shock to the cervid sector in the closed Alberta model. The direct, indirect, and induced effects—captured by *type II* multipliers—on the cervid sector is a reduction in output by $1.00000073, where $1.00 corresponds with the direct effect, and the remaining $0.00000073 corresponds with the indirect and induced effects. The two most impacted industries are the manufacturing industry and household sector, with respective output losses of $0.000648 and $0.000464. The economy-wide effect of this shock is a total decrease in production amounting to $1.003010.

Table 5-2: Closed ABIO Model - Direct, Indirect, and Induced Effects from a $1.00 Final Demand Shock to Cervid Production

Output Multipliers	
Industry Group	**Type II Multiplier**
Cervid Production	1.00000073
Manufacturing	0.00064751
Household Sector	0.00046374
Finance, Insurance, Real Estate and Rental and Leasing	0.00029704
Remaining Crop and Animal Production	0.00027873
Cattle Production	0.00021616
Mining and Oil and Gas Extraction	0.00015637
Wholesale Trade	0.00014798
Transportation and Warehousing	0.00011039
Professional, Scientific and Technical Services	0.00009874
Retail Trade	0.00008202
Remaining 17 Industry Groups	0.00051022
Total Output Multiplier Effect	**1.00300963**

Table 5-3: Income Multipliers from a $1.00 Final Demand Shock to Cervid Production in the ABIO model

Income Multipliers	
Income Category	**Multiplier**
Industry GDP (Basic Price)	0.00088793
Labor Income	0.00031084
Returns to Capital	0.00051309
Taxes collected by Government	0.00008075

Table 5-3 contains the income multipliers from a $1.00 final demand stimulus to the farmed cervid industry. A $1.00 reduction in final demand for cervid sector output yields a decrease in industry GDP of $0.000888, a decrease in labour income of $0.000311, a decrease in the returns to capital by $0.000513, and a reduction in the taxes collected by government by $0.000081.

5.1.1.2 Cattle Industry Impact Analysis

All of the multiplier effects from shocks to farmed cervid production are small. These results are likely due to the small size of the industry, with few and small sales and purchase linkages with other sectors. Shocking the farmed cattle sector in the ABIO model yields considerably larger multiplier effects on the economy. Table 5-4 shows that a $1.00 reduction for cattle output generates total output losses of $1.5381. The most impacted industries are manufacturing, remaining crop and animal production, and finance, insurance, real estate, and rental and leasing, with output losses of $0.1468, $0.0804, and $0.0362, respectively. The own sector output effects from a $1.00 reduction in final demand are losses of $1.0623.

Table 5-4: Open ABIO Model - Direct and Indirect Effects from a $1.00 Final Demand Shock to Cattle Production

Output Multipliers	
Industry Group	**Type I Multiplier**
Cattle Production	1.06234201
Manufacturing	0.14678076
Remaining Crop and Animal Production	0.08038994
Finance, Insurance, Real Estate and Rental and Leasing	0.03623854
Mining and Oil and Gas Extraction	0.03538885
Wholesale Trade	0.03375503
Transportation and Warehousing	0.02377861
Professional, Scientific and Technical Services	0.02165394
Operating, Office, Cafeteria and Laboratory Supplies	0.01801063
Construction	0.01048063
Utilities	0.01032373
Remaining 16 Industry Groups	0.05891939
Total Output Multiplier Effect	**1.53806204**

Examining table 5-5, we again see that the closed model produces consistently larger multipliers for all industry sectors than the open model, with the total direct, indirect, and induced effects on the entire economy amounting to losses of $1.8921 from a $1.00 drop in final demand for cattle output. The household sector is again among the most impacted sectors, with output losses of $0.1375. The addition of induced effects yields only a marginal reduction to own-sector output, with losses of $1.0641.

Table 5-5: Closed ABIO Model - Direct, Indirect, and Induced Effects from a $1.00 Final Demand Shock to Cattle Production

Output Multipliers	
Industry Group	**Type II Multiplier**
Cattle Production	1.06407172
Manufacturing	0.19193217
Household Sector	0.13745803
Finance, Insurance, Real Estate and Rental and Leasing	0.08804697
Remaining Crop and Animal Production	0.08262039
Mining and Oil and Gas Extraction	0.04635100
Wholesale Trade	0.04386191
Transportation and Warehousing	0.03272238
Professional, Scientific and Technical Services	0.02926736
Retail Trade	0.02431290
Operating, Office, Cafeteria and Laboratory Supplies	0.02150875
Remaining 17 Industry Groups	0.12994289
Total Output Multiplier Effect	**1.89209646**

Table 5-6 shows the impacts to income variables from cattle sector shocks. Demand disruptions of $1.00 cause Alberta's industry GDP to drop by $0.2632, labour income to drop by $0.0921, returns to capital to drop by $0.1521, and taxes collected by government to drop by $0.0239. Relative to the income effects from cervid sector shocks (shown in table 5-3), cattle sector shocks generate substantial losses to the economy's income components—particularly GDP and returns to capital.

Table 5-6: Income Multipliers from a $1.00 Final Demand Shock to Cattle Production in the ABIO model

Income Multipliers	
Income Category	**Multiplier**
Industry GDP (Basic Price)	0.26319536
Labor Income	0.09213707
Returns to Capital	0.15208707
Taxes collected by Government	0.02393655

5.1.2 Canada Input-Output (CANIO) Model

5.1.2.1 Cervid Industry Impact Analysis

Results of final demand shocks to the farmed cervid sector in the CANIO model are presented in this section, with open model, closed model, and income results detailed in tables 5-7, 5-8, and 5-9, respectively. Like the ABIO model, farmed cervid sector shocks generate very small impacts throughout the economy. A $1.00 reduction of final demand in the open model yields own sector and total economic losses of $1.00000086 and $1.004122, respectively (table 5-7). In the closed model (table 5-8), these same impacts generate losses of $1.00000093, and $1.007983, respectively.

The income multipliers from cervid sector shocks in the CANIO model are presented in table 5-9. Like the ABIO model, the multipliers are marginal: a $1.00 reduction in cervid demand yields GDP losses of $0.002123, labour income losses of $0.000890, returns to capital losses of $0.001133, and losses in tax revenue by $0.000152. Even when examining the entire Canadian economy, the cervid sector generates very minor spillover effects onto other productive sectors. Furthermore, negative impacts to the cervid industry produce very minor effects on value-adding income variables.

Table 5-7: Open CANIO Model - Direct and Indirect Effects from a $1.00 Final Demand Shock to Cervid Production

Output Multipliers	
Industry Group	**Type I Multiplier**
Cervid Production	1.00000086
Crop Production (except Greenhouse, Nursery and Floriculture Production)	0.00074940
Animal Food Manufacturing	0.00047621
Cattle Production	0.00022559
Wholesale Trade	0.00021677
Oil and Gas Extraction	0.00016473
Remaining Animal Production (except Animal Aquaculture)	0.00013128
Truck Transportation	0.00012817
Petroleum Refineries and Other Petroleum and Coal Products Manufacturing	0.00012465
Pesticides, Fertilizer and Other Agricultural Chemical Manufacturing	0.00010484
Other Professional, Scientific and Technical Services	0.00010323
Remaining 276 Industry Groups	0.00169650
Total Output Multiplier Effect	1.00412224

Table 5-8: Closed CANIO Model - Direct, Indirect, and Induced Effects from a $1.00 Final Demand Shock to Cervid Production

Output Multipliers	
Industry Group	**Type II Multiplier**
Cervid Production	1.00000093
Household Sector	0.00144755
Crop Production (except Greenhouse, Nursery and Floriculture Production)	0.00076750
Animal Food Manufacturing	0.00048330
Wholesale Trade	0.00032129
Cattle Production	0.00024169
Retail Trade	0.00024066
Oil and Gas Extraction	0.00023393
Owner-Occupied Dwellings	0.00022454
Petroleum Refineries and Other Petroleum and Coal Products Manufacturing	0.00018311
Banking and Other Depository Credit Intermediation	0.00015330
Remaining 277 Industry Groups	0.00368476
Total Output Multiplier Effect	1.00798256

Table 5-9: Income Multipliers from a $1.00 Final Demand Shock to Cervid Production in the CANIO model

Income Multipliers	
Income Category	**Multiplier**
Industry GDP (Basic Price)	0.00212346
Labor Income	0.00088960
Returns to Capital	0.00113347
Taxes collected by Government	0.00015213

5.1.2.2 Cattle Industry Impact Analysis

Tables 5-10, 5-11, and 5-12 detail the *type I*, *type II*, and income multipliers from cattle sector shocks in the CANIO model. In the open model (table 5-10), the total economic multiplier effect and own sector multiplier effect from $1.00 of reduced final demand to cattle output are losses of $2.0770, and $1.0589, respectively. In the closed model (table 5-11), these output reductions are $3.0855, and $1.0631. Both models' total multiplier effects are quite large—particularly the closed model; when examining the national economy, the cattle industry's spillover effects onto the rest of the economy are considerable.

The CANIO model's income multipliers from cattle sector shocks are also considerable: $1.00 of final demand shock induces industry GDP losses of $0.5548, labour income losses of $0.2324, returns to capital losses of $0.2961, and reductions in tax collection by $0.0397. The GDP losses are particularly salient, where $0.55 is lost for every $1.00 of reduced cattle output. This indicates that at the national level, the cattle sector's linkages with the rest of the economy are substantial, and that the entire economy is sensitive to cattle output disruptions.

Table 5-10: Open CANIO Model - Direct and Indirect Effects from a $1.00 Final Demand Shock to Cattle Production

Output Multipliers	
Industry Group	**Type I Multiplier**
Cattle Production	1.05893741
Crop Production (except Greenhouse, Nursery and Floriculture Production)	0.19578808
Animal Food Manufacturing	0.12441400
Wholesale Trade	0.05663460
Oil and Gas Extraction	0.04303680
Remaining Animal Production (except Animal Aquaculture)	0.03429847
Truck Transportation	0.03348659
Petroleum Refineries and Other Petroleum and Coal Products Manufacturing	0.03256698
Pesticides, Fertilizer and Other Agricultural Chemical Manufacturing	0.02739145
Other Professional, Scientific and Technical Services	0.02697012
Electric Power Generation, Transmission and Distribution	0.02544419
Remaining 276 Industry Groups	0.41800960
Total Output Multiplier Effect	2.07697830

Table 5-11: Closed CANIO Model - Direct, Indirect, and Induced Effects from a $1.00 Final Demand Shock to Cattle Production

Output Multipliers	
Industry Group	**Type II Multiplier**
Cattle Production	1.06314398
Household Sector	0.37818801
Crop Production (except Greenhouse, Nursery and Floriculture Production)	0.20051699
Animal Food Manufacturing	0.12626707
Wholesale Trade	0.08394014
Retail Trade	0.06287525
Oil and Gas Extraction	0.06111550
Owner-Occupied Dwellings	0.05866347
Petroleum Refineries and Other Petroleum and Coal Products Manufacturing	0.04783888
Banking and Other Depository Credit Intermediation	0.04005218
Truck Transportation	0.03978957
Remaining 277 Industry Groups	0.92313456
Total Output Multiplier Effect	3.08552560

Table 5-12: Income Multipliers from a $1.00 Final Demand Shock to Cattle Production in the CANIO model

Income Multipliers	
Income Category	**Multiplier**
Industry GDP (Basic Price)	0.55477509
Labor Income	0.23241664
Returns to Capital	0.29613004
Taxes collected by Government	0.03974668

5.2 Interregional Input-Output (IRIO) Model

The IRIO models include industrial trade interactions between Alberta, and the remaining provinces and territories of Canada. After disaggregating the agriculture sector, the open model consists of 54 industry sectors. When closing the model in respect to households, the model consists of 56 industry sectors.

In both models, half of all industries are Albertan, and the other half belong within the rest of Canada region. Hence, each industry is represented two times: once as a sector operating from Alberta, and again as a sector operating from the rest of Canada. All industry impact multipliers are followed with either "AB" or "REST" in parenthesis to signify which of the two regions the industry belongs within. Furthermore, both the open and closed models are shocked twice: once with cervid sector shocks, and then with separate cattle sector shocks.

5.2.1 Cervid Industry Impact Analysis

Tables 5-13 and 5-14 list the *type I* (open) and *type II* (closed) multipliers from shocks to Alberta's cervid sector in the IRIO models. Even with the multiplicative effects of interregional trade, the multipliers in both models are small. Furthermore, all of the 10 most impacted industries in both models are from the Alberta region. The economy-wide total output losses—including both regions—from a $1.00 demand shock to Alberta's cervid sector are $1.001928 in the open model, and $1.003278 in the closed model.

Table 5-13: Open IRIO Model - Direct and Indirect Effects from a $1.00 Final Demand Shock to Cervid Production

Output Multipliers	
Industry Groups	**Type I Multipliers**
Cervid Production (AB)	1.00000071
Manufacturing (AB)	0.00049738
Remaining Crop and Animal Production (AB)	0.00027166
Cattle Production (AB)	0.00021067
Finance, Insurance, Real Estate and Rental and Leasing (AB)	0.00012267
Mining and Oil and Gas Extraction (AB)	0.00012052
Wholesale Trade (AB)	0.00011427
Transportation and Warehousing (AB)	0.00008095
Professional, Scientific and Technical Services (AB)	0.00007349
Operating, Office, Cafeteria and Laboratory Supplies (AB)	0.00006090
Construction (AB)	0.00003541
Remaining 43 Industry Groups (AB & REST)	0.00033920
Total Output Multipler Effect	1.00192782

Table 5-14: Closed IRIO Model - Direct, Indirect, and Induced Effects from a $1.00 Final Demand Shock to Cervid Production

Output Multipliers	
Industry Groups	**Type II Multipliers**
Cervid Production (AB)	1.00000073
Manufacturing (AB)	0.00065403
Household Sector (AB)	0.00046813
Finance, Insurance, Real Estate and Rental and Leasing (AB)	0.00030020
Remaining Crop and Animal Production (AB)	0.00027943
Cattle Production (AB)	0.00021670
Mining and Oil and Gas Extraction (AB)	0.00015902
Wholesale Trade (AB)	0.00014923
Transportation and Warehousing (AB)	0.00011214
Professional, Scientific and Technical Services (AB)	0.00009999
Retail Trade (AB)	0.00008319
Remaining 45 Industry Groups (AB & REST)	0.00075556
Total Output Multipler Effect	1.00327837

5.2.2 Cattle Industry Impact Analysis

Tables 5-15 and 5-16 present the open and closed IRIO model results from a $1.00 final demand shock to Alberta's farmed cattle sector. Again, in both models the 10 most impacted industries are all from the Alberta region. The total economic output effects—the sum of all multipliers in both Alberta and rest of Canada—are losses of $1.5714 in the open model, and losses of $1.9718 in the closed model.

Contrasting the IRIO model results from tables 5-13 through 5-16 with the single-region ABIO model results (tables 5-1, 5-2, 5-4, 5-5) reveals that the inclusion of interregional trade increases the multiplier effect only slightly. In the IRIO models, the majority of the spillover effects are contained within the Alberta region; hence, the additional rounds of spending with out-of-region trading partners increases the total multiplier effects by only a small margin.

Table 5-15: Open IRIO Model - Direct and Indirect Effects from a $1.00 Final Demand Shock to Cattle Production

Output Multipliers	
Industry Groups	**Type I Multipliers**
Cattle Production (AB)	1.06244619
Manufacturing (AB)	0.14743098
Remaining Crop and Animal Production (AB)	0.08052427
Finance, Insurance, Real Estate and Rental and Leasing (AB)	0.03636104
Mining and Oil and Gas Extraction (AB)	0.03572258
Wholesale Trade (AB)	0.03387264
Transportation and Warehousing (AB)	0.02399340
Professional, Scientific and Technical Services (AB)	0.02178465
Operating, Office, Cafeteria and Laboratory Supplies (AB)	0.01805092
Construction (AB)	0.01049480
Utilities (AB)	0.01035070
Remaining 43 Industry Groups (AB & REST)	0.09040240
Total Output Multipler Effect	1.57143456

Table 5-16: Closed IRIO Model - Direct, Indirect, and Induced Effects from a $1.00 Final Demand Shock to Cattle Production

Output Multipliers	
Industry Groups	**Type II Multipliers**
Cattle Production (AB)	1.06423196
Manufacturing (AB)	0.19386372
Household Sector (AB)	0.13876079
Finance, Insurance, Real Estate and Rental and Leasing (AB)	0.08898448
Remaining Crop and Animal Production (AB)	0.08282702
Mining and Oil and Gas Extraction (AB)	0.04713635
Wholesale Trade (AB)	0.04423437
Transportation and Warehousing (AB)	0.03324137
Professional, Scientific and Technical Services (AB)	0.02963980
Retail Trade (AB)	0.02465976
Operating, Office, Cafeteria and Laboratory Supplies (AB)	0.02163275
Remaining 45 Industry Groups (AB & REST)	0.20254219
Total Output Multipler Effect	1.97175455

5.3 Discussion of Results

A CWD outbreak can give rise to a number of final demand disruptions to the cervid farming industry. Analyzing a hypothetical, worst-case CWD outbreak scenario provides researchers with an upper limit, or threshold, of the magnitude of its effects. In the case of cervid farming, this worst-case scenario would be the closure of the entire industry, and a reduction of cervid sector output to zero. Farm cash receipts for elk and deer farms are a suitable proxy for the output value of the cervid industry. The upper-limit scenario would diminish these cash receipts to zero, making output zero, where the size of shock to the cervid industry is the loss of all cash receipt value.

In Alberta, total farm cash receipts for cervid production are $11,471,494; in Canada, estimates of these receipts are $43,350,194 (Statistics Canada, 2007; Agriculture and Rural Development, 2006). When these outputs are reduced to zero, the total economic effects in the closed ABIO, IRIO, and CANIO models are output losses of $11,506,019, $11,509,102, and $43,696,240, respectively. These economy-wide output losses are only marginally higher than the direct output losses to the cervid industry. These results demonstrate how small the multiplier values from cervid shocks are. The complete closure of the industry also yields total industry GDP losses of $10,186, and $92,052 in the ABIO and CANIO models, respectively. These values are also quite small.

Comparing the CANIO model results with those of Anderson, Frosch, and Outlaw (2007), whom calculated the economic impacts of cervid farming on the U.S. economy, further emphasizes how small the Canadian cervid sector multipliers are. They estimated cervid operations to generate $893.5 million in direct expenditures within the U.S. economy each year, and they calculated the indirect effects from those expenditures to be approximately $2.3 billion. Those numbers suggest a total economic multiplier effect of 2.57. This multiplier is considerably larger than the 1.008 multiplier yielded from the closed CANIO model. The small impact this industry has on the rest of the economy is attributable to at least one of the following reasons: 1) the forward (sales) and backward (purchases) linkages with other industry sectors are small, thus giving rise to a small ripple effect throughout the economy; 2) the disaggregation method used in this thesis fails to estimate the correct multipliers this sector generates. In the open and closed versions of the ABIO, CANIO, and IRIO models, the cervid sector generates small multiplier effects on other industries, on the entire economy, and on income variables.

Despite the small impacts generated in this research project, sector disaggregation techniques are widely accepted in the literature (Lindberg & Hansson, 2009; Wolsky, 1984; Collins & Glade, 1981). The disaggregation of industry sectors, although not absolutely accurate, is an unfortunate necessity in I-O model construction. National statistical agencies do not publish data at levels that are detailed enough for many researchers. Hence, in-house disaggregation methods are often implemented. Doing so can transform a broad-level I-O model into one that provides results for specific research questions, and targets industries of particular interest.

In contrast to the cervid industry, the cattle sector in the open and closed versions of the ABIO, IRIO, and CANIO models has a much larger effect on the rest of the economy. A hypothetical worst-case BSE scenario in Canada would result in the closure of the entire cattle farming industry. Again, this type of scenario provides an upper limit on the potential economic impacts of BSE. This closure would reduce all cattle production to zero.

Total farm cash receipts for cattle production—cattle and calves, as well as dairy production—in Alberta is $3,400,315,000; total farm cash receipts for cattle production in Canada is $11,325,687,000 (Statistics Canada, 2007; Agriculture and Rural Development, 2006). Reducing these outputs to zero generates total economic output losses in the closed ABIO, IRIO, and CANIO models of $6,433,723,974, $6,704,586,573, and $34,945,697,176, respectively. Additionally, the closure of the cattle industry results in GDP losses of $894,947,131 in Alberta, and $6,283,209,025 in Canada.

Samarajeewa et al. (2006) performed an I-O analysis of BSE impacts in Canada. $10 million of reduced cattle exports, which is equivalent with $10 million in reduced final demand for cattle, generated GDP losses in Alberta of $8.9 million; this amounts to a GDP income multiplier of 0.89. In the ABIO model, the GDP income multiplier is 0.26. Their total output multiplier for the cattle industry in Alberta was 2.44. In the ABIO model, the total output multiplier for the cattle industry is 1.89. When interregional trade is included (IRIO model), the multiplier increases to 1.97. The ABIO and IRIO model results are not too dissimilar from the findings of Samarajeewa et al. (2006). The multipliers in this thesis are lower, but still within a similar range of effects as the Samarajeewa et al. (2006) study.

As expected, the closed versions of the three models produce larger multipliers than the open versions. This is congruent with the theory of the household's role; when households are endogenized into the industrial system of production, they sell labour that is used as input by other sectors, and they expend their wages and salaries on the outputs of other firms. The multiple rounds of sales and purchases involved in the industrial economy are extended to the household sector in the closed models, thereby increasing the overall multiplier effect.

Because the multipliers generated from cervid sector shocks are so small, *type II* multipliers are only marginally higher than *type I* multipliers when cervid demand is disrupted. Conversely, when the cattle sector is shocked, all three models' closed versions yield considerably larger total output multiplier effects than their open versions: in the ABIO model, the *type II* total output multiplier effect (1.892) is 23% higher than the *type I* effect (1.538); in the IRIO model, the *type II* total output multiplier effect (1.972) is 26% higher than the *type I* effect (1.571); and in the CANIO model, the *type II* total output multiplier effect (3.086) is 49% higher than the *type I* effect (2.077). These results indicate how important the household sector is to total economic output.

Comparing the ABIO and IRIO models shows that the inclusion of interprovincial trade with the rest of Canada increases multipliers only slightly. The additional feedback effects from interregional trade ranged from 0.01% when comparing the open ABIO and open IRIO models from cervid shocks, and 4.23% when comparing the closed ABIO and closed IRIO models from cattle shocks. All things considered, these marginal increases to the total output multipliers are quite small. This demonstrates that the majority of multiplier effects are captured within the Alberta region, and that the inclusion of out-of-region industries magnifies economic impacts only slightly. These results are similar to the ones calculated by Miller (1966), who concluded that single-region I-O models, relative to two-region IRIO models, understate results by less than one percent on average. These results are also congruent with Brown's (1972) research, which revealed that interregional spillovers add at most an additional 0.01 multiplier effect to the regional model.

Policy makers would find it in their best interest to consider the multisectoral impacts of prion disease outbreaks in Alberta and Canada. Failure to do so may result in gross underestimates of the economic effects these diseases can generate. By only considering the partial equilibrium effects on the cervid and cattle farming sectors, an underprovision of mitigatory programs from public authorities may arise. Furthermore, sectors that experience large disruptions may be overlooked in any planning or response program.

Regardless of the size of impact endured, the results from all models suggest a common theme in the distribution of impacts, where the most disrupted industries are agricultural sectors, mining and energy sectors, and industries involved in trade, transportation, and warehousing. In Alberta and Canada, shocks to the cervid and cattle industries generate the largest impacts to these three broad areas. When assessing the economic vulnerability from prion disease outbreaks, sound policy making should consider these industries, and the indirect shocks they experience.

Chapter 6 Discussion and Conclusion

6.1 Research Summary

This research project aimed to estimate the total economic impacts from potential CWD and BSE outbreaks in farmed herds. Livestock disease outbreaks can induce trade sanctions, losses in consumer confidence, and many other disruptions to final demand. If a CWD or BSE outbreak was to occur, the economic impacts will transcend the farmed cervid and cattle industries; industry sectors with direct and indirect ties to cattle and cervid production will also experience economic consequences. These indirect effects on other sectors are accounted for by the I-O system's complex network of forward and backward linkages.

In contrast to the partial equilibrium approach, which only captures equilibrium changes to individual markets, the I-O approach captures simultaneous effects to all markets—even when only a single market is disrupted. I-O analysis was employed to model the economy-wide effects from final demand disturbances to cattle and cervid sectors. These models capture the successive expenditure rounds undertaken throughout an economy that results from a single sector undergoing an output change. In doing so, these models calculate output changes to the industry that is directly affected, to the industries in the regional economy that are indirectly affected, and to the total economy. They are also able to calculate changes to income variables such as GDP, returns to capital, labour income, and taxes collected by government.

Single-region models were constructed for the Alberta and Canada economies using Statistics Canada's 2006 input-output data. Interregional models were also constructed for the Alberta economy using this same data source; these models took into account trade linkages with industries outside of Alberta. Open and closed versions of models were both constructed for Alberta, Canada, and the interregional framework, amounting to a total of six models.

All six of the models were imputed with two different final demand shocks: a shock to the farmed cervid sector, and another separate shock to the farmed cattle sector. Income multipliers were also calculated for the single-sector models. To date, no Canadian study exists that quantifies the total economic effects from farmed cervid sector impacts. Though, several economic impact studies of BSE in Canada have been undertaken.

The I-O models revealed that spillover effects from cervid sector shocks were marginal in all scenarios. This can be attributed to the small size of the industry, where sales and purchase linkages with other sectors are minor. The cattle sector, in contrast, generated large multiplier effects. In the closed Canada model, the total economic impacts were more than three times the size of the initial cattle sector stimulus. This model also yielded total economy GDP changes to be approximately 55 percent of the final demand stimulus.

In the single-sector and interregional Alberta models, the most extensively impacted industries were: farmed cervid production; farmed cattle production; manufacturing;

remaining crop and animal production; finance, insurance, real estate, and rental and leasing; mining and oil and gas extraction; wholesale trade; transportation and warehousing; professional scientific, and technical services; and, when closing the model in respect to households, the endogenized household sector. In the Canada model, the industries that experienced the largest multiplier effects were: farmed cattle production; farmed cervid production; crop production; animal food manufacturing; wholesale trade; oil and gas extraction; remaining animal production; retail trade; truck transportation; petroleum refineries and other petroleum and coal products manufacturing; and, finally, the household sector in the closed model.

The magnitude and ordinality of effects varied from model to model, however, a notable trend is identifiable irrespective of model. In all six models, when the cervid or cattle sector was shocked, the types of industries that were consistently the most disrupted were agricultural sectors, mining and energy sectors, and industries dedicated to trade, transportation, and warehousing. Within Canada, and even within Alberta, farmed cervid and cattle production generates the largest spillovers into these three aforementioned areas.

In addition to the direct economic effects to cattle and cervid industries, prudent policy making would find it in its best interest to consider the indirect economic effects to the other aforementioned sectors. These indirect effects are important, and in certain cases quite severe. If a public or private planner wanted to create a program or enact a policy aimed at mitigating disruptions to the economy from a prion disease outbreak, it is these sectors that would require their attention.

6.2 Limitations

Two limitations to the analytic approach loom above this research project. The first lies in the inherent assumptions underlying Leontief production technology. No substitution technology, which implies constant returns to scale, means that all the productive sectors in the model are incapable of altering their production methods when faced with price changes. An industry will utilize its factor inputs—which it purchases from other industries—in the exact same ratios, irrespective of changes to system parameters.

This behavioural stagnancy is unlikely in real-world scenarios, and it defies the principles of neoclassical production theory. It is expected that rational producers substitute for cheaper inputs if the option is available. Despite this structural drawback, the I-O approach still provides considerable value to researchers for the expeditious results it yields.

The second limitation to the analytic approach lies in how the models were disaggregated. Statistics Canada's input-output accounts are not detailed enough to include farmed cervid and cattle industries—even at the highly disaggregated worksheet level. Hence, it is up to the analyst to modify the data or model accordingly to ensure their inclusion. However, due to data limitations, the approach utilized in this thesis sacrifices accuracy for expeditiousness. The approach that was used involves duplicating broad-category industry sectors, and rescaling the duplicates according to farm-sector-cash-receipt proportions. In effect, the cervid and cattle sector vector elements in the Leontief matrix are approximations of their *real* values. The following section discusses a method—albeit a costly and time consuming one—to accurately disaggregate industry sectors.

6.3 Avenues for Future Research

In order to hone better estimates, industrial consumption and production data of the cervid and cattle sectors are required. This information would allow analysts to augment the primary I-O data tables—the use, supply, and final demand tables—to include these two industry sectors among the existing sectors. This process would require extensive detail and information, which would be both difficult to acquire and costly. For example, at the worksheet level, adding the cervid and cattle industries to the use and supply tables would require data on the value of inputs used and outputs produced of each of the 713 commodities and primary factors.

With a sufficient budget, an analyst could oversee the construction of a survey aimed at eliciting the specific information needed for accurate table disaggregation. In this case, the survey would require commodity use and production information commensurate with the tables already published by Statistics Canada. Augmenting the most detailed worksheet level tables would require information on 713 commodities and primary factors. A more attainable approach would be to augment the small-level information tables, which include only 59 commodities and primary factors. The survey would need to be compiled in a manner that effectively acquires data on the dollar value of each of the 59 commodities and primary factors used and produced by both the farmed cervid and cattle industries. These new vectors would then be incorporated into the primary I-O tables. The final step would be to subtract these new vectors from the crop and animal production vector. At this point, the methods outlined in this thesis would be utilized to construct an analytic I-O model, and undertake an I-O analysis.

Keep in mind however that the aforementioned survey-based disaggregation approach, while accurate, is quite expensive. In the case that adequate finances are available for research expansion, this route need not be the only one explored. On the contrary, the existing I-O framework can be expanded into either a social accounting matrix, or a computable general equilibrium model. The latter requires more data and time, but it also produces results that hinge upon fewer assumptions.

A SAM is essentially an I-O model that takes into account distributional effects. Socioeconomic data is required to augment the existing I-O model, such that output and income effects are decomposed according to income clusters. For example, if the cattle sector endured a final demand shock, a SAM would be able to reveal how wages and salaries are affected according to low-income, middle-income, and high-income brackets.

Once a SAM is constructed, it can be further extrapolated into a CGE model. A CGE model is a general equilibrium model that relaxes the assumption of no substitution technology. These models are quite complex, and considerable data on supply, demand,

and substitution elasticities are required for their construction. It is these elasticities, though, that enables these models to account for firms' behavioural responses to price changes—something that the I-O and SAM frameworks are unable to do.

A basic intuition of economic activity dictates an understanding that prion diseases will impact the industry sectors that are directly associated with them—in this case, cattle and cervid farming. However, the results drawn from this thesis reveal the extent that CWD and BSE affect the broader economy. This information is a boon to industry and government, as it fosters an understanding of the way that economic interactions, however basic, influence most if not all sectors of the economy. In effect, this multisectoral analysis yields results that approach *actual*, real-world economic impacts. Various avenues for research expansion have also been discussed, and can be undertaken if necessary.

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Appendix

A.1 Industry Groups: Small Level Aggregation

No.	Code	Industry Group	No.	Code	Industry Group
1	1A	Crop and Animal Production	15	56	Administrative and Support, Waste Management and Remediation Services
2	1B	Forestry and Logging	16	61	Educational Services
3	1C	Fishing, Hunting and Trapping	17	62	Health Care and Social Assistance
4	1D	Support Activities for Agriculture and forestry	18	71	Arts, Entertainment and Recreation
5	21	Mining and Oil and Gas Extraction	19	72	Accommodation and Food Services
6	22	Utilities	20	81	Other Services (Except Public Administration)
7	23	Construction	21	F1	Operating, Office, Cafeteria and Laboratory Supplies
8	3A	Manufacturing	22	F2	Travel, Entertainment, Advertising and Promotion
9	41	Wholesale Trade	23	F3	Transportation Margins
10	4A	Retail Trade	24	NP	Non-Profit Institutions Serving Households
11	4B	Transportation and Warehousing	25	GS	Government Sector
12	51	Information and Cultural Industries			
13	5A	Finance, Insurance, Real Estate and Rental and Leasing			
14	54	Professional, Scientific and Technical Services			

Source: Statistics Canada, 2009b.

A.2 Commodity Groups: Small Level Aggregation

No.	Commodity Group	No.	Commodity Group
1	Grains	27	Chemicals, pharmaceuticals and chemical products
2	Other agricultural products		
3	Forestry products	28	Miscellaneous manufactured products
4	Fish and seafood and hunting and trapping products	29	Residential building construction
		30	Non-residential construction
5	Metal ores and concentrates	31	Repair construction
6	Mineral fuels	32	Transportation and storage
7	Non-metallic minerals	33	Communications services
8	Services incidental to mining	34	Other utilities
9	Meat, fish and dairy products	35	Wholesaling margins
10	Fruit, vegetable and other food products and feeds	36	Retailing margins and services
11	Soft drinks and alcoholic beverages	37	Gross imputed rent
12	Tobacco and tobacco products	38	Finance, insurance, and real estate services
13	Leather, rubber, and plastic products	39	Business and computer services
14	Textile products	40	Education, tuition and other fees services
15	Hosiery, clothing and accessories	41	Health and social services
16	Lumber and wood products	42	Accommodation services and meals
17	Furniture and fixtures	43	Other services
18	Wood pulp, paper and paper products	44	Transportation margins
19	Printing and publishing	45	Operating, office, cafeteria and laboratory supplies
20	Primary metal products	46	Travel, entertainment, advertising and promotion
21	Fabricated metal products	47	Services provided by non-profit institutions serving households
22	Machinery		
23	Motor vehicles, other transportation equipment and parts	48	Government sector services
		49	Non-competing imports
24	Electrical, electronic and communication products	50	Unallocated imports and exports
25	Non-metallic mineral products	51	Sales of other government services
26	Petroleum and coal products		

Source: Statistics Canada, 2009b.

A.3 Final Demand Categories: Small Level Aggregation

No.	Final Demand Category	No.	Final Demand Category
1	Personal expenditures, durable goods	9	Housing construction, non-government sector
2	Personal expenditures, semi-durable goods	10	Construction, government sector
3	Personal expenditures, non-durable goods	11	Inventories, additions
4	Personal expenditures, services	12	Inventories, withdrawals
5	Machinery and equipment, non-government sector	13	Government net current expenditures
6	Machinery and equipment, government sector	14	Exports, international
7	Machinery and equipment, used cars and equipment and scrap	15	Re-exports, international
		16	Imports, international
8	Construction excluding housing, non-government sector	17	Exports, inter-provincial
		18	Imports, inter-provincial

Source: Statistics Canada, 2009b.

A.4 Industry Groups: Worksheet Level Aggregation

No.	Code	Industry Group
1	111400	Greenhouse, Nursery and Floriculture Production
2	111A00	Crop Production (except Greenhouse, Nursery and Floriculture Production)
3	112500	Animal Aquaculture
4	112A00	Animal Production (except Animal Aquaculture)
5	113000	Forestry and Logging
6	114000	Fishing, Hunting and Trapping
7	115100	Support Activities for Crop Production
8	115200	Support Activities for Animal Production
9	115300	Support Activities for Forestry
10	211100	Oil and Gas Extraction
11	212100	Coal Mining
12	212210	Iron Ore Mining
13	212220	Gold and Silver Ore Mining
14	212230	Copper, Nickel, Lead and Zinc Ore Mining
15	212290	Other Metal Ore Mining
16	212310	Stone Mining and Quarrying
17	212320	Sand, Gravel, Clay, and Ceramic and Refractory Minerals Mining and Quarrying
18	212392	Diamond Extraction
19	212393	Salt Mining
20	212396	Potash Mining
21	21239X	Asbestos and Other Non-Metallic Mineral Mining and Quarrying
22	213100	Support Activities for Mining and Oil and Gas Extraction
23	221100	Electric Power Generation, Transmission and Distribution
24	221200	Natural Gas Distribution
25	221300	Water, Sewage and Other Systems
26	2300A0	Residential Building Construction
27	2300B0	Non-residential Building Construction
28	2300C0	Transportation Engineering Construction
29	2300D0	Oil and Gas Engineering Construction
30	2300	Electric Power Engineering Construction
31	2300F0	Communication Engineering Construction
32	2300G0	Other Engineering Construction
33	2300H0	Repair Construction
34	2300I0	Other Activities of the Construction Industry
35	311100	Animal Food Manufacturing
36	311210	Flour Milling and Malt Manufacturing
37	311220	Starch and Vegetable Fat and Oil Manufacturing
38	311230	Breakfast Cereal Manufacturing
39	311300	Sugar and Confectionary Product Manufacturing
40	311410	Frozen Food Manufacturing
41	311420	Fruit and Vegetable Canning, Pickling and Drying
42	311500	Dairy Product Manufacturing
43	311611	Animal (except Poultry) Slaughtering
44	311614	Rendering and Meat Processing from Carcasses
45	311615	Poultry Processing
46	311700	Seafood Product Preparation and Packaging
47	311810	Bread and Bakery Product Manufacturing
48	311821	Cookie and Cracker Manufacturing
49	311822	Flour Mixes and Dough Manufacturing from Purchased Flour
50	31182A	Dry Pasta and Tortilla Manufacturing
51	311910	Snack Food Manufacturing
52	311920	Coffee and Tea Manufacturing
53	3119A0	Other Miscellaneous Food Manufacturing
54	312110	Soft Drink and Ice Manufacturing
55	312120	Breweries
56	312130	Wineries
57	312140	Distilleries
58	312200	Tobacco Manufacturing
59	313100	Fibre, Yarn and Thread Mills
60	313200	Fabric Mills
61	313300	Textile and Fabric Finishing and Fabric Coating
62	314110	Carpet and Rug Mills
63	314120	Curtain and Linen Mills
64	314910	Textile Bag and Canvas Mills
65	314990	All Other Textile Product Mills
66	315110	Hosiery and Sock Mills
67	315190	Other Clothing Knitting Mills
68	315210	Cut and Sew Clothing Contracting
69	315220	Men's and Boys' Cut and Sew Clothing Manufacturing
70	315230	Women's and Girls' Cut and Sew Clothing Manufacturing
71	315290	Other Cut and Sew Clothing Manufacturing
72	315900	Clothing Accessories and Other Clothing Manufacturing

No.	Code	Industry Group	No.	Code	Industry Group
73	316100	Leather and Hide Tanning and Finishing	108	326110	Unsupported Plastic Film, Sheet and Bag Manufacturing
74	316200	Footwear Manufacturing	109	326120	Plastic Pipe, Pipe Fitting and Unsupported Profile Shape Manufacturing
75	316900	Other Leather and Allied Product Manufacturing			
76	321100	Sawmills and Wood Preservation	110	326130	Laminated Plastic Plate, Sheet and Shape Manufacturing
77	321215	Structural Wood Product Manufacturing			
78	32121A	Veneer and Plywood Mills	111	326160	Plastic Bottle Manufacturing
79	32121B	Particle Board, Fibreboard, and Waferboard Mills	112	3261A0	Polystyrene, Urethane and Other Foam Product Manufacturing
80	321911	Wood Window and Door Manufacturing	113	326193	Motor Vehicle Plastic Parts Manufacturing
81	321919	Other Millwork			
82	321920	Wood Container and Pallet Manufacturing	114	32619A	Miscellaneous Plastic Product Manufacturing
83	321990	All Other Wood Product Manufacturing	115	326210	Tire Manufacturing
84	322110	Pulp Mills	116	326220	Rubber and Plastic Hose and Belting Manufacturing
85	322121	Paper (except Newsprint) Mills			
86	322122	Newsprint Mills	117	326290	Other Rubber Product Manufacturing
87	322130	Paperboard Mills	118	327100	Clay Product and Refractory Manufacturing
88	322210	Paperboard Container Manufacturing			
89	322220	Paper Bag and Coated and Treated Paper Manufacturing	119	327200	Glass and Glass Product Manufacturing
			120	327310	Cement Manufacturing
90	322230	Stationery Product Manufacturing	121	327320	Ready-Mix Concrete Manufacturing
91	322290	Other Converted Paper Product Manufacturing	122	3273A0	Concrete Product Manufacturing
			123	327400	Lime and Gypsum Product Manufacturing
92	323110	Printing			
93	323120	Support Activities for Printing	124	327900	Other Non-Metallic Mineral Product Manufacturing
94	324120	Asphalt Paving, Roofing and Saturated Materials Manufacturing			
			125	331100	Iron and Steel Mills and Ferro-Alloy Manufacturing
95	3241X0	Petroleum Refineries and Other Petroleum and Coal Products Manufacturing	126	331210	Iron and Steel Pipes and Tubes Manufacturing from Purchased Steel
96	325110	Petrochemical Manufacturing	127	331220	Rolling and Drawing of Purchased Steel
97	325120	Industrial Gas Manufacturing	128	331313	Primary Production of Alumina and Aluminum
98	325130	Synthetic Dye and Pigment Manufacturing			
			129	331317	Aluminum Rolling, Drawing, Extruding and Alloying
99	3251A0	Other Basic Chemical Manufacturing			
100	325200	Resin, Synthetic Rubber, and Artificial and Synthetic Fibres and Filaments Manufacturing	130	331410	Non-Ferrous Metal (except Aluminum) Smelting and Refining
			131	3314A0	Non-Ferrous Metal (except Aluminum) Rolling, Drawing, Extruding and Alloying
101	325300	Pesticides, Fertilizer and Other Agricultural Chemical Manufacturing			
102	325400	Pharmaceutical and Medicine Manufacturing	132	331510	Ferrous Metal Foundries
			133	331520	Non-Ferrous Metal Foundries
103	325510	Paint and Coating Manufacturing	134	332100	Forging and Stamping
104	325520	Adhesive Manufacturing	135	332200	Cutlery and Hand Tool Manufacturing
105	325610	Soap and Cleaning Compound Manufacturing	136	332311	Prefabricated Metal Building and Component Manufacturing
106	325620	Toilet Preparation Manufacturing	137	33231A	All Other Plate Work and Fabricated Structural Product Manufacturing
107	325900	Other Chemical Product Manufacturing			

No.	Code	Industry Group	No.	Code	Industry Group
138	332320	Ornamental and Architectural Metal Products Manufacturing	165	335100	Electric Lighting Equipment Manufacturing
139	332410	Power Boiler and Heat Exchanger Manufacturing	166	335200	Household Appliance Manufacturing
140	332420	Metal Tank (Heavy Gauge) Manufacturing	167	335311	Power, Distribution and Specialty Transformers Manufacturing
141	332430	Metal Can, Box and Other Metal Container (Light Gauge) Manufacturing	168	335312	Motor and Generator Manufacturing
142	332500	Hardware Manufacturing	169	335315	Switchgear and Switchboard, and Relay and Industrial Control Apparatus Manufacturing
143	332600	Spring and Wire Product Manufacturing	170	335910	Battery Manufacturing
144	332710	Machine Shops	171	335920	Communication and Energy Wire and Cable Manufacturing
145	332720	Turned Product and Screw, Nut and Bolt Manufacturing	172	3359A0	Wiring Devices and All Other Electrical Equipment and Component Manufacturing
146	332800	Coating, Engraving, Heat Treating and Allied Activities	173	336100	Motor Vehicle Manufacturing
147	332900	Other Fabricated Metal Product Manufacturing	174	336200	Motor Vehicle Body and Trailer Manufacturing
148	333110	Agricultural Implement Manufacturing	175	336300	Motor Vehicle Parts Manufacturing
149	333120	Construction Machinery Manufacturing	176	336400	Aerospace Product and Parts Manufacturing
150	333130	Mining and Oil and Gas Field Machinery Manufacturing	177	336500	Railroad Rolling Stock Manufacturing
151	333X00	Industrial, Commercial and Service Industry Machinery Manufacturing	178	336611	Ship Building and Repairing
152	333400	Ventilation, Heating, Air-Conditioning and Commercial Refrigeration Equipment Manufacturing	179	336612	Boat Building
153	333500	Metalworking Machinery Manufacturing	180	336900	Other Transportation Equipment Manufacturing
154	333600	Engine, Turbine and Power Transmission Equipment Manufacturing	181	337110	Wood Kitchen Cabinet and Counter Top Manufacturing
155	333910	Pump and Compressor Manufacturing	182	337127	Institutional Furniture Manufacturing
156	333920	Material Handling Equipment Manufacturing	183	33712A	Household Furniture Manufacturing
157	333990	All Other General-Purpose Machinery Manufacturing	184	337200	Office Furniture (including Fixtures) Manufacturing
158	334100	Computer and Peripheral Equipment Manufacturing	185	337900	Other Furniture-Related Product Manufacturing
159	3342X0	Telephone Apparatus, Radio and Television Broadcasting, and Wireless Communication Equipment Manufacturing	186	339100	Medical Equipment and Supplies Manufacturing
160	334290	Other Communications Equipment Manufacturing	187	339920	Sporting and Athletic Goods Manufacturing
161	334300	Audio and Video Equipment Manufacturing	188	339930	Doll, Toy and Game Manufacturing
162	334400	Semiconductor and Other Electronic Component Manufacturing	189	339940	Office Supplies (except Paper) Manufacturing
163	334500	Navigational, Measuring, Medical and Control Instruments Manufacturing	190	339950	Sign Manufacturing
164	334600	Manufacturing and Reproducing Magnetic and Optical Media	191	3399X0	Jewellery, Silverware and All Other Miscellaneous Manufacturing
			192	410000	Wholesale Trade
			193	4A0000	Retail Trade
			194	481000	Air Transportation
			195	482000	Rail Transportation
			196	483000	Water Transportation
			197	484000	Truck Transportation

No.	Code	Industry Group
198	485100	Urban Transit Systems
199	485200	Interurban and Rural Bus Transportation
200	485300	Taxi and Limousine Service
201	485A00	All Other Transit and Ground Passenger Transportation
202	486200	Pipeline Transportation of Natural Gas
203	486A00	Crude Oil and Other Pipeline Transportation
204	487000	Scenic and Sightseeing Transportation
205	488000	Support Activities for Transportation
206	49X000	Postal Service and Couriers and Messengers
207	493130	Farm Product Warehousing and Storage
208	4931A0	All Other Warehousing and Storage
209	511A00	Newspaper, Periodical, Book and Diertory Publishers (except by Internet)
210	511200	Software Publishers
211	512130	Motion Picture and Video Exhibition
212	5121A0	Motion Picture and Video Production, Distribution, Post-Production and Other Motion Picture and Video Industries
213	512200	Sound Recording Industries
214	515100	Radio and Television Broadcasting (except Internet)
215	515200	Pay and Specialty Television
216	516000	Internet Publishing and Broadcasting
217	517500	Cable and Other Program Distribution
218	517A00	Telecommunications except Cable and Other Program Distribution
219	518100	Internet Service Providers, Web Search Portals
220	518200	Data Processing, Hosting, and Related Services
221	519000	Other Information Services
222	5A0110	Monetary Authorities - Central Bank
223	5A0120	Local Credit Unions
224	5A0130	Banking and Other Depository Credit Intermediation
225	5A0200	Insurance Carriers
226	5A0300	Lessors of Real Estate
227	5A0400	Owner-Occupied Dwellings
228	5A0510	Automotive Equipment Rental and Leasing
229	5A0520	Rental and leasing (except Automotive Equipment) and Lessors of Non-Financial Intangible Assets (except Copyrighted Works)
230	5A0610	Non-Depository Credit Intermediation and Activities Related to Credit Intermediation
231	5A0620	Agencies, Brokerages and Other Insurance Related Activities
232	5A0630	Securities, Commodity Contracts, Funds, and Other Financial Investment and Financial Vehicles
233	5A0640	Offices of Real Estate Agents and Brokers and Activities Related to Real Estate
234	5A0650	Management of Companies and Enterprises
235	541A00	Legal, Accounting, Tax Preparation, Bookkeeping and Payroll Services
236	541300	Architectural, Engineering and Related Services
237	541500	Computer Systems Design and Related Services
238	541800	Advertising and Related Services
239	541B00	Other Professional, Scientific and Technical Services
240	561500	Travel Arrangement and Reservation Services
241	561600	Investigation and Security Services
242	561700	Services to Buildings and Dwellings
243	561A00	Other Administrative and Support Services
244	562000	Waste Management and Remediation Services
245	611B00	Other Schools, Instruction and Educational Support Services
246	621100	Offices of Physicians
247	621200	Offices of Dentists
248	621A00	Miscellaneous Ambulatory Health Care Services
249	623000	Nursing and Residential Care Facilities
250	624000	Social Assistance
251	711000	Performing Arts, Spectator Sports and Related Industries
252	712000	Heritage Institutions
253	713200	Gambling Industries
254	713A00	Amusement and Recreation Industries
255	721100	Traveller Accommodation
256	721A00	RV (Recreational Vehicle) Parks, Recreational Camps, and Rooming and Boarding Houses
257	722000	Food Services and Drinking Places
258	811100	Automotive Repair and Maintenance

No.	Code	Industry Group	No.	Code	Industry Group
259	811A00	Repair and Maintenance (except Automotive Repair and Maintenance)	274	NP1300	Non-Profit Sports and Recreation Clubs
260	812200	Funeral Services	275	NP2000	Non-Profit Education Services
261	812300	Dry Cleaning and Laundry Services	276	NP1900	Other Non-Profit Institutions Serving Households
262	812A00	Personal Care Services and Other Personal Services	277	GS1100	Hospitals
263	813A00	Grant-Making, Civic, and Professional and Similar Organizations	278	GS1200	Government Residential Care Facilities
264	814000	Private Households	279	GS2100	Universities
265	F10100	Operating Supplies	280	GS2210	Government Elementary and Secondary Schools
266	F10200	Office Supplies	281	GS2220	Government Community Colleges and C.E.G.E.P.s
267	F10300	Cafeteria Supplies	282	GS2230	Other Government Education Services
268	F10400	Laboratory Supplies	283	GS4000	Other Municipal Government Services
269	F20100	Travel and Entertainment	284	GS5000	Other Provincial and Territorial Government Services
270	F20200	Advertising and Promotion	285	GSX000	Other Federal Government Services including Defence
271	F30000	Transportation Margins			
272	NP1100	Religious Organizations			
273	NP1200	Non-Profit Welfare Organizations			

Source: Statistics Canada, 2009b.

A.5 Commodity Groups: Worksheet Level Aggregation

No.	Code	Commodity Group
1	10	Cattle and calves
2	30	Hogs
3	40	Poultry
4	59	Other live animals
5	71	Wheat, unmilled, excluding imputed feed
6	72	Wheat, unmilled, imputed feed
7	81	Grain corn, excluding imputed feed
8	82	Corn fodder, imputed feed
9	83	Barley, excluding imputed feed
10	84	Other grains, excluding imputed feed
11	85	Other grains and fodder, imputed feed
12	90	Fluid milk, unprocessed
13	100	Eggs in the shell
14	110	Honey and beeswax
15	130	Fresh fruit, excluding tropical
16	141	Potatoes, fresh or chilled
17	142	Other vegetables, fresh or chilled
18	151	Hay and straw, excluding imputed feed
19	152	Hay and straw, imputed feed
20	169	Seeds, excluding oil seeds
21	170	Nursery stock, flowers, and other horticulture products
22	181	Canola
23	182	Soybeans and other oil seeds
24	200	Raw tobacco
25	219	Raw wool and mink skins
26	2311	Services incidental to crop production
27	2312	Services incidental to animal production
28	2313	Veterinary fees
29	2314	Tree pruning and surgery services
30	2315	Animal (pet) training, grooming and boarding services
31	232	Services incidental to forestry
32	249	Logs
33	259	Other wood in the rough including poles, piling and bolts
34	260	Pulpwood
35	270	Other forestry products including fuel wood and cork
36	280	Custom forestry
37	2901	Fish and seafood (except animal aquaculture), fresh, chilled or frozen
38	2902	Animal aquaculture products, fresh, chilled or frozen
39	300	Hunting and trapping products
40	320	Gold and alloys in primary forms
41	340	Iron ores and concentrates
42	3501	Bauxite ore
43	3502	Alumina (refined bauxite)
44	3601	Copper, nickel, lead and zinc ores and concentrates
45	03602X	Radioactive and all other miscellaneous metal ores and concentrates
46	370	Coal
47	380	Crude mineral oils
48	390	Natural gas, excluding liquefied
49	410	Sulphur
50	430	Gypsum
51	440	Salt
52	450	Peat
53	460	Clays
54	470	Natural abrasives and industrial diamonds
55	4801	Unsorted and non-industrial diamonds
56	04802X	Asbestos and other miscellaneous non-metallic minerals
57	490	Sand and gravel, excluding silica
58	501	Stone and silica sand for industrial use
59	502	Building and crushed stone
60	510	Services incidental to mining
61	521	Beef, fresh, chilled or frozen
62	522	Pork, fresh, chilled or frozen
63	523	Other meat excluding poultry, fresh, chilled or frozen
64	524	Edible offal excluding poultry, fresh, chilled or frozen
65	540	Cured meat
66	559	Prepared meat products
67	570	Animal fat and lard
68	580	Margarine and shortening
69	590	Sausage casings
70	619	Feeds from animal by-products
71	620	Raw animal hides and skins
72	639	Animal by-products for industrial use
73	640	Custom work, meat and food
74	650	Poultry, fresh, chilled or frozen
75	679	Fluid milk, processed
76	680	Fresh cream
77	690	Butter
78	700	Cheese
79	719	Evaporated and condensed dairy products
80	720	Ice cream
81	731	Powdered dairy products
82	732	Other miscellaneous dairy products
83	740	Mayonnaise, salad dressing and mustard
84	751	Fish and seafood products, fresh, chilled or frozen
85	752	Fish and seafood products, canned or otherwise preserved
86	761	Frozen fruit and juice concentrates

No.	Code	Commodity Group
87	762	Fruit juices, excluding frozen concentrates
88	763	Other fruit products including dried fruit and fruit peel
89	770	Fruit and jam in airtight containers
90	781	Frozen potatoes
91	782	Other frozen vegetables
92	783	Other preserved vegetables
93	790	Vegetables and vegetable juices in airtight containers
94	800	Soups in airtight containers
95	810	Infant and junior foods in airtight containers
96	820	Pickles, relishes and other sauces
97	830	Vinegar
98	841	Mineral water, fruit-flavoured beverages and ice
99	842	Pasta products, excluding dry pasta
100	843	Prepared meals
101	850	Feed supplements and premixes
102	860	Complete feeds
103	879	Feeds from grain by-products
104	889	Feeds from vegetable by-products
105	890	Pet feeds
106	900	Wheat flour
107	919	Starches
108	920	Breakfast cereal products
109	930	Biscuits
110	940	Bread and rolls
111	951	Other bakery products
112	952	Food snacks excluding potato chips and nuts
113	960	Cocoa and chocolate
114	979	Nuts
115	989	Chocolate confectionery
116	999	Other confectionery
117	1010	Sugar
118	1030	Feeds from vegetable oil by-products including oil cake and other residues
119	1040	Crude vegetable oils
120	1059	Nitrogen function compounds
121	1069	Other flours and processed grains
122	1071	Maple sugar and syrup
123	1072	Molasses and other syrups
124	1080	Prepared cake and other mixes
125	1090	Dehydrated soup mixes and bases
126	1100	Roasted coffee
127	1110	Tea
128	1120	Potato chips and flakes
129	1131	Spices
130	1132	Peanut butter
131	1133	Food and drink powders
132	1134	All other miscellaneous food products
133	1135	Infant and junior foods, excluding in airtight containers
134	1136	Dry pasta
135	1140	Soft drink concentrates
136	1150	Carbonated soft drinks
137	1161	Distilled alcohol beverages, bought in stores
138	1162	Distilled alcohol beverages, consumed on license premises
139	1191	Beer including coolers, bought in stores
140	1192	Beer including coolers, consumed on license premises
141	1201	Wine including coolers, bought in stores
142	1202	Wine including coolers, consumed on license premises
143	1219	Unmanufactured tobacco
144	1220	Cigarettes
145	1239	Other tobacco products
146	1240	Waterproof footwear
147	1250	Motor car tires
148	1279X	Tires and tubes excluding motor car tires
149	1289	Tire repair material and rethreaded tires
150	1300	Conveyor and transmission belting
151	1311	Self-adhesive tape (in rolls of a width not exceeding 20 cm)
152	1312	Other rubber products
153	1320	Hose and tubing, mainly rubber
154	13511	Plastic film and sheet, not laminated
155	13512	Laminated plastic plates, sheets and shapes
156	1352	Foamed and expanded plastics
157	1353	Other plastic products, including cups
158	1354	Plastic building supplies
159	1355	Other rubber end-products
160	1360	Plastic containers and closures
161	1389	Plastic pipe and pipe fittings
162	1399	Leather, chamois, composition leather and parings and other waste of leather
163	1400	Footwear, excluding waterproof
164	1410	Leather gloves
165	1430	Trunks, suitcases, briefcases, school satchels and similar containers
166	1440	Handbags, wallets and similar personal articles such as eyeglass and cigar cases and coin purses
167	1450	Cotton yarn
168	1470	Cotton woven fabric
169	1480	Tire cord fabric

No.	Code	Commodity Group
170	1509	Bedding
171	1519	Wool and wool mix yarn and thread
172	1520	Wool and wool mix woven fabric
173	1539	Felt
174	1540	Man-made staple fibres
175	1550	Polyamide resins, including nylon
176	1561	Filament yarn
177	1562	Yarn of staple fibres
178	1570	Tire yarn
179	1581	Man-made fabric for clothing
180	1582	Man-made fabric for industrial use
181	1583	Pile fabric
182	1620	Cotton thread
183	1630	Man-made thread
184	1659	Rope and twine
185	1679	Narrow fabrics, including lace
186	1700	Textile floor covering
187	1710	Textile dyeing and finishing service
188	1729	Tarpaulins, awnings and sunblinds
189	1730	Tents, sails and sleeping bags
190	1789	Other household textile products
191	1791	Textile medical products
192	1792	Other textile products
193	1800	Hosiery
194	1829	Knitted fabrics
195	1831	Men's and boys' knitted clothing
196	1832	Sweaters
197	1833	Women's knitted clothing
198	1834	Children's knitted clothing
199	1841	Men's and boys' clothing, excluding knitted
200	1842	Women's underwear and sleepwear
201	1843	Other women's clothing, excluding knitted
202	1844	Children's wear, excluding knitted
203	1859	Other clothing and accessories, excluding dressed furs and fur apparel
204	1869	Dressed furs
205	1880	Fur apparel
206	1890	Custom tailoring
207	1900	Wood chips
208	1911	Lumber and timber, not treated
209	1912	Lumber and timber, treated
210	1930	Wood waste including saw dusts, shavings and peeler log cores
211	1940	Custom wood work and millwork
212	1950	Plywood and veneer
213	1961	Wooden doors and windows
214	1962	Kitchen cabinets
215	1963	Other millwork
216	1979	Wood structural products
217	1980	Wood prefabricated buildings
218	1999	Wood containers and pallets
219	2000	Caskets and coffins
220	2011	Shingles and shakes
221	2012	Particle and wafer board
222	2013	Other wood end-products
223	2041	Household furniture
224	2042	Furniture parts
225	2050	Office furniture
226	2069	Commercial and institutional furniture
227	2079	Mattresses and other furniture
228	2089	Table, desk, bedside and floor lamps
229	2090	Wood pulp
230	2100	Newsprint paper
231	2119	Other paper, containing wood
232	2129	Other paper, wood free
233	2139	Tissue and sanitary paper stock
234	2149	Wrapping and sack paper and paper bag stock
235	2159	Paperboard, including boxboard
236	2161	Building board and paper
237	2162	Asphalt building products
238	2179	Toilet paper, facial tissues, paper towel, paper serviettes and paper napkins and tablecloths
239	2199	Paper waste and scrap
240	2200	Vinyl floor and wall covering
241	2211	Paper bags and sacks
242	2212	Paper boxes, cartons and drums
243	2213	Plastic bags
244	2221	Corrugated paper and board
245	2222	Wallpaper
246	2223	Other coated paper and coated paper products
247	2239	Aluminium foil
248	2241	Paper diapers and sanitary napkins
249	2242	Textile hygiene products
250	2259	Paper containers for commercial use
251	2261	Paper stationery
252	2262	Other stationery supplies
253	2263	Photographic paper
254	2270	Other paper end-products
255	2281	Newspapers
256	2282	Magazines and periodicals
257	2291	Books
258	2292	Greeting cards, post cards, maps and charts

No.	Code	Commodity Group	No.	Code	Commodity Group
259	2300	Unused postage stamps, banknotes, cheque forms, and stock and bonds certificates and similar documents of title	295	2650	Other primary products of non-alloy copper, excluding castings
260	2311	Printed business forms	296	2660	Other primary products of copper alloys, excluding castings
261	2312	Advertising flyers, catalogues, and directories	297	2670	Other primary products of lead and lead alloys, excluding castings
262	2313	Other printed products	298	2680	Other primary products of nickel and nickel alloys, excluding castings
263	2320	Advertising in print media	299	2690	Non-ferrous metal castings
264	2330	Specialized publishing service	300	2710	Soldering rods and wire
265	23401	Printing type, blocks, plates, cylinders and other printing components	301	2720	Fabricated steel plate
266	23402	Support activities for printing	302	2730	Metal tanks
267	2369X	Ferro-alloys and iron and steel ingots, billets and other primary forms	303	2749	Power boilers
268	2380	Steel castings	304	2760	Iron and steel structural materials
269	2391	Steel bars and rods, non-alloy, excluding reinforced	305	2781	Prefabricated metal buildings
270	2392	Reinforcing bars and rods	306	2782	Prefabricated metal structures
271	2393	Alloy steel bars and rods	307	2791	Metal doors and windows
272	2419	Flat iron and steel, not alloy, not coated	308	2792	Other metal building products
273	2429	Flat iron and steel, alloy, coated	309	2810	Corrugated metal culvert pipe
274	2440	Iron and steel railway construction material	310	2820	Iron and steel stampings
275	2450	Tar and pitch	311	2839	Metal roofing, siding, ceilings, partitions, decks and balconies
276	2460	Carbon and graphite products	312	2851	Metal kitchen utensils
277	2480	Oil and gas casing and drill pipe	313	2852	Other kitchen utensils
278	2490	Oil and gas line pipe	314	2861	Other metal containers and closures
279	2509	Other iron and steel pipes and tubes	315	2862	Food, beverage and other cans
280	2511	Other cast iron products	316	2870	Iron and steel wire and cable
281	2512	Grinding balls and ingot moulds	317	2880	Iron and steel wire fencing and screen
282	2521	Cast iron pipe and fittings	318	2890	Chain, excluding motor vehicle and power transmission
283	2522	Other iron and steel pipe fittings	319	2900	Welding rods and wire electrodes
284	2530	Nickel in primary forms	320	2919	Wire products, including springs
285	2540	Copper in primary forms	321	2929	Fastener hardware
286	2571	Aluminium and alloy ingots, billets, blocks and slabs	322	2939	Builders' hardware
287	2572	Aluminium and alloys in other primary forms	323	2949	Other hardware
288	2590	Precious metals in primary forms excluding gold	324	2961	Machine tools
289	2600X	Lead, zinc and other non-ferrous metals in primary forms	325	2962	Tool accessories
290	2609	Other primary products of other non-ferrous metals	326	2979	Hand and measuring tools
291	2629	Other inorganic bases and metallic oxides	327	2980	Scissors, razor blades and manicure and pedicure sets
292	2631	Metal scrap and waste, excluding iron and steel	328	2991	Household clothes washers and dryers
293	2632	Iron and steel scrap and waste	329	2992	Household dishwashers
294	2649	Other primary products of aluminium and aluminium alloys, excluding castings	330	2993	Lawn mowers, snow blowers, and lawn sprinklers
			331	3019	Non-electric furnaces and heating equipment
			332	3049	Commercial cooking equipment
			333	30501	Custom metal working, excluding coating, engraving, and heated treated metal

No.	Code	Commodity Group
334	30502	Coated, engraved, heat treated or similarly treated metal products
335	3060	Iron and steel forgings
336	3070	Valves
337	3081	Metal plumbing fixtures and fittings
338	3082	Plastic plumbing fixtures and fittings
339	3090	Gas and water meters
340	3100	Fire fighting and traffic control equipment
341	3120	Firearms and military hardware
342	31491X	Wheel and crawler tractors and engines, parts and assemblies thereof
343	3150	Other agricultural machinery
344	3161	Bearings
345	3162	Mechanical power transmission equipment
346	3170	Pumps, compressors, fans and blowers
347	3180	Conveyors, elevators and hoisting machinery
348	3190	Industrial trucks and material handling equipment
349	3200	Fans and air circulation units, not industrial
350	3211	Packaging and bottling machinery
351	3212	Air purification equipment
352	3213	Other general purpose machinery
353	3220	Industrial furnaces, kilns and ovens
354	32311	Construction machinery
355	32312	Mining and oil and gas field machinery
356	3232	Logging and pulp and paper industry machinery
357	3233	Metal working machinery
358	3234	Other industry specific machinery
359	3235	Service industry machinery
360	3240	Power hand tools
361	3261	Air conditioning equipment, wall and window
362	3262	Air conditioning and refrigeration equipment, commercial and transport
363	3270	Scales and balances
364	3280	Vending machines
365	3291	Computers and peripherals equipment such as terminals, printers and storage devices
366	3292	Office equipment, excluding photocopy and fax machines
367	3310X	Aircraft and aircraft engines
368	3320	Aircraft parts and equipment
369	3330	Aircraft service and repairs
370	33401	Automobiles, excluding passenger vans
371	33402	Passenger vans
372	33403	Used motor vehicles (business to persons)
373	3350	Trucks, road tractors and chassis
374	3360	Buses and chassis
375	3371	Off-highway trucks
376	3372	Military motor vehicles
377	3373	Motor homes, motorcycles and atvs
378	3380	Mobile homes
379	3391	Non-commercial trailers
380	3392	Commercial trailers and semi-trailers
381	3409	Truck and bus bodies and cargo containers
382	3410	Motor vehicle engines and parts
383	3420	Motor vehicle electric equipment
384	3431	Motor vehicle stampings
385	3432	Motor vehicle steering and suspension
386	34331	Motor vehicle wheels
387	34332	Motor vehicle brakes
388	3434	Motor vehicle plastic parts and trim
389	3435	Motor vehicle fabric accessories
390	34361X	Motor vehicle transmission and power train parts and other motor vehicle parts and accessories
391	3459	Locomotive, railway and urban transport rolling stock
392	3470	Parts for locomotive, railway and urban transport rolling stock
393	3489	Ships and boats and parts thereof, excluding pleasure boats and sporting craft
394	3500	Ship repairs
395	3519	Snowmobiles
396	3520	Pleasure boats and sporting craft
397	3531	Microwave ovens
398	35321	Sewing machines, vacuum cleaners and floor polishers
399	35322	Other small household appliances
400	3549	Electric furnace and other electric heating equipment
401	3550	Household refrigerators and freezers
402	3560	Household cooking equipment, excluding microwave ovens
403	3571	Radio, stereo, cassette and CD players and similar equipment, and accessories
404	35721	TV, VCR, and accessories
405	35722	Unrecorded tapes (blanks)
406	3580	Telephone and related equipment, including fax machines
407	3599	Broadcasting and radio communications equipment

No.	Code	Commodity Group	No.	Code	Commodity Group
408	3600	Radar and radio navigation equipment	451	3970	Lubricating oils and greases
409	3619	Semi-conductors	452	3980	Benzene, toluene and xylene
410	3621	Printed circuits	453	3990	Liquid petroleum gases
411	3622	Integrated circuits	454	4000	Naphtha
412	3623	Other electronic equipment components	455	4011	Asphalt compound, hot bulk
413	3630	Electronic alarm and signal systems	456	4012	Other asphalt products
414	3650	Welding machinery and equipment	457	4020	Petrochemical feed stock
415	3661	Power generation and marine propellers, non-electric	458	4031	Animal and vegetable fertilizers, imputed
416	3662	Electrical generators and motors	459	4032	Animal and vegetable fertilizers, excluding imputed
417	3671	Ballast	460	4033	Potash
418	3672	Transformers and converters	461	4034	Chemical fertilizers
419	3689	Industrial electric equipment, including safety	462	4041	Ethylene polymers
			463	4042	Vinyl polymers
420	3690	Batteries	464	4043	Other polymers
421	3700	Insulated wire and cable, excluding aluminium	465	4050	Cellulosic plastic film and sheet
			466	4070	Monoethylene glycol
422	3710	Aluminium wire and cable	467	4080	Pharmaceuticals
423	3729	Wiring materials and electrical meters	468	4090	Paints and related products
424	3739	Electric light bulbs and tubes	469	4109	Refined vegetable oils
425	3741	Electric lighting fixtures, excluding portable	470	4120	Oral care products
			471	4131	Soaps
426	3742	Vehicle lighting equipment	472	4132	Detergents
427	3750	Cement	473	4133	Other cleaning products
428	3760	Lime	474	4149	Other industrial chemical preparations
429	3779	Concrete products	475	4151	Cosmetic products
430	3790	Ready-mix concrete	476	4152	Hair care products
431	3800	Bricks and other clay building products	477	4153	Other personal care products
432	3810	Porcelain insulators	478	4154	Bleach and fabric softeners
433	3820	Ceramic household products	479	4160	Chlorine
434	3830	Refractory products	480	4170	Oxygen
435	3849	Natural stone products	481	4180	Phosphorous
436	3860	Gypsum building products	482	4190	Other chemical elements
437	3870	Mineral wool building products	483	4200	Sulphuric acid
438	3880	Asbestos products	484	4229	Other inorganic acids and oxygen compounds
439	3890	Other non-metallic mineral basic products			
440	3901	Glass and other glass products	485	4230	Ammonia
441	3902	Safety glass	486	4240	Caustic soda
442	3903	Optical fibre cables	487	4260	Sodium chlorate
443	3904	Glass fibres including glass wool and articles thereof, excluding glass woven fabrics and tire cord fabrics	488	4280	Sodium phosphates
			489	4290	Sodium carbonate
			490	4329	Other metallic salts and peroxysalts
444	3910X	Glass containers, mirrors and other glass household products	491	4331	Deuterium oxide (heavy water)
			492	4332	Radioactive chemicals
445	3930	Abrasive products	493	4333	Other inorganic chemicals
446	3950	Motor gasoline	494	4340	Ethylene
447	3961	Aviation fuel	495	4350	Butylenes
448	3962	Diesel oil	496	4360	Butadiene
449	3963	Light fuel oil	497	4380	Styrene
450	3964	Heavy fuel oil	498	4400	Vinyl chloride

No.	Code	Commodity Group	No.	Code	Commodity Group
499	4449	Other hydrocarbons and derivatives	540	5110	Floor and wall covering, backed with paper
500	4450	Methyl alcohol			
501	4499	Other alcohols and derivatives	541	5120	Illuminated signs, illuminated name-plates and the like
502	4520	Ethers and epoxy derivatives of alcohols			
503	4539	Other phenols, aldehydes and ketones	542	5130	Shades and blinds
504	4599	Organic acids and derivatives	543	5151	Custom work, refined petroleum and coal
505	4630	Organo-inorganic compounds	544	5159	Other custom work
506	4640	Other organic chemicals	545	5179	Hair and bristles of pigs, hogs, boars, baggers and horses, coarse animal hair not carded or combed, and waste of these products
507	4650	Titanium dioxide, excluding slag			
508	4660	Carbon			
509	4679	Pigments, lakes and dyes			
510	4700	Synthetic rubber	546	5189	Other metal end-products
511	4710	Antifreeze preparations	547	5190	Sewing needs
512	4729	Additives and automobile chemicals	548	52011	Recorded media, including music, movies and pre-packaged software
513	4740	Rubber and plastic compounding agents			
514	4759	Explosives and non-military ammunition	549	52012	Musical instruments and artists' supplies
515	4770	Military ammunition and ordnance	550	5202	Smokers' supplies
516	4790	Crude vegetable materials and extracts	551	5219	Art and decorative goods and miscellaneous end products
517	4810	Insecticides and herbicides			
518	4820	Adhesives	552	5220	Repair construction
519	4860	Catalysts	553	5230	Residential building construction
520	4870	Metal working industrial chemicals	554	5240	Non-residential building construction
521	4880	Printing and other inks	555	5250	Road, highway and airport runway construction
522	4900	Polish, cream and wax products			
523	4949	Other oils, fats and waxes	556	5260	Gas and oil facility construction
524	4970	Aircraft and nautical navigation instruments, excluding radio	557	5270	Electric power, dams and irrigation construction
525	4999X	Laboratory and scientific instruments, flight simulators, and measuring and controlling instruments	558	5280	Railway and telecommunications construction
			559	5290	Other engineering construction
526	5001	Medical and dental equipment and supplies	560	5301	Air transportation, passenger
			561	5302	Air transportation, freight
527	5002	Ophthalmic goods	562	5303	Air transportation, specialty
528	5003	Personal medical goods	563	5304	Services incidental to air transportation
529	5010	Industrial safety equipment	564	53111	Scenic and sightseeing transportation, bus
530	5020	Clocks and watches and parts thereof, excluding watch straps, bands and bracelets	565	53112	School bus and other transportation
			566	5312	Ambulance services
531	5031	Optical and photographic equipment	567	5321	Travel agents, tour wholesaler and operator services
532	5032	Photocopy and microfilm equipment			
533	5033	Photographic film and plate	568	5322	Parking services
534	5049	Pearls and precious stones excluding diamonds, jewellery and imitation jewellery, and articles of precious metals including silverware	569	5323	Other services incidental to transportation
			570	5331	Water transportation, passenger
			571	5332	Water transportation, freight
			572	5333	Water transportation, other
535	5060	Brooms, mops and brushes of all kinds	573	5340	Services incidental to water transportation
536	5079	Bicycles	574	5351	Rail transportation, passenger
537	5080	Recreational equipment	575	5352	Rail transportation, freight
538	5099	Toys and games, including electronic	576	5353	Services incidental to rail transport
539	5100	Impregnated and coated fabrics	577	5360	Truck transportation

No.	Code	Commodity Group	No.	Code	Commodity Group
578	5371	Bus transportation, interurban and rural, passenger	612	55581	Other securities, funds, and related services
579	5372	Bus transportation, interurban and rural, parcel express	613	55582X	Other non-depository credit intermediation services and royalties and licence fees (excluding natural resource)
580	5380	Urban transit			
581	5390	Taxi and limousine transportation services	614	55583	Management fees of companies and enterprises
582	54001	Pipeline transportation of natural gas	615	5559	Real estate commissions and management fees
583	54002	Crude oil and other pipeline transportation			
			616	5561	Life insurance
584	5410	Highway and bridge maintenance	617	5562	Non-life insurance
585	5421	Grain storage	618	5563	Trusteed pension funds
586	5422	Other storage and warehousing	619	5564	Insurance commissions
587	54301	Radio and television broadcasting, except cable	620	5570	Gross imputed rent
			621	5580	Gross paid residential rent
588	54302	Cable and other subscription programming	622	5591	Imputed lodging
			623	5592	Lodging in universities
589	5440	Telephone and other telecommunication services	624	5593	Other paid lodging, excluding universities
590	5450X	Postal and courier services	625	5594	Non-residential rent
591	5460	Electric power	626	56101	University fees
592	5470	Gas distribution	627	56102	Elementary and secondary school fees
593	5480	Coke	628	56103	College and C.E.G.E.P. fees
594	5491	Water supply	629	56104	Other education fees
595	5492	Other utilities	630	5620	Private hospital services
596	5500	Wholesaling margins	631	5631	Private residential care facilities
597	55101	Automotive repair and maintenance service	632	5632	Child care, outside the home
			633	5633	Other health and social services
598	55102	Other repair and maintenance	634	56341	Laboratory services
599	5520	Rental of office equipment	635	56342	Physician services
600	5531	Retailing margins	636	56343	Dental service
601	5532	Retailing service	637	56344	Other health practitioner services
602	5541	Central bank	638	5641	Motion picture, audio, and video product and distribution
603	55421	Implicit charges, deposits, banking and other deposit credit intermediation	639	5642	Motion picture exhibition
604	55422	Implicit charges, loans, banking and other deposit credit intermediation	640	5651	Lottery and other gambling
			641	5652	Race track services
605	5551	Paid charges, banks and other deposit account intermediation	642	5653	Other amusement and recreation services
			643	5661	Architect, engineering, and scientific services
606	55521	Implicit charges, deposits, local credit unions	644	5662	Accounting and legal services
607	55522	Implicit charges, loans, local credit unions	645	5670	Advertising services
			646	5680	Laundry and dry cleaning services
608	5553	Paid charges, credit unions and caisses pop	647	56901	Hotel and motel accommodation services
			648	56902	Other accommodation services
609	5555	Commissions, investment banking and securities dealing	649	57001	Meals (outside home)
			650	57002	Board paid
610	5556	Implicit charge, non-depository credit intermediation	651	5721	Barber and beauty services
			652	5722	Funeral services
611	5557	Mutual funds	653	5723	Child care, in the home

No.	Code	Commodity Group	No.	Code	Commodity Group
654	5724	Private household service	683	58702	Social assistance services provided by non-profit institutions serving households
655	5725	Other personal care services	684	58703	Art, entertainment and recreation services provided by non-profit institutions serving households
656	5730	Photographic services	685	58704	Education services provided by non-profit institutions serving households
657	5740	Services to buildings and dwellings	686	587051	Other services provided by non-profit institutions serving households
658	57511	Software products development	687	587052	Aboriginal government services
659	57512	Own-account Software	688	58706	Government funding of hospital
660	5752	Computer lease and rental (hardware)	689	58707	Government funding of residential care facilities
661	57531	Data processing services	690	58708	Government funding of universities
662	57532	Computer systems design and related services	691	587091	Government funding of elementary and secondary schools
663	57533	On-line information services	692	587092	Government funding of community colleges and C.E.G.E.P's
664	57611	Other information services	693	587093	Government funding of other education
665	57612	Investigation and security services	694	58710	Defence services
666	57613	Other professional, scientific and technical services	695	58711	Other municipal government services
667	57614	Other administrative and support services	696	58712	Other provincial government services
668	57615	Other personal services	697	58713	Other federal government services
669	5770	Rental of automobiles and trucks	698	5880	Raw cotton
670	57801	Trade unions dues	699	5890	Natural rubber and gums
671	57802	Political parties	700	5900	Raw sugar
672	57803	Other membership organization dues	701	5910	Cocoa beans
673	5791	Rental, video and recreation equipment	702	5920	Coffee, not roasted
674	5792	Rental, other machinery and equipment including construction	703	5930	Tropical fruit
675	5800	Spare parts and maintenance supplies	704	5940	Unallocated imports and exports
676	5810	Office supplies	705	5950	Sales of other government services
677	5820	Cafeteria supplies			
678	5830	Transportation margins			
679	5840	Laboratory equipment and supplies			
680	5850	Travelling and entertainment			
681	5860	Advertising and promotion			
682	58701	Religious organization services			

Source: Statistics Canada, 2009b.

A.6 Final Demand Categories: Worksheet Level Aggregation

No.	Code	Final Demand Category
1	PE0011	Personal expenditures, food and non-alcoholic beverages
2	PE0012	Personal expenditures, food (imputed)
3	PE002	Personal expenditures, alcoholic beverages bought in stores
4	PE003	Personal expenditures, tobacco products
5	PE004	Personal expenditures, men's and boy's clothing
6	PE005	Personal expenditures, men's and boy's clothing, repair and alterations
7	PE006	Personal expenditures, women's and children's clothing
8	PE007	Personal expenditures, women's clothing, repair and alterations
9	PE008	Personal expenditures, footwear
10	PE009	Personal expenditures, shoe repair
11	PE010	Personal expenditures, gross imputed rent
12	PE011	Personal expenditures, gross rent paid
13	PE012	Personal expenditures, other shelter expenses
14	PE013	Personal expenditures, electricity
15	PE014	Personal expenditures, natural gas
16	PE015	Personal expenditures, other fuels
17	PE016	Personal expenditures, furniture and floor covering
18	PE017	Personal expenditures, upholstery and furniture repair
19	PE018	Personal expenditures, household appliances
20	PE019	Personal expenditures, household equipment repairs
21	PE020	Personal expenditures, semi-durable household furnishings
22	PE021	Personal expenditures, non-durable household supplies
23	PE022	Personal expenditures, domestic and child care services
24	PE023	Personal expenditures, other household services
25	PE024	Personal expenditures, medical care
26	PE025	Personal expenditures, hospital care and the like
27	PE026	Personal expenditures, accident and sickness insurance
28	PE027	Personal expenditures, drugs and pharmaceutical products
29	PE028	Personal expenditures, new and used (net) motor vehicles
30	PE029	Personal expenditures, motor vehicles parts and accessories
31	PE030	Personal expenditures, motor vehicle repairs
32	PE031	Personal expenditures, motor fuels and lubricants
33	PE032	Personal expenditures, other motor vehicle related services
34	PE033	Personal expenditures, purchased transportation
35	PE034	Personal expenditures, communications
36	PE035	Personal expenditures, recreation, sporting and camping equipment
37	PE036	Personal expenditures, recreation equipment repair and rentals
38	PE037	Personal expenditures, reading and entertainment supplies
39	PE038	Personal expenditures, recreational services
40	PE039	Personal expenditures, educational and cultural services
41	PE040	Personal expenditures, jewellery and watches
42	PE041	Personal expenditures, jewellery and watch repair
43	PE042	Personal expenditures, leather goods and other personal effects
44	PE043	Personal expenditures, toilet articles and cosmetics
45	PE044	Personal expenditures, personal care
46	PE045	Personal expenditures, restaurants and accommodation services
47	PE046	Personal expenditures, financial, legal and other services
48	PE047	Personal expenditures, operating expenditures of non-profit institutions serving households
49	PE0481	Personal expenditures, travel expenditures, international imports
50	PE0482	Personal expenditures, travel expenditures, international exports
51	MEB49	Machinery and equipment, crop and animal production
52	MEB50	Machinery and equipment, forestry and logging
53	MEB51	Machinery and equipment, fishing, hunting and trapping
54	MEB52	Machinery and equipment, support activities for agriculture and forestry

No.	Code	Final Demand Category
55	MEB53	Machinery and equipment, oil and gas extraction
56	MEB54	Machinery and equipment, metal ore mining
57	MEB55	Machinery and equipment, coal and non-metallic mineral mining and quarrying
58	MEB56	Machinery and equipment, support activities for mining and oil and gas extraction
59	MEB57	Machinery and equipment, utilities
60	MEB58	Machinery and equipment, construction
61	MEB59	Machinery and equipment, food manufacturing
62	MEB60	Machinery and equipment, beverage manufacturing
63	MEB61	Machinery and equipment, tobacco manufacturing
64	MEB62	Machinery and equipment, textile and textile product mills
65	MEB63	Machinery and equipment, clothing manufacturing
66	MEB64	Machinery and equipment, leather and allied product manufacturing
67	MEB65	Machinery and equipment, wood product manufacturing
68	MEB66	Machinery and equipment, paper manufacturing
69	MEB67	Machinery and equipment, printing and related support activities
70	MEB68	Machinery and equipment, petroleum and coal products manufacturing
71	MEB69	Machinery and equipment, chemical manufacturing
72	MEB70	Machinery and equipment, plastics and rubber products manufacturing
73	MEB71	Machinery and equipment, non-metallic mineral product manufacturing
74	MEB72	Machinery and equipment, primary metal and fabricated metal product manufacturing
75	MEB73	Machinery and equipment, machinery manufacturing
76	MEB74	Machinery and equipment, computer and electronic product manufacturing and electrical equipment, appliance and component manufacturing
77	MEB75	Machinery and equipment, transportation equipment manufacturing
78	MEB76	Machinery and equipment, furniture and related product manufacturing
79	MEB77	Machinery and equipment, miscellaneous manufacturing
80	MEB78	Machinery and equipment, wholesale trade
81	MEB79	Machinery and equipment, retail trade
82	MEB80	Machinery and equipment, transportation (except pipeline transportation)
83	MEB81	Machinery and equipment, pipeline transportation
84	MEB82	Machinery and equipment, warehousing and storage
85	MEB83	Machinery and equipment, information and cultural industries
86	MEB84	Machinery and equipment, finance and insurance
87	MEB85	Machinery and equipment, real estate and rental and leasing services
88	MEB86	Machinery and equipment, professional, scientific and technical services
89	MEB87	Machinery and equipment, management of companies and enterprises
90	MEB88	Machinery and equipment, administration and support, waste management and remediation services
91	MEB89	Machinery and equipment, private educational services
92	MEB90	Machinery and equipment, health care and social assistance
93	MEB91	Machinery and equipment, arts, entertainment and recreation
94	MEB92	Machinery and equipment, accommodation and food services
95	MEB93	Machinery and equipment, other services
96	MEB94	Machinery and equipment, used cars and equipment and scrap
97	MEG95	Machinery and equipment, public educational services
98	MEG96	Machinery and equipment, universities
99	MEG97	Machinery and equipment, hospitals
100	MEG98	Machinery and equipment, federal government public administration
101	MEG99	Machinery and equipment, provincial and territorial public administration
102	MEG100	Machinery and equipment, local, municipal and regional public administration
103	CONB101	Construction, crop and animal production

No.	Code	Final Demand Category
104	CONB102	Construction, forestry and logging
105	CONB103	Construction, fishing, hunting and trapping
106	CONB104	Construction, support activities for agriculture and forestry
107	CONB105	Construction, oil and gas extraction
108	CONB106	Construction, metal ore mining
109	CONB107	Construction, coal, non-metallic mineral mining and quarrying
110	CONB108	Construction, support activities for mining and oil and gas extraction
111	CONB109	Construction, utilities
112	CONB110	Construction, construction
113	CONB111	Construction, food manufacturing
114	CONB112	Construction, beverage manufacturing
115	CONB113	Construction, tobacco manufacturing
116	CONB114	Construction, textile and textile product mills
117	CONB115	Construction, clothing manufacturing
118	CONB116	Construction, leather and allied product manufacturing
119	CONB117	Construction, wood product manufacturing
120	CONB118	Construction, paper manufacturing
121	CONB119	Construction, printing and related support activities
122	CONB120	Construction, petroleum and coal products manufacturing
123	CONB121	Construction, chemical manufacturing
124	CONB122	Construction, plastics and rubber products manufacturing
125	CONB123	Construction, non-metallic mineral product manufacturing
126	CONB124	Construction, primary metal and fabricated metal product manufacturing
127	CONB125	Construction, machinery manufacturing
128	CONB126	Construction, computer and electronic product manufacturing and electrical equipment, appliance and component manufacturing
129	CONB127	Construction, transportation equipment manufacturing
130	CONB128	Construction,furniture and related product manufacturing
131	CONB129	Construction, miscellaneous manufacturing
132	CONB130	Construction, wholesale trade
133	CONB131	Construction, retail trade
134	CONB132	Construction, transportation (except pipeline transportation)
135	CONB133	Construction, pipeline transportation
136	CONB134	Construction, warehousing and storage
137	CONB135	Construction, information and cultural industries
138	CONB136	Construction, finance and insurance
139	CONB137	Construction, real estate and rental and leasing services
140	CONB138	Construction, professional, scientific and technical services
141	CONB139	Construction, management of companies and enterprises
142	CONB140	Construction, administration and support, waste management and remediation services
143	CONB141	Construction, private educational services
144	CONB142	Construction, health care and social assistance
145	CONB143	Construction, arts, entertainment and recreation
146	CONB144	Construction, accommodation and food services
147	CONB145	Construction, other services
148	CONB146	Construction, transfer costs, non-residential construction
149	CONB147	Construction, housing construction, non-government sector
150	CONG148	Construction, public educational services
151	CONG149	Construction, universities
152	CONG150	Construction, hospitals
153	CONG151	Construction, federal government public administration
154	CONG152	Construction, provincial and territorial public administration
155	CONG153	Construction, local, municipal and regional public administration
156	INV152A	Inventoriy additions, finished goods and goods in process
157	INV152W	Inventory withdrawals, finished goods and goods in process
158	INV153A	Inventory additions, raw materials and goods purchased for resale
159	INV153W	Inventory withdrawals, raw materials and goods purchased for resale
160	GCE154	Government net current expenditures, hospitals and residential care facilities
161	GCE155	Government net current expenditures, education

No.	Code	Final Demand Category	No.	Code	Final Demand Category
162	GCE156	Government net current expenditures, defence	165	GCE159	Government net current expenditures, other federal government
163	GCE157	Government net current expenditures, other municipal government	166	EXP160	Exports, international
			167	REX161	Re-exports, international
164	GCE158	Government net current expenditures, other provincial and territorial government	168	IMP162	Imports, international

Source: Statistics Canada, 2009b.

A.7 Disaggregation Proxies for ABIO Model (S Level Aggregation)

	Cervid Production	Cattle Production	Remaining Crop and Animal Production
Year	2006	2006	
Farm Cash Receipts	11,471,494	3,400,315,000	
Total Farm Cash Receipts (AB)	7,796,488,000	7,796,488,000	
Variable	*w1*	*w2*	*w3 (w3=1-w2-w1)*
Proxy	0.001471367	0.436134193	0.56239444

Source: Statistics Canada, 2007; Agriculture and Rural Development, 2006.
Note: Cervid Production Receipt Variable by Deer Predominant Farms (50.5% deer and over).

A.8 Disaggregation Proxies for CANIO Model (W Level Aggregation)

	Cervid Production	Cattle Production	Remaining Animal Production (Except Animal Aquaculture)
Year	2006	2006	
Farm Cash Receipts	43,350,194	11,325,687,000	
Total Farm Cash Receipts (CAN)	17,959,991,000	17,959,991,000	
Variable	*w1*	*w2*	*w3 (w3=1-w2-w1)*
Proxy	0.002413709	0.630606496	0.366979794

Source: Statistics Canada, 2007; Agriculture and Rural Development, 2006.
Note: Cervid Production Receipt Variable by Deer Predominant Farms (50.5% deer and over).

A.9 Disaggregation Proxies for IRIO Model (S Level Aggregation)

	Cervid Production	Cattle Production	Remaining Crop and Animal Production
CANADA			
Year	2006	2006	
Farm Cash Receipts	43,350,194	11,325,687,000	
Total Farm Cash Receipts (CAN)	37,014,256,000	37,014,256,000	
Variable	*w1*	*w2*	*w3 (w3=1-w2-w1)*
Proxy	0.001171176	0.305981755	0.69284707
REST OF CANADA			
Year	2006	2006	
Farm Cash Receipts	31,878,700	7,925,372,000	
Total Farm Cash Receipts (CAN)	29,217,768,000	29,217,768,000	
Variable	*w1*	*w2*	*w3 (w3=1-w2-w1)*
Proxy	0.001091072	0.271251794	0.727657133

Source: Statistics Canada, 2007; Agriculture and Rural Development, 2006.
Note: Cervid Production Receipt Variable by Deer Predominant Farms (50.5% deer and over).