The Distribution of the Economic and Health Benefits from Canola Research

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Abstract

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Supervisor: Dr. R. Gray

Research and development have influenced the development of the canola industry in Canada. This study uses a three region equilibrium displacement model to examine the effects of two kinds of research and development on canola seed producers, canola processors, canola meal consumers and canola oil consumers. Given health information changes taste the conventional estimate of consumer surplus can not be applied. We modify the Dixit and Norman (1978) methodology to define an *ex post* measure of consumer surplus.

Two hypotheses are examined. The first is that canola producers, processors and consumers have benefited from the health and nutrition research, that increased the demand for canola oil. The second hypothesis is that producer, processor and consumer groups experienced a net gain from the canola's industry decision to focus on the agronomic research that reduced the potential yield of the canola seed in exchange for better quality characteristics.

The empirical findings of the study lead to a rejection of the first hypothesis. Although the industry as a whole has gained from health research, Canadian consumers, surprisingly, were worse off with improved health information because they were already enjoying the health benefit at a lower price. Furthermore, the increased consumption

of canola oil is shown to generate a positive externality due to a reduction in coronary heart disease costs. These external benefits exceeded the total internal/private benefits within the industry.

We fail to reject the second hypothesis. There is not enough empirical evidence to determine whether or not the canola industry or other social groups are worse off from focusing research on the quality characteristics of canola products at the expense of potential yield. It is interesting to note that, according to the mathematical model presented, there are some instances, or parameter ranges, which show that the entire canola industry and/or other social groups were made worse off by pursuing quality based research goals. While this result seems negative at the outset, one should keep in mind the opportunity cost of not pursuing the quality based research goals. In other words, had quality based research not been pursued one might expect the growth of the industry to be either inhibited or ceased altogether.

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CHAPTER I

Introduction

1.1 Statement of the Problem

Agricultural research is an economic activity that involves investment of scarce resources in the production of knowledge and innovations (Ruttan, 1982). Agricultural research can be classified into two main categories: supply-shifting research (agronomic research) and demand-increasing research. The first category has received much attention and several models have been developed to analyze cases of tradable and non-tradable commodities, agricultural policies, multistage frameworks, etc. (for a review see Norton and Davis, 1981; Ruttan, 1982; and Alston, 1991). On the other hand, demand-increasing research is a relatively new topic and few attempts have been made in this area (e.g., Unnevehr, 1986; Lemieux and Wohlegenant, 1989; Voon, 1991; Voon and Edwards, 1989, 1991a, 1992).

The development of the canola industry is the result of research in Canada. As with any industry that relies on sales to foreign markets, there is a constant struggle to maintain a competitive advantage. In Canada, canola is probably the most recent and most pronounced example of how research and development can improve the comparative advantage of an industry. At the beginning of the 1970s, rapeseed/canola was a minor crop, and no canola crushing industry existed. By the beginning of 1990s, due to extensive research on many aspects of canola, canola had become a major crop and a large industry had been built around it.

The effect of rapeseed/canola research on agriculture and agricultural income in western Canada has been enormous. Evidence of the impact of canola in Saskatchewan is most prominent in the black soil zone. In fact, since 1960, canola has managed to steadily displace other traditional crops from the black soil zone crop rotation. Across Canada, the canola seeded acreage has increased from 5,628,265 acres in 1971 to 13,923,393 acres in 1994 (Canadian Wheat Board, various issues). As a result, the value of canola production in Saskatchewan, during the same period, has increased from $134.4 million to $2,160.9 million (Statistics Canada 21-603, various issues).

While much of the agronomic research focused on increasing yields, considerable effort was also made to improve the quality of rapeseed varieties. Extensive breeding efforts were made to reduce the level of erucic acid and glucosinolate in rapeseed. After some success the higher quality double zero varieties were given the name canola. Given this focus on quality a reasonable question to ask is whether the welfare impacts of the decision to breed for quality came at the expense of some yield increase.

Agronomic research has affected canola production, while medical/nutritional research has promoted the consumption of canola oil. Recent medical/nutritional research findings that monounsaturated oils are preferable to polyunsaturated or saturated oils, combined with the granting of generally regarded as safe (GRAS) status to canola in the United States, have increased demand for canola. Thus, farmers are not the only group to benefit from the agronomic research that produced canola: consumers and taxpayers may benefit from oilseed research as a result of better health and lower health care costs.

The literature on the cost-benefit analysis of research and development (R&D) stresses that not all economic benefits of research accrue to farmers (e.g., Alston, 1991; Alston and Mullen, 1992). Because the sources of research funding are many, the distribution of returns among the different sectors involved in canola production is very important.

The estimation of the benefit from the R&D in canola industry is more accurate if an open economy model is used. Specifically, Canada is a relatively large exporter of canola products (oil and meal), but is also a large exporter of unprocessed canola seed. Hence, as the canola industry operates in a open-economy environment, the return to research should be measured within this environment in order to estimate the health benefits accruing in Canada.

In estimating the R&D benefit to the canola industry it is necessary to use a multimarket setting. The canola industry is composed primarily of four sectors: the seed sector, the processing sector, the meal sector and the oil sector. Although these sectors are separated by degrees of canola product refinement, they are linked by the prices of their respective products. As the sectors are linked, a change in one sector affects all the other markets. Consequently, an increase in the demand for canola oil affects not only consumers, but producers and processors as well. Similarly, the reduction in yield affects not only producers, but consumers and processors also. In addition, the intermediate goods as well as the final products are traded internationally.

1.2 Need for the Study

There is a need for further evaluation of the economic impact from the rapeseed/canola research. The existing literature on the costs and benefits of canola research indicates agronomic research has paid large dividends in terms of increased industry growth, increased producer income and lower consumer prices (Nagy and Furtan, 1977). However, some aspects of agronomic research on canola seed have not been examined extensively. Little research has been done to examine the impact of medical/nutritional research on the demand for canola oil. The health benefits and savings in health care costs also lack documentation. As well, the effect of research from outside agriculture (e.g. health) on the agriculture industry has not been examined. Finally, the calculation of the R&D benefit in a canola industry in the multimarket setting and in the open-economy environment has seldom been attempted.

1.3 Objective of the Study

The main objective of the study is to examine the welfare impacts of quality related health information and agronomic research on participants in canola market. Specifically, this study will estimate the welfare implications of the increased demand for canola oil arising from medical and nutritional research. This will include an estimate of the reduction in the cost of coronary heart disease due to the increased consumption of canola oil. The study will also estimate the welfare implications of the reduction in potential yield that occurred in the switch from rapeseed to higher quality canola varieties. Yield enhancing research and development is not examined. This analysis will also examine the distribution of research benefits among the different sectors (canola seed sector, canola processing input sector, canola oil sector and canola meal sector) and between certain social groups (producers, processors and consumers of canola oil and meal) in Canada, Japan and the rest of the world.

1.4 Hypothesis of the Study

With the framework described in the previous section, two hypotheses will be examined:

(1) The canola industry as a whole, and the producer, processor and consumer groups within it, benefited from health/nutrition research, which increased the demand for canola oil, and

(2) The canola industry as a whole, and the producer, processor and consumer groups, experienced a net gain from the decision to focus on agronomic research that focused on better quality characteristics of the canola products at the expense of crop yield potential.

1.5 Organization of the Study

The remainder of the thesis is organized into five chapters. The second chapter gives a brief description of the rapeseed/canola industry in Canada, which includes a discussion of the change in yield of rapeseed/canola seed throughout the years of its development. In addition, there will be a discussion of the revealed nutritional properties of canola oil. A review of the literature on measurement of welfare with demand and supply shifts is provided in Chapter III. The economic surplus measures and the different critical assumptions of the economic surplus analysis are also discussed. Chapter III concludes with a discussion of alternative estimation methods to economic surplus analysis. Chapter IV contains the graphical and mathematical form of the model, which will be used to estimate the welfare effects of the demand/supply shifts. This chapter also discusses the necessity of using a multimarket and open-economy setting to model the canola market. The analysis and empirical results of the estimation are presented in Chapter V. Finally, Chapter VI contains a summary and the conclusions of the thesis.

Chapter II

Overview of the Rapeseed/Canola Industry in Canada

2.1 Introduction

The purpose of this chapter is to discuss the background of the rapeseed/canola industry in Canada. The chapter begins with a historical overview of the utilization of rapeseed/canola, from the time it was primarily used as a lubricant until the present, when it has become an edible oil reputed to be the world's healthiest vegetable oil. The yield improvement of rapeseed/canola seed will also be discussed, based on agronomic research findings. This chapter concludes with a discussion of canola's nutritional properties.

2.2 History and Utilization of Rapeseed/Canola

Rapeseed has historically had limited use. The first known usage of rapeseed oil is believed to have occurred in China and India about 4000 years ago. The Chinese used rapeseed oil mainly in lamps but also for cooking. In contrast, European agriculture only began cultivating rapeseed since roughly the 13th century. The Europeans also used rapeseed oil in lamps and in industrial products, but rarely for human consumption. Rapeseed oil was rarely consumed because it was dark, had a strong unpleasant taste and was believed to be toxic (National Research Council, 1992).

Despite the early production of rapeseed in the Eastern Hemisphere, the practice of cultivating rapeseed in Canada was not introduced until the early 19th century. In fact, prior to 1942, due to the absence of a market for rapeseed, the cultivation of rapeseed was limited in scope and generally served research purposes. During the Second World War, the rapid increase in the use of steam engines in naval and merchant ships created a demand for rapeseed oil. Rapeseed oil had been found to be the best lubricant available for use in steam engines because it could cling to water and steam-wasted metal surfaces (White, 1974).

After the war, the demand for rapeseed diminished, as did the demand for other industrial inputs, such as steel, rubber and petroleum. Rapeseed oil was an inferior low-grade industrial lubricant and had no other significant purpose when petroleum products were once again available to meet market demands. In addition, combustion engines were supplanting steam engines. A small portion of the rapeseed oil had been used for human consumption during the war, due to a serious shortage of edible fat and oil in Canada, but with the greater availability of edible fats and oils after the war, rapeseed oil was no longer in demand. Consequently, the production of rapeseed also declined in the post-war period.

In Canada, after the war, there was a realization that there was no secure domestic supply of edible oils. Canadian crushers paid premiums for whatever imported oilseed they could find. Consequently, there was no guarantee that, if the market situation changed, there would be an adequate import supply of oils to satisfy Canadian consumers. Hence, the development of a Canadian edible oil source was perceived as a matter of national security (National Research Council, 1992).

Desiring a domestic source of edible oil, Canada began to investigate agronomically feasible alternatives. Although rapeseed could be cultivated in Canada, it was not immediately considered because of the adverse properties of the oil and meal. Specifically, rapeseed was known to yield a high-quality oil suitable only for specific industrial purposes, and a meal suitable only as fertilizer. It was found that the rapeseed oil was green and unappetizing because it contained a lot of chlorophyll. The agronomic potential of rapeseed led to a significant push, through scientific research and technological development, to try to develop a rapeseed plant that would yield oil for human use. However, efforts in the early to mid-1950s to transform rapeseed into an acceptable oil for margarine and salad oil focused on the processing techniques and technology. From 1951 to 1956, a relatively small quantity of edible liquid oil was marketed in Montreal. This represents the first significant use of rapeseed oil for human consumption in the Canadian domestic market since the war years (Youngs, 1974).

Early medical/nutritional research provided evidence that rapeseed products had adverse properties. Research efforts, prior to 1956, were focused on the palatability of the rapeseed oil. The health implications of rapeseed consumption were not a large consideration in that research. However, for the first time, in 1956, K.K. Carroll, Department of Medical Research, University of Western Ontario, presented evidence which suggested that the consumption of rapeseed oil was not as safe as previously believed. Specifically, Carroll found that the consumption of rapeseed oil resulted in reduced weight gains, fatty heart, increased cholesterol content and increased weight of adrenal glands in rats (Sauer and Kramer, 1983). Additionally, rapeseed meal was found to have adverse affects on animal health, because it affected the thyroid gland. Consequently, the high levels of glucosinolates could cause metabolic upset, lowering the efficiency of feed-to-weight-gain ratios in the case of non-ruminant animals (Blakely and Anderson, 1948; Bell, 1955; Nordfeldt et al., 1954; Bowland et al., 1965; Bell and Wetter, 1974). Due to these findings, Bell (1955) suggested incorporating no more than 10% of rapeseed meal in the total feed ration for animals. This negative health evidence further reduced the potential development of a domestic market for rapeseed consumption products.

Due to this negative health evidence there was a ban on the use of rapeseed oil for edible purposes. Specifically, on July 23, 1956, the Canadian Food and Drug Directorate of the Department of National Health and Welfare ruled that "rapeseed oil was not approved edible oil in Canada and that, in view of literature reports of abnormalities arising from feeding rapeseed oil to experimental animals, sale of this oil for edible purposes was to cease immediately and all stocks currently on retail shelves were to be withdrawn" (Youngs, 1974).

The ban on the use of rapeseed oil did not last long. The Department of Health and Welfare was persuaded to withdraw its objection after a thorough review at the Canadian Committee on Fats and Oils meeting in October, 1956. The committee concluded that, even though erucic acid was identified as the cause of difficulty, there was no indication that rapeseed oil represented a hazard to human health, because of the limited use in the Canadian diet and the lack of evidence regarding the effects of human consumption. The committee also set three goals in the meeting: to obtain more nutritional data and information about the harmful effects of high erucic acid; to examine whether breeding plants could develop rapeseed varieties with low erucic acid content; and to review the health records and autopsy reports in Germany, because during the war rapeseed oil was the primary oil there in human diets (Boulter, 1983).

The rapeseed breeding program started to focus on the quality characteristics of the rapeseed products after the ban on the use of rapeseed oil for human consumption. Prior to 1956, although food processors were preoccupied with processing innovations, rapeseed breeders were preoccupied with the agronomic improvements of rapeseed, particularly with increasing the rapeseed yield. However, after Carroll's findings that rapeseed oil caused "fatty heart" on rats, scientists became increasingly concerned with the quality (health) characteristics of rapeseed products. They were most concerned with the high level of erucic acid in rapeseed oil and the high level of glucosinolates in the rapeseed meal. Since the focus of research was now on the quality characteristics of rapeseed, the rapeseed breeding program played an important part role in the development of varieties low in erucic acid. Specifically, the first low erucic acid rapeseed variety was released in Canada in 1968. During this time there were also many other low erucic acid varieties under development (Stefansson, 1990).

The concern over the erucic acid issue was renewed in the beginning of the 1970s. In the 1970, the International Rapeseed

Conference, Ste. Adele, Quebec, released results of nutritional research on experimental animals fed quantities of rapeseed oil containing a high level of erucic acid (e.g., Salmon, 1970; Walker, et al., 1970; Abdellatif and Vles, 1970; Beare-Rogers, 1970). These results showed that high erucic acid oils, such as rapeseed oil, caused changes in the heart tissue of some experimental animals. This additional evidence of the relation between the myocardial lesions and consumption of high erucic acid oils renewed the concern over the erucic acid issue. On the other hand, plant breeders reported that new low erucic acid rapeseed varieties had been developed in many countries. Consequently, the conference recommendations stated that all countries should gradually change over to these new rapeseed varieties. Canada was committed to converting to low erucic acid rapeseed varieties (Proceedings of the International Conference on the Science, Technology and Marketing of Rapeseed and Rapeseed Products, 1970; Bell, 1981).

After the International Rapeseed Conference in 1970, the rapeseed industry underwent, with great effort, the conversion to low erucic acid rapeseed varieties. Although the breeding program began shortly after the war, the first landmark quality (health) improvement did not occur until 1968, with the development of the first rapeseed variety low in erucic acid, which was Oro (from Argentina). Ten years later, Agriculture Canada registered the first rapeseed variety with low erucic acid and low glucosinolate (double-low), Tower (from Argentina). Finally, in 1977 Agriculture Canada registered the first Polish rapeseed variety with low erucic acid and low glucosinolate, Candle. The producers' adaptation to the newer (better quality) varieties of rapeseed was reasonably quick. By

1974 the conversion to low erucic acid rapeseed was 95% complete, and by 1984 the conversion to the double-low varieties had occurred (Kneen, 1992).

Due to the significant improvement in the quality of the rapeseed products, there needed to be a means of differentiating the new varieties from the older varieties in the market place. In 1978 the name "canola" was initially registered by the Western Canadian Oilseed Crushers Association to designate rapeseed varieties with low erucic acid (5% or less) in oil and low glucosinolate content (three milligrams per gram or less) in the meal. In 1980, to complete the process, the Canola Council assumed the canola trademark. Later, in 1985, the Canola Council of Canada and the Agriculture Canada presented data to the Food and Drug Administration of the United States Department of Health and Human Services which granted canola oil the status of "Generally Regarded as Safe" (GRAS) (FDA: Act. 21 CFR Part 184, 1555c). This designation developed a new marketplace for the canola oil. In the following year, the Trade Marks Branch of Consumer and Corporate Affairs further tightened the quality restrictions on the canola trademark. The new canola trademark designated rapeseed varieties with erucic acid less than 2% and glucosinolate less than 30 micromoles per gram. This restriction continues in effect, as of 1995 (Kneen, 1992; Dupont et al., 1989).

2.3 Yield Improvement of Canola Varieties

Two types of canola varieties, Argentinian species (Brassica napus L) and Polish species (Brassica rapa L), are grown in Canada. These varieties grow best in cool, moist areas, in soil containing a high amount of organic matter. Thus, the main production areas are in the Peace River regions of Alberta, north-central Saskatchewan, and the northwest and southern regions of Manitoba. These areas are often classified as the Park Belt or Black and Gray soil zones.

These two species of canola have different agronomic characteristics. Argentinian varieties are higher yielding (15% to 20%), need to be sown earlier (between May 8 and 25), take longer to mature (10 to 20 days), and are less tolerant to frost (spring or fall frost) than Polish varieties. However, the yield advantage of Argentinian varieties depends on the location and the weather pattern in a given year. Under frost or drought conditions Polish varieties yield about the same as Argentinian varieties. Hence, Polish varieties are less risky. Because Polish varieties mature early, they are grown in the northern part of the Park Belt area where the early fall frost is very common. Moreover, Polish varieties are slower to improve genetically than Argentinian varieties because their breeding requires more cumbersome techniques. Regardless of the difference between the species of rapeseed/canola, there tends to be no distinction between them in the market. Typically, Argentinian varieties and Polish varieties are mixed and sold together (Canadian International Grains Institute, 1993).

Although rapeseed/canola breeding has been successful in producing both better agronomic and quality characteristics, the quality-improvement often came at the expense of yield. Specifically, there was a significant steady yield gain from 1954 to 1972, when the first Argentinian variety, Golden became available. In 1972, with a switch to low erucic acid varieties, the yield potential declined. Then, there was a jump in yield in the period 1981-85. After that, the yield potential followed a steady increase. Similarly, there was an increase in yield in Polish rapeseed/canola varieties until the period 1971-75. The change in quality attributes affected the Polish varieties too. In 1977, with the release of the double-low Candle variety, a similar decline in yield was observed. However, the yield started to increase in the period 1981-85 and since then yield growth has been steady, but quite slow compared to Argentinian varieties (Forhan, 1993; similar results were found by Ulrich, Furtan and Downey, 1984; Ulrich and Furtan, 1985).

2.4 Medical/Nutritional Considerations

Balanced nutrition and physical health appear to be a growing concern for consumers, particularly in developed countries, where the average dietary fat intake is relatively high. This issue first gained attention in 1957, when the American Heart Association (AHA) published evidence that there existed a relationship between high-caloric diets (characterized by high saturated fat intake), high cholesterol levels and coronary heart disease (CHD). As a result, in the late 1950s public awareness and concern about daily fat intake began to increase (Ahrens et al., 1957).

The Food and Agricultural Organization/World Health Organization (FAO/WHO) (1977) estimated that the average daily fat intake in developed countries represented more than 40% of the total dietary caloric intake. Approximately 50% of the average daily fat intake was visible fat (lard, butter and the various vegetable oils). The remaining was invisible fat, which comes (indirectly) from consumption of products like milk, meat and meat products, cheese, and eggs. Medical research findings since 1957 have shown that a high concentration of saturated fatty acids, as found in fats of animal origin, increase the blood cholesterol level (Ahrens et al., 1957; Keys et al., 1965; Hegsted et al., 1965; Keys, 1970). These findings started a trend away from animal fat consumption and an increase in the demand for vegetable oils. During the late 1970s and early 1980s, medical research discovered that different saturated fatty acids raise cholesterol to varying degrees. It was also found that some vegetable oils high in saturated fats, particularly coconut and palm oil, were as harmful as animal products (Grundy and Vega, 1988).

In the middle of the 1980s a continued concern about nutrition and fat intake brought about research that highlighted the nutritional differences between the two categories of vegetable oil: oils high in polyunsaturated fatty acids and oils high in monounsaturated fatty acids. Polyunsaturated fatty acids such as soybean, sunflower, maize and safflower oil, lowered serum cholesterol levels, while monounsaturated fatty acids present in oils such as olive, canola and groundnut oil were thought to have a neutral effect (Keys et al., 1965; Hegsted et al., 1965; O'Brien et al., 1976; Jackson et al., 1978). However, diets rich in polyunsaturated fatty acids, especially when fed in high amounts, have been shown to lower both low-density lipoprotein (LDL) (positively correlated with CHD) and high-density lipoprotein (HDL) which is negatively correlated with CHD (Vega et al., 1982; Ehnholm et al., 1984; Kuusi et al., 1985; Mattson and Grundy, 1985; Spady and Dieteschy, 1988). In 1984, for the first time, it was shown that the consumption of monounsaturated fatty acids such as canola oil are preferable to polyunsaturated fatty acids, because the monounsaturated fatty acids lower LDL (harmful) cholesterol levels but do not lower HDL (beneficial) cholesterol levels (Ferro-Luzzi et al., 1984; Mattson and Grundy, 1985; Siritori et al., 1986; Mensink and Katan, 1989; Baggio et al., 1988; Garg et al., 1988; Grundy and Vega, 1988; McDonald et al., 1989; Rudel et al., 1990).

The fatty acid composition of canola oil is the most impressive of all the vegetable oils. Canola oil contains the lowest level of saturated fatty acids (7%) of any vegetable oil or animal fat. Corn oil, olive oil and soybean oil contain about double the level of saturated fatty acids of canola oil. Canola oil, like olive oil, is high (61%) in the monounsaturated fatty acid oleic acid. Canola oil also contains an appreciable level of polyunsaturated fatty acid (32%), primarily linoleic acid (22%) and alpha-linolenic acid (11%). Alpha-linolenic acid has been shown to increase blood clotting time (McDonald et al., 1989; Weaver et al., 1990) and so can reduce the likelihood of thrombosis and hence a CHD risk. The only other major edible oil that contains a significant amount of alpha-linolenic acid (8%) is soybean. Canola oil contains more polyunsaturated fatty acid than palm oil and olive oil, but less polyunsaturated fatty acid than sunflower oil, corn oil, soybean oil or cottonseed oil.

2.5 Total Cholesterol, CHD and Canola Oil Diet

Dietary fat is very important in the human diet (McDonald, 1994). Dietary fat can be an important source of essential fatty acids, a primary source of metabolic energy and a carrier for necessary fat-soluble vitamins. Additionally, dietary fat improves both food palatability and the feeling of satisfied hunger.

Although dietary fat serves many important functions, it has implications in the development of CHD. Specifically, a high level of serum cholesterol is a major risk factor in CHD. A number of other risk factors have been found to be associated with CHD: cigarette smoking, high blood pressure, obesity, physical inactivity, diabetes mellitus and hypertension. However, the contribution of these factors to the development of CHD is relatively small compared to a high level of serum cholesterol (Reeder et al., 1995).

CHD is caused by two major events: altherosclerosis and thrombosis (Fitzpatrick, 1991). The formation of altherosclerotic plaques clog the channels of the coronary arteries, the vessels that supply the heart. Altherosclerosis develops slowly and most often causes inschemic heart disease (IHD). On the other hand, thrombosis, or the formation of a blood clot, blocks narrow arteries, which results in a sudden coronary heart attack or a stroke.

2.5.1 A Major Risk Factor of CHD

The evidence from epidemiologic, clinical-trial (Grundy, 1990), animal (Steiner and Kendall, 1946; Atkinson et al., 1992; Kusumi et al., 1993; McGill et al., 1981; Armstrong et al., 1970; Clarkson et al., 1988) and genetic (Brown and Goldstein, 1986; Goldstein and Brown, 1989; Tybjaerg-Hansen and Humphries, 1992; Rauh et al., 1992) investigations strongly supports a relationship between cholesterol and CHD. For instance, as far as the epidemiologic evidence is concerned, there are three types of studies which provide evidence of the correlation between cholesterol and CHD: between-countries studies, migration studies and within-a-single-country studies.

All three types of epidemiological studies generally reveal a similar relationship between cholesterol and CHD. The first type of epidemiologic evidence, from between-countries studies, shows that, in countries with the highest cholesterol levels, the occurrence of CHD was highest and, in countries with the lowest cholesterol levels, the occurrence of CHD was lowest (Keys, 1980; Keys et al., 1984; People's Republic of China-United States Cardiovascular and Cardiopulmonary Epidemiology Research Group, 1992). The second type of epidemiologic evidence, from migration studies, shows that migration from countries with low cholesterol levels (e.g., Japan) to countries with high cholesterol levels results in a rise in the cholesterol level and a rise in CHD (Kagan et al., 1974; Toor et al., 1960). The third type of epidemiologic evidence, from studies within a single country, reveals a strong correlation between serum cholesterol level (both in women and men) and CHD (Gordon et al., 1981; Stamler, 1986; Pooling Project Research Group, 1978; Jacobs et al., 1992; Anderson et al., 1987). This kind of cross-study support strengthens the validity of the revealed relationship between cholesterol and CHD.

Of particular interest is the important result of the "in-country" study of the cholesterol-CHD correlation. Specifically, one study screened 361,662 men for the Multiple Risk Factor Intervention Trial (MRFIT) (MRFIT Research Group, 1991). The results of this survey show a strong, positive, curvilinear relationship between cholesterol level and CHD, which specifically showed that men with higher cholesterol levels have higher CHD mortality rates and men with lower cholesterol levels have lower CHD mortality rates. According to the derived relationship, even those with lower cholesterol levels can develop CHD. On the contrary, the CHD mortality rate is still significant even in the lower cholesterol levels. Hence, this evidence supports the concept that a high level in serum cholesterol is a major factor in CHD.

According to medical research and the relationship between serum cholesterol and CHD, it is possible to reduce the CHD rate by reducing serum cholesterol intake. In fact, clinical-trial evidence shows that, in the short term, a 1% reduction in serum cholesterol levels may result in a 2% reduction in CHD rates (National Institutes of Health, 1993). Moreover, epidemiological studies suggest that, in the long term, a 1% reduction in serum cholesterol levels may result in a 3% reduction in CHD rates (Davis et al., 1990; National Cholesterol Education Program, 1991; National Cholesterol Education Program, 1992).

2.5.2 The Major Causes of Death

CHD is the major cause of death world-wide. In the early 1990s, the age-standardized mortality rate for CHD in 20 selected countries showed that the death rates from CHD ranged from 771 per 100,000 population (Romanian males) to 252 per 100,000 population (Japanese males). The country with the highest morality rate is Romania, followed by the Russian Federation, Poland, Argentina, Finland and Germany. During the same period, Canada's rate of death from CHD for men was 460 per 100,000 population and for women 270 per 100,000 population (Reeder et al., 1995).

In 1992, 38% of the total deaths recorded were due to CHD in Canada. CHD is followed by cancer (28%), accidents (7%) and all other causes of death (27%). Of this 38%, Ischemic Heart Disease (IHD), strokes and other forms of CHD account for 22%, 7% and 9% of deaths in Canada, respectively. The death rate due to IHD has decreased from 25% to 22% from 1988 to 1992 (Reeder et al., 1995).

2.5.3 Economic Impact of CHD

The direct cost of CHD in Canada is enormous: "Direct cost is the value of resources actually expended that could have been allocated elsewhere in the absence of disease." It is estimated that in 1993 the cardiovascular disease or CHD cost $8.3 billion in Canada (Reeder et al., 1995). In fact, CHD is the most expensive disease category. In terms of the cost of other diseases, CHD is followed by respiratory, musculoskeletal, digestive, cancer and other diseases. In 1993, CHD accounted for 16% of the total direct costs of disease in Canada (Reeder et al., 1995).

Indirect cost is not included in the estimation of the cost of CHD because it is not available. "Indirect cost refers to the value of lost productivity due to illness or disability, and the loss of future earning due to premature death" (Reeder et al., 1995). Hence, the cost of CHD would be even more than $8.3 billion if the indirect costs of the disease were included as well.

The direct cost of CHD is composed of hospital expenditures, medical care, drugs, pensions and benefits, and research. Hospital expenditures account for $5.2 billion, which represents 63% of the total direct cost of CHD. Drug expenditures account for $1.6 billion, which represents 18.9% of the total direct cost of CHD. Medical care and pensions/benefits represent 11% and 6.3% of the total direct cost of CHD. Finally, CHD ranked third in research cost. The cost of CHD research accounts for $65 million, which represents 0.8% of the total direct cost of CHD (Reeder et al., 1995).

Medical/nutritional research has revealed that a canola oil diet can reduce the total cholesterol level and consequently may affect the cost of CHD. Studies in Canada, the United States and Finland show that diets including canola oil instead of other energy sources result in significant decreases in serum cholesterol level from 2.30% to 18.4%. For instance, Bierenbaum et al. (1991) found that replacing 30 ml/day of fat in the diets of a group of 36 with a mean serum cholesterol level of 6.56 mmol/L with 30 ml/day canola oil resulted in reducing the mean serum cholesterol by 2.3%. Chan et al. (1991) also found that replacing 26% of total energy in the diets of a group of 8 people with a mean serum cholesterol level 4.4 mmol/L with 26% of total energy provided by canola oil resulted in a reduction in the mean serum cholesterol by 18.4%. Similar results were found by Wardlaw et al. (1991), McDonald et al. (1989), Miettined and Vanhanen (1994), and Valsta et al. (1992). Finally, as mentioned earlier, from 1988 to 1992 the deaths due to IHD have been reduced from 25% to 22% (Reeder et al., 1995). During the same period, the consumption of canola oil in Canada increased from 328,000 tonnes to 451,000 tonnes (United States Department of Agriculture, Foreign Agriculture Service, 1995). These results show a relationship between an increase in the consumption of canola oil and a decrease in the morality rate due to CHD. Hence, the consumption of canola oil may affect the social cost of health care and provide an extra benefit to the canola industry. Consequently, it is of interest to estimate the total reduction in health care costs due to substituting canola oil for a portion of the fat in regular diets.

2.6 Conclusion

This section has looked at the historical development and utilization of rapeseed/canola products. Although many important issues were discussed, only three are directly relevant to our hypothesis:

(a) The switch to canola quality research resulted in a drop in potential yield (The combined yield of B. napus L and B. rapa L varieties decreased from the middle of 1970s to the beginning of 1980s).

(b) Through the promotion of medical/nutritional research, consumers of edible oils have become aware of the nutritional/healthy properties of canola oil. As a result, the demand for canola oil has increased since the late 1980s.

(c) Consumption of canola oil produces health benefits external to the market.

Chapter III

Literature Review

3.1 Introduction

As discussed in the overview of the rapeseed/canola industry in Chapter II, an observed decrease in the yield of canola/rapeseed varieties occurred as research efforts focused on producing varieties with higher quality. Simply put, there seemed to be a notable tradeoff between yield and quality, in terms of new variety innovation. Furthermore, beginning in the late 1980s, the demand for canola oil increased, as more health-related information was revealed to consumers. The purpose of this chapter is to establish an economic framework in which these events can be analyzed.

This chapter has three parts. The first part of this chapter reviews contemporary economic surplus analysis. Included in this review is an illustration of the economic surplus measures in the case of supply and demand shifts. This section also discusses why the conventional welfare economics' basic assumption, regarding fixed taste, does not hold in all the cases and introduces a modification of conventional welfare economics that can be applied when there is taste change. The first part ends with a discussion of the different critical assumptions of economic surplus analysis. The second part of Chapter III briefly examines the extension of this framework to include a variety of market scenarios (i.e., the presence of market distortions and government interventions, varying degrees of commodity trading, complex multimarket systems, and technological changes in productivity and/or quality-improvement(s)). This part is not extensively discussed because a number of economic studies (i.e., Ruttan, 1982; Norton and Davis, 1981; Alston, 1991) have already done that and it is not within the scope of this thesis to pursue this further. Chapter III concludes with a discussion of the "alternatives" to economic surplus analysis.

3.2 Issues Regarding the Measurement of Research Benefits

Agricultural research is an economic activity that involves the investment of scarce resources in the production of knowledge and innovation (Ruttan, 1982). The benefits from agricultural research include: more output for a given quantity of inputs, less inputs for a given quantity of output, new and better products, and better organization and quicker response to changing circumstances.

The economic surplus (welfare analysis) approach has been widely used to estimate the economic effect(s) of agricultural research. This approach measures the economic effects of shifts in the supply/demand curve(s) that result from research-induced technical change. Simply stated, this approach measures the static equilibrium situation before and after a technical change; thus it is a comparative-static model.

This thesis applies the economic surplus (welfare analysis) approach to evaluate research benefit. This approach is better suited to the goal of this study because it can focus on one part of the economy at a time (e.g., a specific industry) by considering all the other economic variables as exogenous (i.e., a partial-equilibrium framework). Specifically, this approach can trace the magnitude and the distribution of the gross annual flow of economic benefit(s) which occur due to research-driven technological change.

3.2.1 The Economic Surplus Approach: A Multistage Framework

Two main approaches have been used to estimate the economic effect(s) of agricultural research in a multistage market system. The first assumes that the elasticity of substitution between the inputs is zero. The second is based on the Muth model, which allows substitution between the inputs. According to available evidence, the elasticity of substitution between farm products and market services is generally not zero (Gardner, 1975). Moreover, it was shown that the elasticity of substitution between the inputs is crucial to the distribution of research benefits among the different social groups (Alston and Scobie, 1983). Hence, in general, the second approach yields more accurate estimates of the economic effects of agriculture research. Although the extension of the Muth model (1964) is more general and could give better estimates of the distribution of research benefits, there are some cases where inputs are used in fixed proportions to produce the final product. In these cases, a fixed proportions comparative static model is preferable because it is methodologically simple, while still providing accurate estimates of the distribution of research benefits.

3.2.2 Graphical Illustration of the Economic Surplus Measures

Technical change usually results in an induced shift in either the demand curve or the supply curve, depending on the nature of the technology. Agricultural mechanization is an illustrative example of cost-reducing technical change, while the "green revolution" is the corresponding counterpart of output-expanding technical change. On the other hand, quality-improvement technical change includes health, environmental and nutritional effects. Supply shifts imply movement of the supply curve downward and to the right, while demand shifts correspond to movement upward and to the right.

3.2.2.1 The Case of Supply Shift

The simple representation of the research benefit from the supply-shifting technical change can be shown in Figure 3.1. The demand and supply curve before the technological change are given as D and S respectively. P and Q are the corresponding equilibrium price and quantity.

The consumer surplus is given by the area beneath the demand curve less the cost of consumption, which is equal to the area aPb. The producer surplus is the total producer revenue less the cost of production, which is equal to the area Pbd. The sum of producer and consumer surplus gives the total surplus, area abd, which represents the total value of consumption less the total cost of production.

Technical change shifts the supply curve downward and to the right (S to S') and results in a new equilibrium price and quantity, P' and Q' respectively. The change in consumer surplus is equal to the area $PBCP'$ and the change in producer surplus is equal to the area defc - $PdfP'$. Consumers are unambiguously better off but producers gain (lose) only if the area defc is greater (smaller) than $PDFP'$. With the technical change,

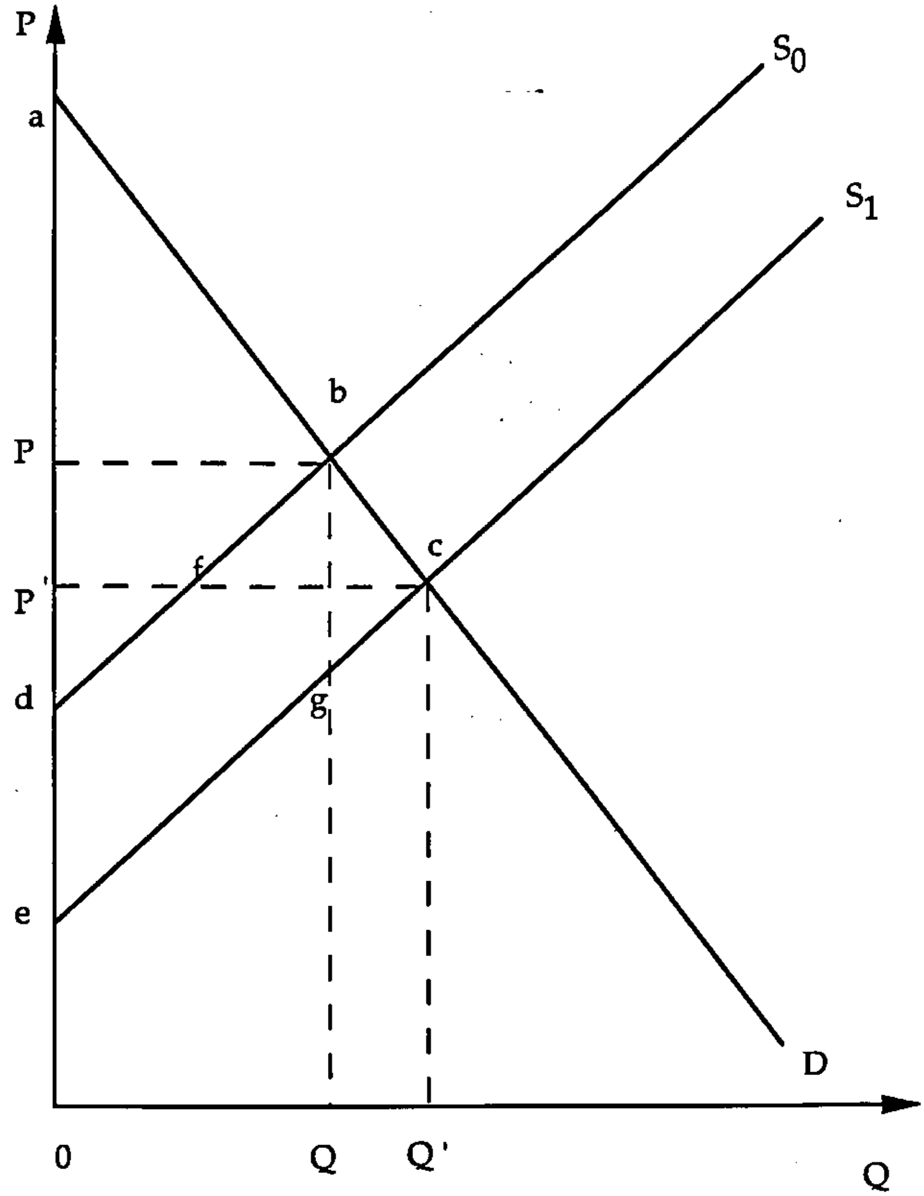


Figure 3.1. Cost-reducing or Output-expanding Technical Changes

producers supply a greater quantity of goods, but at a lower price, so these two effects work in opposite directions. The change in producer surplus is affected by the supply and demand elasticities and the nature of the supply shift. The change in total welfare, which corresponds to the return to gross research (R&D), is equal to the sum of changes in producer and consumer surpluses, i.e. bced, which is positive. Thus, the gainers could compensate losers and still be better off.

Technical change, specifically a new technology, can be qualified to be a net welfare improvement, if it satisfies the Pareto criteria and the Kaldor-Hicks criteria. The first condition is the Pareto criterion, which says that the gainers **do** fully compensate the losers (compensation actually takes place) and still experience some gain themselves (sufficient condition). The second condition is the Kaldor-Hicks criteria, which says that the gainers **could** fully compensate the losers (although compensation doesn't need to take place) and still experience some gain themselves (necessary condition).

Technical change can be considered to be a case of Kaldor-Hicks improvement (without a distortion in trade); that is, it results in a pure welfare improvement for the society as a whole. This does not necessarily mean that the benefits of technical change are equally distributed among social groups, nor that all social groups are better off afterwards. Hence, it cannot be said *a priori* that either producers or consumers benefit from technical change. However, society becomes better off, so either group can compensate potential losers in order to move to a Pareto superior solution.

3.2.2.2 The Case of Demand Shift

The distribution of welfare benefits from quality-improvement technical change can be analyzed with reference to Figure 3.2. The quality-improvement in the good is depicted by a shift in the demand curve upward and to the right (Unnevehr, 1986 and 1990; Voon and Edwards, 1991a). This reflects the notion that the consumers' demand for an improved quality product will increase at each price level or, in other words, the technical change that led to the quality-improvement results in a rise in the commodity's demand curve. However, the quality-improvement technical change usually causes a shift in a supply curve as well. Specifically, the increase (decrease) in the quality characteristics of a final product is often associated with an increase (decrease) in the cost of producing or processing inputs, which in turn shifts the supply of producing or processing inputs to the left (right). Hence, a shift in the demand curve alone is only valid under specific circumstances, such as when quality change does not affect the cost of production. For sake of simplicity, the impact of quality change will be graphically illustrated as the shift in the demand curve only. This means that quality-improvement has a positive effect on the quantity demanded, *ceteris paribus*. The implicit assumptions necessary to illustrate that quality-improvement results in an increase in the quantity demanded are that: there are no changes in the prices of other products, consumers' incomes remain unchanged, and there is no change in habits. This illustration also assumes that the demand curve shifts in a parallel manner from D to D' (Rose, 1980) (see Figure 3.2).

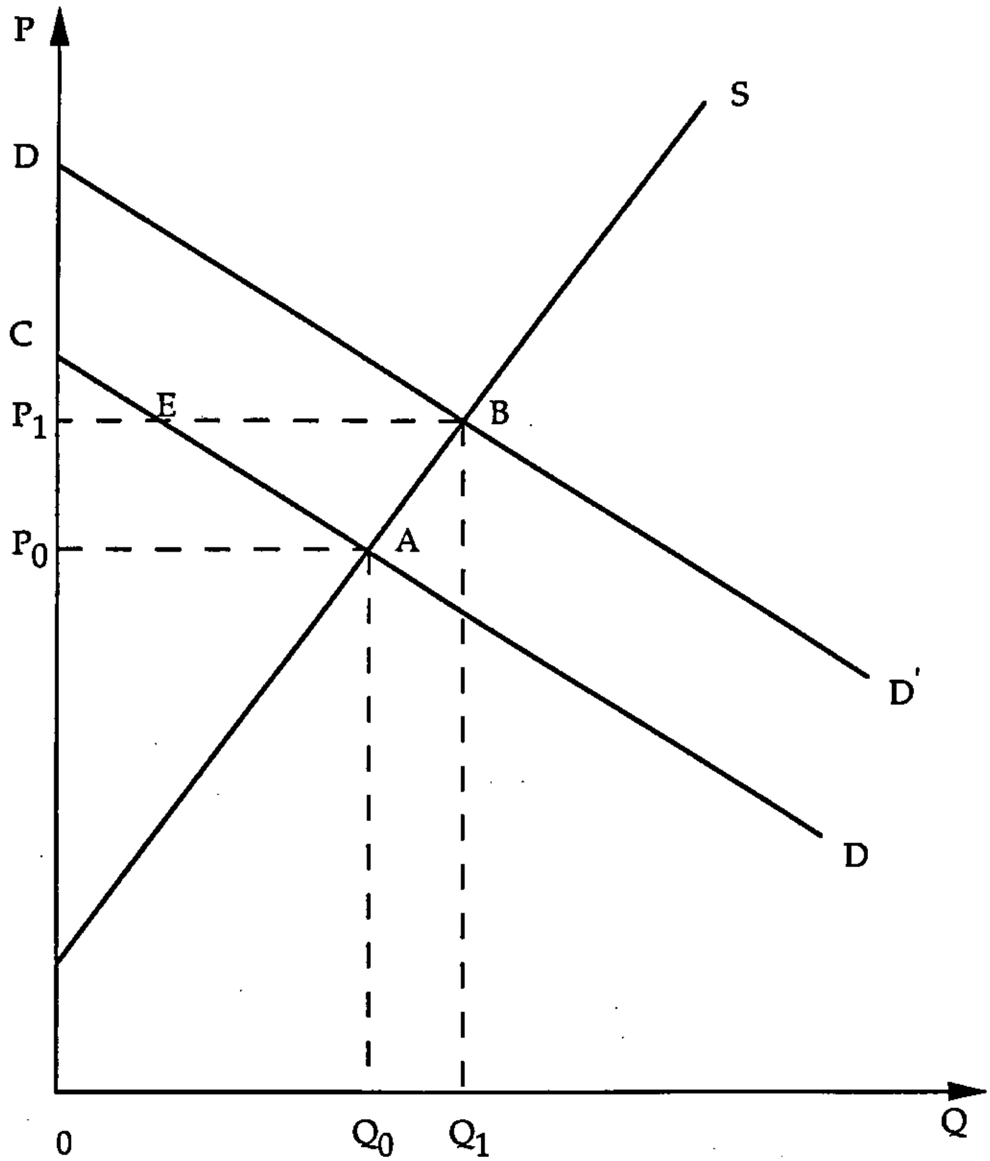


Figure 3.2. Quality Improvement Technical Change

Technological change that reduces the production cost or increases production increases the equilibrium quantity and decreases the equilibrium price. Quality improvement increases both the equilibrium price and quantity. It is generally believed that quality-improvement improves consumers' welfare, but it is clear from Figure 3.2 that producers are unambiguously better off. The change in producer surplus is equal to the area P_1P_0BA. Producers are better off because they can produce greater quantity at a higher price due to technological change. The increase in benefit is greater than the increase in cost as production increases, since the supply curve is upward sloping and the change in producer surplus is therefore positive. Consumers are better off, too. The change in consumer surplus is equal to the area $CDBE - P_1EAP_0$, which is positive since Q_1 is greater than Q_0. Q_1 is greater than Q_0 when the shift of the demand curve is parallel.

The quality-improvement technical change, similar to the other kinds of technological change, leads to an increase in social welfare and thus it is a potential Pareto improvement. The change in social welfare is estimated by adding up the changes to producer and consumer surpluses and is equal to the area ABCD.

3.2.2.3 Ex post Measures of Consumer Surplus

One of the analytical mainstays of contemporary welfare analysis is the use of "willingness-to-pay" as a measure of consumer surplus or welfare. Consumer surplus, as measured by willingness to pay, is measured as the change in area above the price line and below a Hicksian demand curve. This calculation gives an exact measurement of compensating variation from a change in price. This conventional approach relies heavily on an assumption that preferences or tastes remain stable before and after a price change. If preferences change, then the change in area under the demand curve no longer represents the dollar value of the change in welfare. This issue has been discussed extensively in the advertising literature. Unfortunately, if evidence does exist that indicates that preferences have changed, then economists are left without an applicable welfare framework. Hence, by convention, economists have often adopted the policy of assuming that the demand curves before and after the taste change can be used to calculate the compensation variation of the advertising effect. This approach is used for the lack of a better alternative.

Product advertising (either *informed* or *persuaded*) or the provision of additional consumer information may alter the preferences or tastes of certain consumer groups. When consumer preferences or tastes change, there are generally three reasons: (1) consumers believe that the product has new merits, which have been verified to be true (e.g., good quality, less risk associated with a consumption of a product), (2) consumers believe that the product has new merits, which have not been verified to be true, and (3) consumers derive some utility from the association of the advertised product with another image. Since there are cases where preferences or tastes change, conventional welfare analysis cannot be used to evaluate the benefit of research and development on different social groups.

Dixit and Norman (1978) propose a way to apply conventional welfare measures to estimate the benefit from advertising when there is preference or taste change in a case of a single market. This application is depicted in Figure 3.3. The initial or pre-advertising demand curve is denoted as D, and S is a supply curve. The intercept of the supply and demand curve (point E) gives the equilibrium price P and quantity X. Advertising shifts the demand curve from D to D' (from pre- to post-advertising demand curve) and consequently the equilibrium from point E to E', with some increase in both price (P to P') and quantity (X to X'). They propose the use of either the pre- or post-advertising demand curve to measure the benefit from advertising with taste change. The premise of this proposal is based on the fact that each demand curve corresponds to a fixed level of advertising, and a constant set of tastes. The use of the difference between the pre- and post-advertising demand curves, to measure the welfare benefit, is not appropriate because they represent different preferences or tastes. Hence, the gross benefit (monopoly) can be measured by subtracting the area under the marginal cost curve (the opportunity cost of resources transferred from the rest of the economy to this industry) from the area between the two output levels under either the pre- or post-advertising demand curves. The gross benefit, when the pre-advertising preference is taken as the standard, is equal to the area ABGE. When the post-advertising is taken as the standard, the gross benefit is the area ABE'F. To sum up, Dixit and Norman (1978) suggested that, when taste is variable, conventional welfare economics should be used only if either the pre- or post-advertising situation (or in other words, either the pre- or post-advertising demand curve) is taken as the standard to evaluate the welfare effects of the advertising induced shift.

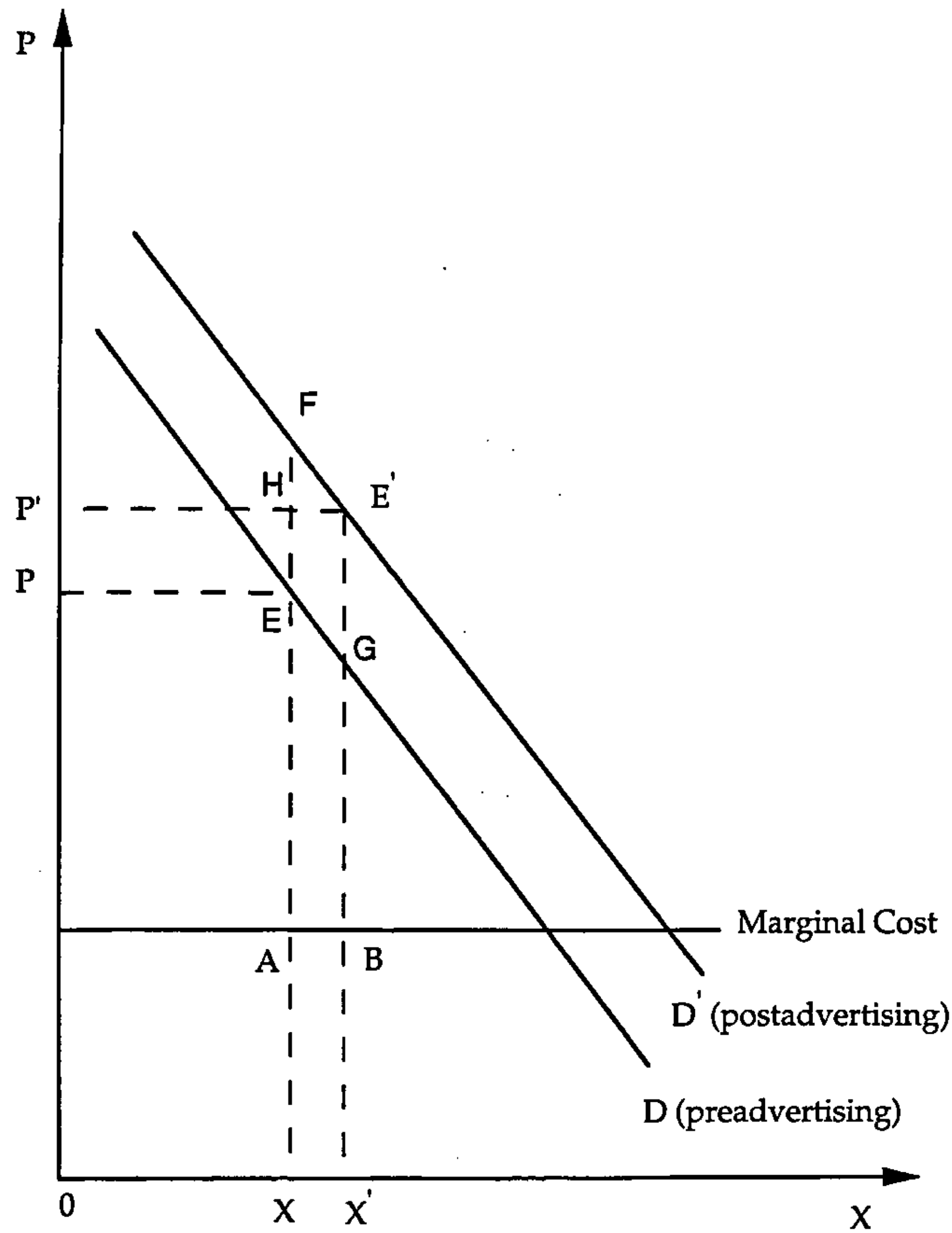


Figure 3.3. Effect of Advertising under Pre- or Post-advertising Standard

Source: Dixit and Norman (1978) pp.4

In this thesis we are examining the welfare impact of improved health information. This definitely involves changing preferences or tastes (at given set of price and income, demand will change). The Dixit and Norman (1978) approach will be adopted to estimate the benefit from the health information. An alternative measure of the compensation variation using the *ex post* demand curve will be introduced, which will be called the "*ex post* measure of consumer surplus." As the name suggests, the valuation of consumer surplus is made on the basis of the preference set that exists after the information is available.

The welfare estimate of the benefit from health information is depicted in Figure 3.4. The initial or *ex ante* demand curve is represented as D, and S is the supply curve. The intercept of the supply and demand curve gives the equilibrium price P and quantity Q. The health information shifts the demand curve upwards and to the right from D to D' (from the *ex ante* to *ex post* health information demand curve), which increases both the equilibrium price (P to P') and quantity (Q to Q'). Unlike advertising, health information represents an accumulation of knowledge. One would suspect that over time scientific research will give increasingly more accurate estimates of the actual health benefits. For this reason it may be reasonable to measure the health benefits to the individual using the informed *ex post* health preference as a standard. Logically speaking, it stands to reason that if a consumer in 1995 is willing to pay $30/tonne for a health benefit that she/he has been made aware of, then it is reasonable to assume that this same benefit already existed before the consumer was made aware of it. In terms of welfare analysis, the initial consumer surplus was PABC (the area beneath the *ex post*

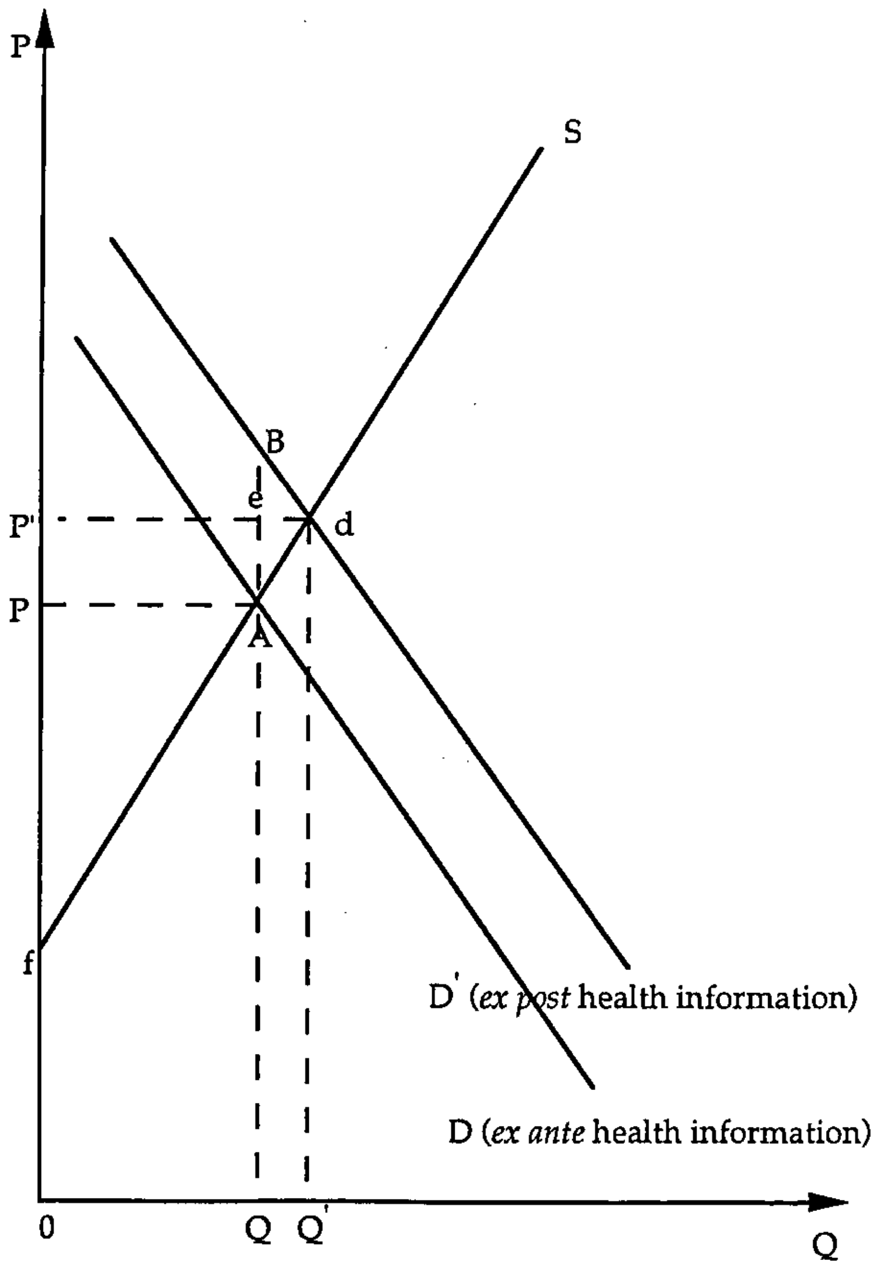


Figure 3.4. Effect of Health News under *ex ante* or *ex post* Health News Standard

demand curve less the cost of consumption at the initial quantity) and the consumer surplus after the health information is P'DC (the area beneath the *ex post* demand curve less the cost of consumption at the new quantity). Hence, the change in consumer surplus is equal to the area BAD-P'PAE. The change in producer surplus is equal to the area P'PDA (from PAF to P'DF). Consequently, the total benefit (change in consumer surplus plus change in producer surplus) from the health information is equal to the area ABD. In other words, the total benefit or gross benefit from the health information is the area between the two output levels under the *ex post* health information demand curve less the cost of consumption, which is in accordance with the methodology of Dixit and Norman.

3.2.3 The Critical Assumptions of Economic Surplus Analysis

Assumptions play a large role in any economic model. Some critical assumptions in economic surplus analysis can affect the resulting measurements. To understand how these assumptions affect surplus measurements, there are basic theoretical properties of economic surplus analysis which should be identified.

The total benefit from research and development depends primarily on the size of the shift; and next, on the type of shift (Alston, 1991). Typically, the chosen functional form and the elasticities of demand and supply are relatively unimportant, in comparison to the type of supply shift, when measuring the total research benefit. On the other hand, the distribution of research benefits is a function of the type of technical change and the demand and supply elasticities in the case of a single market, and further depend on the elasticities of substitution in multistage cases. The functional form is relatively unimportant to the distribution of research benefits. Generally, the total research benefits and their distribution are little affected by the choice of functional form under a parallel supply curve condition (Alston, Norton and Pardey, 1995).

Although different assumptions affect the size and the distribution of research benefits, restrictive assumptions are unavoidable. A good understanding of the sensitivity of results to different assumptions is important in establishing a modeling technique that derives the most suitable estimates. The following sections outline the major assumptions of this study.

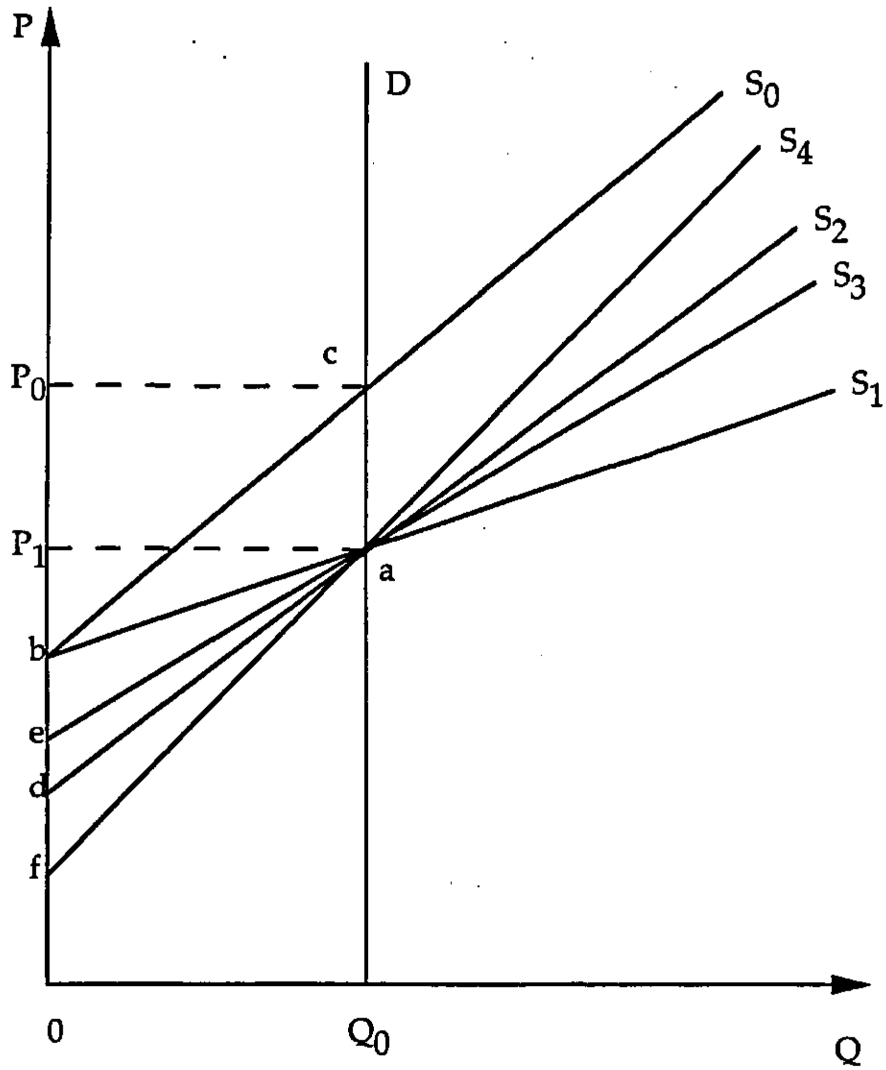
3.2.3.1 The Type of Technical Change

There are three main types of supply shifts used in the literature: divergent, convergent and parallel. The first refers to cases where, as the quantity supplied increases, the absolute horizontal distance between the supply curves also increases. The second case is the extreme opposite of the first case. Finally, the parallel shift represents the middle case of the previous two opposites. The divergent shift assumes that the impact of the technical change decreases as the quantity supplied diminishes. As an aside, there are two special cases of a divergent shift: the pivotal and proportional supply shifts. The second, a convergent shift, assumes that the impact of the technical change increases as the quantity supplied diminishes. Finally, a parallel shift implies that there is equal impact at every level of supply.

The type of supply shift is a most important determinant of the distribution of benefit from research among producers and consumers (Duncan and Tisdell, 1971). In addition, the supply shift also affects the magnitude of R&D benefits (Linder and Jarrett, 1978). The effect of different types of technical change on the absolute magnitude of returns to research is depicted in Figure 3.5., where S_1 is the post-innovation supply curve corresponding to a pivotal supply shift, S_2 to a parallel, S_3 to a divergent proportional and S_4 to a convergent shift. Also, the demand curve is assumed to be perfectly inelastic; thus, any type of supply shift results in the same post-innovation equilibrium quantity and price (e.g., the size of the shifts are determined to make this true). It is clear that the largest returns to research are achieved by a convergent supply shift (fbca); the second largest by a parallel (dbca), third by a divergent proportional (ebac) and the lowest with a pivotal supply shift (bac). Under the special circumstances of Figure 3.5., returns to research under a parallel supply shift (dbca) are exactly twice those under a pivotal supply shift. Moreover, when the shift in the supply curve is parallel, producers are always better off, except for the case of a perfectly elastic supply curve or a perfectly inelastic demand curve, when they are unaffected. Conversely, when the shift in supply curve is pivotal, producers are better off only if the demand is elastic.

3.2.3.2 Elasticity of Supply and Demand

The assumptions concerning supply and demand elasticities do affect welfare measurements. However, the impact of these assumptions is observed more in the measurement of the distribution of benefits than in the measurement of aggregate benefits (Griliches, 1958). Generally, the



Where: D=Original Demand

S_0=Original Supply

S_1=Divergent : Pivotal

S_2=Parallel

S_3=Divergent : Proportional

S_4=Convergent

Figure 3.5. Alternative Cost-reducing or Output-expanding Technical Changes

benefits to any one sector are greater, the more inelastic is its supply curve relative to the other sector. The gain to consumers is greater relative to the gain to producers, the more elastic is the supply curve relative to the demand curve (Freebairn, Davis and Edwards, 1982). In a case of a perfectly elastic supply curve, there is no producer surplus because the downward shift of the supply curve is exactly offset by the reduction in the price received. In the other extreme case, a perfectly elastic demand curve, there is no consumer surplus because there is no price effect resulting from the technical change, Finally, if the elasticities of demand and supply have equal magnitude, the consumers' and producers' shares of total benefits are equal.

3.2.3.3 Functional Form of Supply and Demand

The functional form of the supply and demand curves is relatively unimportant for the distribution of research benefits and for the total welfare gain. The most popular assumption is linearity, because it simplifies the estimation of the consumer and producer surplus. Although the procedure is easier, there is a problem when the supply curve is inelastic. When the supply curve is inelastic, the price intercept is negative, which means that at a negative price producers would be willing to supply a positive quantity. This problem can be overcome by kinking the supply curve at the original quantity (Rose, 1980). The economic surplus calculated with and without kinking the supply curve is the same if the supply shift is pivotal or parallel (Alston, Norton and Pardey, 1995).

The main alternative to the linear supply and demand curves is constant elasticity supply and demand curves. This assumption means that the supply curve passes through the origin regardless of its elasticity. The constant elasticity model usually is accompanied by an assumption that the supply curve shifts in a pivotal manner. This assumption has further implications on the measurement of economic surplus, with regards to the magnitude of the chosen elasticity. For instance, the economic surplus for an elasticity of supply less than one is overestimated by a linear-approximation-to-a-constant-elasticity form compared to simple linear form. The opposite is true for an elasticity of supply greater than one (Alston, Norton and Pardey, 1995).

Finally, there is an assumption of a constant elasticity form of supply function, such that the supply curve always has a positive intercept with a price axis (Lynam and Jones, 1984). The constant elasticity form (with positive price intercept) does not have the typical problems of the standard linear supply and demand model and does not imply any specific type of supply shift (like the constant elasticity model with a zero intercept). Hence, the constant elasticity form has an advantage compared to the previous approaches. However, predicting the nature of the shift, even for a particular innovation, is very difficult (Rose, 1980). Consequently, there may be no actual advantage to that approach. In addition, according to Alston, Norton and Pardey (1995), this approach requires more effort to solve for the change in price and quantity (because it is nonlinear algorithmic) and this extensive exercise may not be warranted.

3.3 Literature Review of the Economic Surplus Measures

3.3.1 The Case of Supply Shift

The usual approach for evaluating the distribution of research gains for social groups uses economic surplus measures. This type of analysis was developed from a simple competitive market situation. Schultz (1953) estimated the value of inputs saved through more efficient production techniques in agriculture in the United States compared to the cost of research and development. Specifically, he calculated the value of resources that would have been required to produce the agricultural output of 1950 using 1910 and 1940 techniques. He evaluated the increase in consumer surplus resulting from the saving in inputs under the special conditions of perfectly inelastic demand, perfectly elastic supply and a parallel supply shift.

Griliches (1958) measured the social rate of return to hybrid corn research from public and private investments. He assumed that the supply curve shifted downward or to the right due to the adoption of hybrid corn. He estimated returns to research for the extreme cases of a perfectly elastic and perfectly inelastic supply curve. He also assumed a linear supply and demand curve and unitary demand elasticity. He concluded that the kind of supply shift does not significantly affect the total benefit from R&D but does affect the distribution of benefit between the social groups. Griliches was later corrected by Linder and Jarrett (1978), who showed that the kind of supply shift does affect the magnitude of the total benefit from R&D. As an aside, he also found that the rate of return to R&D on hybrid corn had been very high.

Peterson (1967) estimated a rate of return to investment in poultry research. Specifically, he calculated the downward shift of the supply curve from the use of new and more efficient inputs, thereby estimating the "resources saved" from the poultry research. After, he derived the social rate of return to research by relating the annual net social returns and the expenditure on poultry research. His analysis assumed an upward sloping supply curve and a downward sloping demand curve, which also featured a supply shift in a proportional (divergent) manner. He found that the investment in poultry research yielded a high return (20%-30%).

Schmitz and Seckler (1970) estimated the gross social returns from mechanical harvesting of tomatoes. They also derived the net social return to research by relating the gross social returns and the value of the costs incurred by displacing harvest workers. In other words, they estimated the net social returns as the value of the inputs saved less the value of labor lost. They found that the net social returns were high (for varying levels of compensation), even if the displaced workers had been compensated for their wage loss.

Akino and Hayami (1975) estimated the social returns to research and the distribution of the returns to research among the social groups (producers and consumers) in autarky and open economy (rice import) cases for rice breeding in Japan. The social rate of return was also calculated to evaluate the efficiency in resource allocation to rice breeding research. Their analysis assumed that the shift in the supply curve was proportional (divergent) and they used a constant elasticity model. They found that the rates of return to rice research were very high.

Hayami and Herdt (1977) examined the social returns to research to develop rice production technology in Asia. They used a constant elasticity approach with pivotal supply shift. They took into account the producer's home consumption (semisubsistence production), which was represented by a perfectly inelastic demand curve. They found that the distribution of the return to research is affected by the elasticities of demand and supply, the proportional shift of the supply curve and the proportion of the commodity marketed.

Nagy and Furtan (1978) estimated the returns to rapeseed breeding research in western Canada. Specifically, they examined the distribution of benefit between consumers and producers from research into increasing the yield of rapeseed varieties. They also calculated the social rate of return by relating the annual social return and the annual expenditure on rapeseed breeding research, thereby evaluating the efficiency of investment in rapeseed research. They used supply and demand curves with a constant elasticity, and the supply curve shifted in a pivotal manner due to the adoption of new, higher yielding rapeseed varieties. This study found that the social rate of return was high and that consumers benefit more than producers from technical change.

Scobie and Posada (1978) evaluated the impact of modern rice varieties for irrigated culture in Colombia. They estimated the benefit (loss) in producer and consumer surplus from increasing production (gross benefit) and calculated the social rate of return by relating the gross benefit to research cost. They examined the distribution of the research cost and benefit among upland producers, irrigated producers and consumers in various income groups. They concluded that all consumers gain from the technical change but all producers lose to a varying degree.

Economic surplus analysis has been further extended to cases incorporating market distortions and government intervention. Alston, Edwards and Freebairn (1988) compared the total benefit and the distribution of that benefit from technical change which reduced the cost of production between different price polices and free market conditions. Specifically, they examined the following policies: output subsidy or tax, an export subsidy or import tax, an output quota, a target price with deficiency payments and an equalization scheme. Supply and demand curves were assumed to be linear and the supply curve was assumed to shift in a parallel manner only for subsidy and tax policies. They concluded that the net world benefits can be reduced (under output quota or target price), increased (under equalization scheme generally) or left unchanged (under import tax or output/export subsidy), depending on the policy and the trade status of the country in the world market. The net national benefits can be larger, smaller or unaffected, depending on the policy and the trade status of the country. Finally, the distribution of research benefits between consumers and producers is also affected.

Murphy, Furtan and Schmitz (1993) examined the total research benefits from output-increasing research under internal producer price support and export subsidies. Two scenarios were examined. In the first, the supply curve shifted downward in a parallel manner due to the technical change. In the second, the shift in supply curve was pivotal. It was also assumed that the supply and demand curves are linear. They concluded that if the export subsidy is increased, even though the export market grows because of the R&D, the gross annual research benefit can be negative.

Alston and Martin (1995) commented on Tyers and Falvey's (1988) analysis regarding the border price changes and domestic welfare in the presence of distortion (export subsidies). Tyers and Falrey used a linear model of excess supply and demand. They concluded that the domestic welfare, in the presence of a per unit export subsidy, was unaffected. They also showed that when there is no transmission of border price changes into the domestic price, the exporter would benefit. Alston and Martin, using two examples, an ad valorem subsidy and a non-linear model of excess supply and demand, illustrated the sensitivity of Tyers and Falrey's results on their assumptions. Alston and Martin (1995) also concluded that:

> More generally, the welfare effect of a border price change in the presence of any distortion may be in the same direction as they would be under free trade or in the opposite direction. What this hinges on is the size and direction of the effect of the border price change on the social cost of the pre-existing distortion, and that will depend, in turn, on the nature of the distortion and the functional form of supply and demand (page 82).

Economic surplus analysis has also been extended into tradable commodities. Edwards and Freebairn (1984) developed a model for evaluating the gains from research into tradable commodities. Specifically, they specified a simple comparative static trade model (or disaggregated commodity supply and demand model) with separate sectors for Australia and the rest of the world (ROW). It was assumed that the supply curve shifted downward in Australia and/or in the ROW and in a parallel manner due to research which reduces the per unit production cost. They also assumed that the supply and demand curves were linear, technology transfer was free and commodity trade was free. They concluded that Australia's gain from research into wheat and wool was higher, the more inelastic the supply curve is relative to the demand curve. They also found that, even when the key assumptions are relaxed (as the parallel supply shift, free commodity trade, free technology transfer, and linear supply and demand curve), the general results of this analysis were still valid.

Freebairn, Davis and Edwards (1982) analyzed the distribution of research gains in a multistage competitive market system. They used a simple comparative static model. Assuming linear supply and demand curves in every stage of production, cost-reducing technical changes and a zero elasticity of substitution between inputs of different stages, they showed that research generated net benefits to all participants in the system. Moreover, in this case, the distribution of research benefits was independent of the stage at which research occurs, and the benefits were distributed according to the demand and supply elasticities (see also Alston (1991) for a detailed review of these issues).

Alston and Scobie (1983), by using a mathematical model based on the Muth model, have demonstrated the sensitivity of the Freebairn, Davis and Edwards (1982) results to the assumption of zero elasticity of substitution. They have shown that producers may lose economic surplus when the marketing service supply curve shifts to the right, as a result of research, and the elasticity of substitution between farm and nonfarm inputs in the production of the retail demand.

Alston and Mullen (1992) estimated the size and the distribution of economic benefits from R&D in the Australian wool industry. The mathematical model followed the methodology of Muth (1964), as it is consisted of supply and demand conditions for the inputs and outputs of the industry. The model takes into account the interdependency of vertically related markets in the wool top industry (i.e., wool top, processing inputs and wool). The model also incorporated trade by including the supply and demand conditions of wool for the rest of the world. They assumed that the supply and demand functions were linear and the function shifts were parallel. They estimated the effect of 1% cost savings in wool production or processing to: woolgrowers in Australia and the ROW, topmakers, and wool top consumers. They found that the Australian share of benefits was 58% from farm-level technology and 27% from processing technology. They also concluded that the nature of the R&D and the source of research funding contributed to the determination of the benefits and costs to the Australian wool industry and Australia as a whole.

More recently, Holloway (1989), by further disaggregating the marketing sector into processing and distribution, has shown that farm benefits from research depend on the stage in the marketing system at which research is directed. For empirical applications of multimarket distribution of research benefits, see Mullen, Wohlgenant and Farris (1988), who analyzed the US beef industry, and Mullen, Alston and Wohlgenant (1989), who dealt with the Australian wool industry.

3.3.2 The Case of Demand Shift

The empirical analysis of economic surplus has also been extended to quality-improvement. Unnevehr (1986) examined the welfare effect of improving grain quality (e.g., fragrance, shape, milling, chemical attributes, chalkiness, better head, less amylose) of modern rice varieties in Thailand, Indonesia and the Philippines. Her analysis assumed that the demand and supply curves were linear and the supply curve was perfectly elastic. When the quality-improvement took place, the demand curve shifted, in parallel, upwards. Hence, the consumer unambiguously gained from quality-improvement and the producer's welfare remained unchanged. This study used a model of consumer demand for goods characteristics adapted from Ladd and Suvannun (1976). The main idea of this model was that the products are demanded for the utility they provide, which is a function of the characteristics of the product. Unnevehr found that the demand for milling quality was similar in all countries, but demand for shape and certain chemical characteristics varied. Results indicated that the estimated return to research for past and future improvements in two quality-improvements (better head, less amylose) was quite high and indicated underinvestment in this type of research.

Lemieux and Wohlgenant (1989) examined the *ex ante* welfare effect of introducing a new growth hormone, porcine somatropin (PST), which will have a significant impact on the US pork industry. This study used a linear elasticity model which accounted for interrelationships between the raw material and final product, the domestic and international markets, the effects of different adoption rates, the supply response of producers and a shift in consumer demand for leaner pork. The purpose of this study was to estimate the impact on price and quantity of pork at retail and farm level and on consumer and producer surplus from the introduction of PST. Their analysis assumed that the demand and supply curves were not linear. Introduction of PST would cause the market supply curve and the demand curve to shift in a parallel manner. The results indicate that, for a five-year adjustment period, the consumers' surplus would increase more than the producers' surplus, which appears to be sensitive to the lagged adjustment of producers.

Voon and Edwards (1991a) examined the economic benefits of reducing backfat depth in Australian pork. They used a simple comparative static closed-market model, similar to Freebairn, Davis and Edwards (1982), to identify the research benefits to commodity producers, input suppliers, marketers and consumers. They made three separate model specifications of supply, demand and the elasticity of substitution. First, they assumed that the supply and demand curves were linear, with a perfectly elastic supply of non-farm inputs and market services, and no substitution between farm product and marketing services. Results indicated that producers benefit the most (about 80%). Second, they assumed that the supply and demand curve were linear, with an imperfectly elastic supply of non-farm inputs and marketing services, and no substitution between farm product and marketing services. They found, in this case, that producers' and consumers' benefits were lower than in the previous scenario. Finally, they assumed that the supply and demand curves were nonlinear, with a perfectly elastic supply of non-farm inputs and of marketing services, and substitution between farm product and marketing services. Results in this case indicated that producers' share of research benefits decreased, with increases in the elasticity of substitution, and consumers' share increased. Combined, the three models estimated that a reduction in backfat depth would result in a $7 million per annum gross research benefit in the Australian pig industry, and that producers would capture the larger share.

Voon (1991) evaluated the welfare effect of research which lowers the mean incidence of pork with pale, soft and exudative (PSE) syndrome. He used a simple comparative static closed-market model to measure the producer, consumer and social gains. Voon's analysis assumes linear demand and supply curves. A reduction in the incidence of pork with PSE syndrome resulted in an increase in the primary quantity supplied; hence, this was represented by a rightward parallel shift in a supply curve. The result of this study showed that the Australian pig industry would be able to derive gross research benefits of about $7 million per year from a 1% reduction in the incidence of pork with PSE conditions, and pork producers would gain about 85% of the total R&D benefit.

Voon and Edwards (1992) developed a simple comparative static trade model for evaluating the size and distribution of economic benefits from research that increases the protein in Australian wheat (export commodity). The model did not allow the measurement of welfare changes from quality-improvement for the importing country because it excluded the demand and supply curve for the rest of the world (ROW). It only included the excess demand of ROW. The excess demand of ROW plus the domestic demand gives the total demand for Australian wheat. Hence, their analysis focused only on the Australian producer surplus and social gains. The analysis assumed that the supply and demand curves were linear, and both the supply and demand curves were shifted upwards in a parallel manner. The shift in the demand curve was greater than the shift in the supply curve. Voon and Edwards estimated that an increase in the protein content of wheat by 1% resulted in net benefits of A$53 million per year, and producers' benefit was over 90% of the total research benefit.

3.4 Complementary Analysis to Economic Surplus Analysis

There are three main ways of embellishing the economic surplus results: the internal rate of return (IRR), the net present value (NPV) and the benefit-cost ratio (B-C) analysis. While the economic surplus approach estimates the **gross** annual flow of economic benefits, the IRR, NPV and BCR are different measures of the **net** economic benefit. Specifically, IRR, NPV and BCR combine the results of the economic surplus analysis with the cost of a specific research program. Hence, these approaches provide a better basis for evaluating research projects.

The NPV which evaluates the economic efficiency of the agricultural research project is defined as

$$NPV = \sum_{K=0}^{T} \frac{B_t - C_t}{(1-r)^t} \; .$$

where: B_t is the sum of benefits that result from the project in year t,

C_t is the sum of the costs associated with the project in year t,

T is the duration of the project, and

r is the rate of discount

If the NPV>0, then the present value of benefits is greater than the present value of costs, and the agricultural project should be pursued. If NPV<0, then the agriculture research project is not desirable, since the outcome is a net loss (Van Kooten, 1993).

Alternatively, the B-C ratio can compare the benefits on a per dollar cost basis. The B-C ratio is defined as:

$$\text{B-C} = \frac{\text{PVB}}{\text{PVC}} .$$

If B-C>1.0, then for every $1 cost of the project, the gain is more than $1 so the project may be undertaken. If there are a lot of projects and a limited source of funding, the ones with the higher B-C ratio should be given preference. Hence, the B-C ratio can be used to rank the agriculture research projects or programs (Van Kooten, 1993).

The IRR is the estimated discount rate which results in a NPV equal to zero. IRR is defined as:

$$0 = \sum_{K=0}^{T} \frac{B_t - C_t}{(1 - \text{IRR})^t} .$$

If IRR is greater than the selected discount rate, then the agricultural research project or program is profitable. The IRR can also be used to rank projects or programs (Van Kooten, 1993).

There are some disadvantages to the application of the IRR, NPV and B-C to evaluate research projects. The NPV method does not consider alternative investments, so a transitive ranking of possible investments cannot occur. The scale of net benefits is measured but the scale of investments is not revealed. The IRR does not measure the value of the program or scale of the investment, but it does allow a transitive ranking of programs by their profitability. Finally, there is often a large, and generally unavailable, information set (i.e., benefit stream, investment cost, time period) required to estimate NPV, IRR and BCR. The lack of necessary information also results in estimation (NPV, IRR and BCR) which combine the public and private rates of return. This combined rate does not provide accurate investment information to either group. Although the total cost of the project may be paid for with public and private funds, or funds from different social groups, the distribution of benefit between these social groups (public and private) is very difficult, if not impossible, to determine. Consequently, the useful application of the IRR, NPV and the B-C approaches depends on the nature of the research project or program and on the questions these estimation are meant to answer.

The IRR, NPV and B-C criteria are not applicable in the context of this thesis. This study's primary interest is to estimate the welfare benefit/loss from the medical/nutritional research on canola oil and agronomic research on canola seed, not only for the canola industry as a whole, but also for each important industry stakeholder. Although the economic surplus approach and the IRR, NPV and BCR are often combined to enhance an analysis, this practice is very complex, time consuming and beyond the scope of this thesis. Hence, the thesis was arbitrary bounded to look only at the benefits side of canola research.

3.5 Conclusions

To recap, conventional welfare estimates require one important assumption: that tastes remain fixed. This assumption, in situations like those involving the measurement of welfare benefits from advertising or health information on a product, does not hold. Hence, a modified welfare estimate was introduced to measure the research benefit in the case of a preference or taste change.

The magnitude and distribution of research benefits are sensitive to a number of factors. Research leads to a potential Pareto improvement. Distribution is important because there are some winners and losers. Specifically, the magnitude of research benefits is sensitive mainly to the type of shift, while the distribution of research benefits is sensitive to the type of shift and the elasticity of demand and supply.

In terms of research efforts and literature, the supply side has received the lion's share of attention. Conversely, there has been little attention to the demand side, which is evident in the limited number of published studies. Furthermore, there has been little empirical work done on developing a simple comparative static model that incorporates multimarket tradable commodities and technical change, which shifts the supply curves (reducing yield) and/or shifts the demand curves (increasing demand). This thesis will produce such a model, in order to examine the distributional impact of research in the Canadian canola market.

Chapter IV

Theoretical Development of Model

4.1 Introduction

In Chapter II, historical changes in both the yield and demand for canola were discussed. The purpose of this chapter is to model the canola market in two situations. The first examines the increase demand for canola oil. The second examines a reduction in canola/rapeseed yield combined with an increase in the demand for canola/rapeseed oil.

This chapter begins with a discussion of the necessity of using a fixed proportion model, a multimarket setting and an open economy setting to model the canola market. The middle portion of the chapter is dedicated to graphically illustrating the multimarket and trade model for two particular cases. The first case is that of a technically induced demand shift (demand increase). In this case, the private and external social benefits are illustrated. The second case is that of a technically induced supply shift (yield reduction) and demand shift (demand increase). In this case, two kinds of supply shifts were examined. Finally, this chapter concludes with the development of the mathematical form of the model.

4.2 The Necessity of an Open Market Setting

Next to wheat, the second largest category of agricultural commodities traded in the world markets, in terms of value, are oilseeds (mainly soybean, cottonseed, canola seed, peanuts and sunflowerseed, and flaxseed) and their products (Peters, 1995). Within this group of oilseeds, canola seed was the second-largest oilseed category, in terms of the volume traded, in the global market from 1989 to 1994. In addition, according to the quantity traded during the same period, canola oil ranked fourth, after palm oil, soybean oil and sunflower oil, in terms of edible oil consumption. Finally, based on the same criteria, canola meal ranked third, after soybean meal and fish meal.

In terms of canola/rapeseed production volume, Canada ranks fourth among the world's producing regions. The top four in 1992 were China (7653 thousand tonnes), EU-12 (6084 thousand tonnes), India (5660 thousand tonnes), and Canada (3689 thousand tonnes) (United States Department of Agriculture, 1994).

Canola is Canada's major oilseed (65%), followed by soybean (20%), flax (12%), sunflower (2%) and mustard (1%). Interestingly, Canada was a net importer of oilseeds until the 1960s. After 1960, due to the rapid increase in oilseed production (most of which was rapeseed), Canada became a net exporter of oilseed and oilseed products. Recently, canola has become the second largest crop, with respect to area in production, in Canada. The farm cash receipts (or farm-gate value) of canola have made it the second most valuable crop in Canada (Canadian International Grains Institute, 1993).

Canola oil and meal are the products derived from crushing canola seed. Like all edible oils, canola oil has important nutritional properties: the ingested oil acts as a carrier for fat soluble vitamins and a source of metabolic energy. In the kitchen, canola oil is primarily used as the base product for many salad dressings, cooking oils, shortenings and margarines. Canola oil is also used, to a small extent, for industrial purposes as a source of fatty acids and polymerization agents. While canola oil is primarily used for human consumption, canola meal is mainly used as a high content, good quality protein source for animal feed. In addition to feed use, canola meal has also found a very limited use as an organic fertilizer for vegetable, citrus and tobacco crops in China and Japan.

Canada is a relatively large exporter of canola products; however, its primary export is still the unprocessed canola seed. Canadian canola seed exports reached 74% of total world exports (excluding the trade flows within the EU) between 1988 and 1992 (Canadian oil and meal represent 18% and 28% of market share in the same period, respectively) (Oils World Annual, 1993). Japan took about 80% of Canadian rapeseed exports between 1988 and 1992. However, in 1993, with the introduction of other large importers such as the EU, Mexico, China and US, the world canola market structure changed. The change was so significant that in 1994 the Japanese share of total Canadian rapeseed exports shrank to 59%.

Canola oil is fast becoming the most preferred edible oil. Co-operative medical research and research into many aspects of utilization and processing has resulted in canola oil becoming the most widely used edible oil in the US. and Canada. The US market is more lucrative than most markets for canola oil since it is a commercial market that recognizes canola oil as a premium health food product (Storey, Furtan, Rosaasen and Taylor, 1993). Specifically, the US accounts for about 80% of the canola oil exports from Canada.

More recently, canola meal has firmly established itself in the world vegetable protein market. The US is the dominant Canadian canola meal importer. Between 1988 and 1992, the US purchased 62% of total Canadian rapeseed meal exports (Oil World Annual, 1993). From 1991 to the present, the quantity of meal imported by the US from Canada has been steadily growing. Compared to the oil market, the canola meal market is more diversified because countries like Taiwan, Korea, Indonesia and Japan import significant quantities of canola meal. Between 1988 and 1992, Japan imported approximately 19% of the total Canadian canola meal exports.

In Japan, imports of canola seed and meal are free of duties and restrictions (Peters, 1995). However, imported canola oil is subject to a high import tariff. The current flat-rate fixed tariff is 17,000 yen/tonne ($162.35/tonne Canadian in 1992, which represents 27.73% of the price of canola oil) on crude canola oil (Kneen, 1992). With this tariff regime the export of oil to Japan is not feasible. The analysis to follow incorporates the result of Japan's policy by allowing the Japanese to import canola seed and meal while prohibiting the import of oil.

4.3 The Necessity of Multimarket Setting

The canola industry is composed of primarily four sectors: the seed sector, the processing sector, the meal sector and the oil sector. Although these sectors are separated by degrees of canola product refinement, they are linked by the prices of their respective products (e.g., the canola seed sector is linked to the canola processing inputs sector, which is linked to the canola oil sector). Because the sectors are linked, a change in one sector affects all the other markets. Thus, an increase in the demand for canola oil affects not only consumers, but producers and processors. Similarly, the reduction in yield affects not only producers, but consumers and processors.

Although the welfare effects of medical research could be cumulatively measured in the final product sector(s) as in any other sector (Just and Hueth, 1979), sometimes it is more useful to measure them in each separate sector (Freebairn, Davis and Edwards, 1982; Alston and Scobie, 1983; Holloway, 1989; Mullen, Wohlgenant and Farris, 1988; Mullen, Alston and Wohlegant, 1989; Alston, 1991). If the welfare effects are only considered in the final product sector, the distribution of research benefits between the social groups will be unknown. Hence, the extension of this analysis into a multiple market setting may reveal new perspectives regarding the distribution of research benefits between particular interest groups. This study focuses on meal and oil consumers, processors and producers, in Canada, Japan and the ROW.

4.4 The Necessity of Fixed Proportion Model

The empirical evidence suggests using the fixed proportion model for modeling the canola industry. However, assuming the elasticity of substitution between the inputs is zero has important implications on the distribution of research benefit among the different social groups. Hence, this assumption should not take lightly. The empirical data was examined carefully before deciding whether or not to use the fixed proportion assumption. The data used in this study suggests that the inputs are used in fixed proportion to produce the canola oil and meal. Specifically, the extraction rate of canola oil and meal is 40% and 58% respectively, over a number of years. Even though the price of canola oil significantly changed in the late 1980s (canola oil became a premium product), there was no change in the extraction rate of canola oil and meal. Consequently, this study will engage a fixed proportion model since it is methodologically simple and can accurately serve the requirements of the thesis.[1]

4.5 Graphical Illustration of the Canola Market

The model for evaluating research benefits from health information is depicted in Figure 4.1. There are three underlying assumptions in this graphical illustration. First, a static (single-period) model is used. Second, competitive market clearing is assumed (i.e., there are no buffer stocks). Finally, supply and demand curves are assumed to be linear.[2]

Panel (a) represents the canola oil market. The demand curves are respectively denoted as D_0^C, D_0^J and D_0^R for Canada, Japan and the ROW. The total demand curve for canola oil is labeled D_0^T, which is the

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[1] The effect of assuming fixed propotions in a closed economy setting was discussed in secton 3.2.1. The effect of the ixed proportion assumption in an open-economy setting is likely to change. However, the examination of the effects of a fixed proportion assumption in an open-economy setting is beyond the scope of this particular thesis. In addition, empirical evidence suggests the use of a fixed proportion model in the case of the canola industry.

[2] A Marshallian demand curve is used instead of aHicksian demand curve for two main reasons. (1)The amount of income spend on canola oil is a small propotion of the consumer budget (less than 1%). Hence, the income effect is likely to be very small. (2)Theoritical and empirical evidence shows that the biases introduced when the income effect is not incorporate in the measurement of research benefits is negligible (Willig, 1976; and Alston and Larson, , 1993).

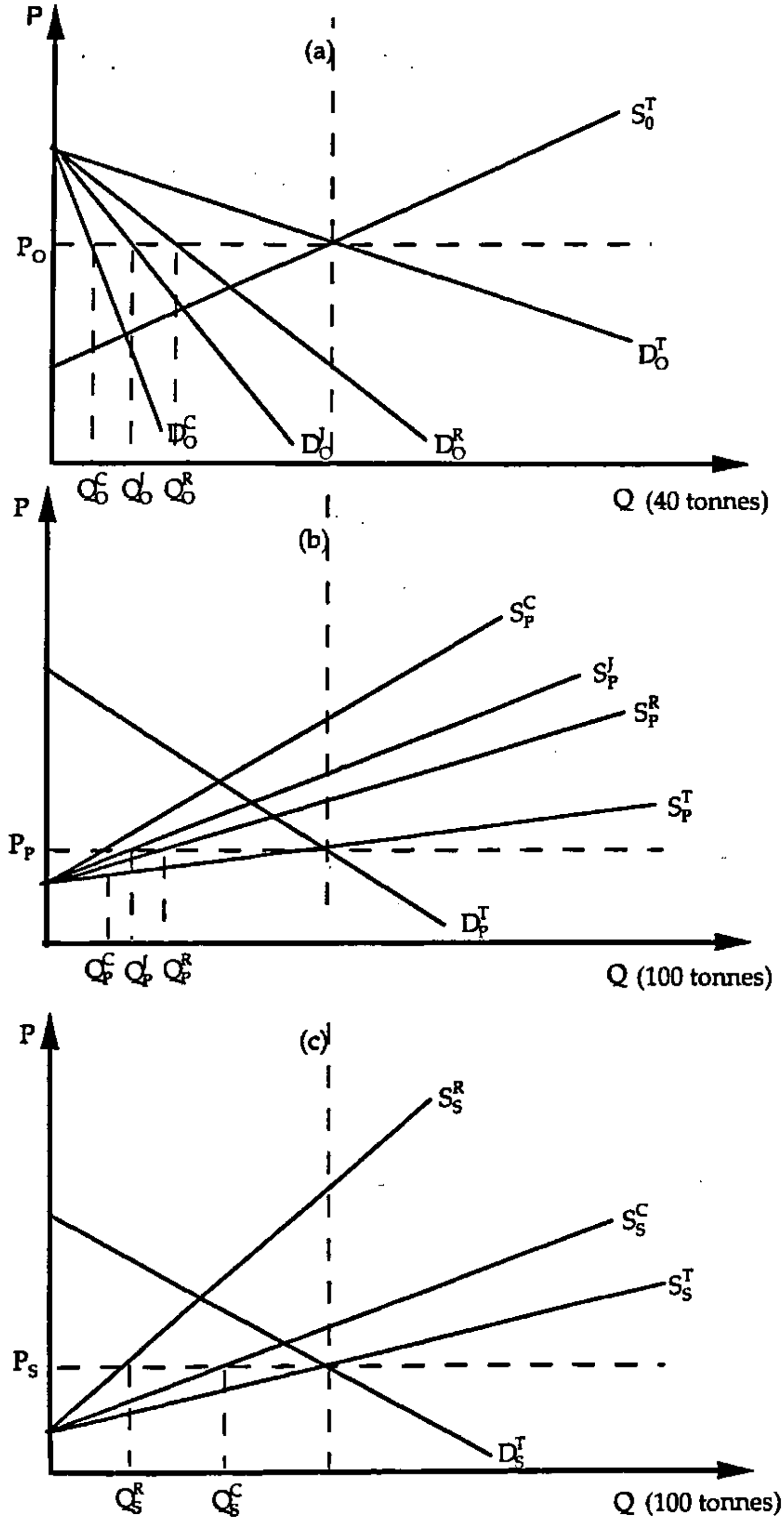

Figure 4.1. Canola Market

horizontal sum of Canadian, Japanese and ROW demand. D_O^C, D_O^J, D_O^R and D_O^T represent the *ex ante* health information demand curves. It is explicitly assumed, in constructing this figure, that there is no government intervention, and production and consumption are determined by the international canola oil price. Canola seed and a composite processing input are used in fixed proportion to produce canola oil and meal. As such, the Q-axis is scaled to units of 40 tonnes of oil instead of 100 tonnes because canola oil makes up 40% of the total volume of canola seed (canola meal makes up 58% of the total volume of canola seed). In panel (b), the market for canola processing input is presented. S_P^C, S_P^J, S_P^R and S_P^T are the corresponding supply curves for Canada, Japan, the ROW and the total supply. Finally, the canola seed market is depicted in panel (c): S_S^C, S_S^J, S_S^R and S_S^T are the supply curves for Canada, Japan, the ROW and the total respectively. The canola meal market is not included in this figure in order to keep the graph as simple as possible. However, the canola meal market is included in the mathematical form of the model.

Since outputs are produced in fixed proportions (oil and meal), it is straightforward to derive canola oil supply and the factor demand curves. The canola oil total supply function (S_O^T) is the vertical sum of the underlying supply curves (S_P^T) and (S_S^T). Hence, the marginal cost of canola oil is equal to the sum of the marginal cost of the corresponding factor quantities of canola processing inputs and canola seed. The total derived curve D_S^T for canola seed is the vertical difference between the total supply of processing inputs (S_P^T) and the total demand for canola oil (D_O^T).[3]

Using this model design, the graphic interpretation of these curves is straightforward. Consumers' willingness to pay for a specific quantity of canola outputs (or the retail price of canola oil) is measured by the vertical distance from the corresponding point on the Q-axis to the demand curve D_O^T. The processors' willingness to supply a specific quantity of canola outputs (or the price of processing input) is measured by the vertical distance from the corresponding point on the Q-axis to the supply curve S_P^T. Therefore, the processors' willingness to pay for a specific quantity of canola seed is the difference between the above two measures. Similarly, the derived demand for total canola processing is given by subtracting the total supply curve for canola seed (vertically) from the total canola oil demand curve. Finally, it is important to note that the demand for canola oil, the supply of canola processing inputs and the supply of canola seed are exogenous.[4]

The combination of vertical systems with trade in primary production and final production is very difficult; there are very few examples in the literature. The Canadian canola industry exports canola seed, canola oil and canola meal. The system attains market clearing conditions in the canola seed, oil and meal markets. In order for the entire system to clear and relate vertically, a clearing condition in the processing market is also necessary. That is, the price in the processing

[3] If the meal market were included the derived demand for canola seed would be the sum of both the demand for oil and the demand for meal.

[4] If the meal market were included the derived demand for canola processing would be the sum of both the demand for oil and the demand for meal.

sector has to be equal between the countries that trade primary and final products. This restriction means that, regardless of where the seed is crushed, the equilibrium conditions are the same. Consequently, since processors perform at their minimum cost, the allocation of the seed is determined according to relative crushing prices. An exception to this situation occurs in Japan, which only imports canola seed and canola meal, and the price in the processing sector is derived independently of other markets.

The intersection of a total supply and demand curve gives the international prices P_O, P_P and P_S (free trade) for canola oil, processing input and canola seed, respectively. At the price P_S for canola seed, the seed quantity supplied in Canada is Q_S^C. Processing service supply in Canada is equal to Q_P^C, which is less than Q_S^C, so the remainder (Q_S^C - Q_P^C) is exported at price P_P. The quantity of oil demanded in Canada is equal to Q_O^C, which is less than the quantity of processing services (e.g., quantity of oil produced), so the remainder (Q_P^C - Q_O^C) is exported at price P_S. Japan, on the other hand, does not produce seed (only 1% of the total consumption between 1988 and 1992), so the quantity of processing services supplied is equal to Q_P^J, the amount of seed it imports. In the oil sector, the quantity of oil demanded is equal to the quantity supplied in processing. By a similar analytical process, the import level can be determined for the ROW.

4.6 Graphical Illustration of Quality Improvement Technical Change in the Canola Market

4.6.1 Internal/Private Benefits

Next, consider the effect of health research in the canola market in Canada. This is depicted in Figure 4.2., where only the total supply and demand curves are examined. The effect of health research is depicted by an upward parallel shift in the demand for canola oil. This assumes that the willingness to pay a premium for the canola oil after the health information is the same for all consumers at all prices. Lindner and Jarrett (1978) have shown how the nature of supply shifts affects the estimation of total benefits and their distribution. However, Rose (1980) argues that, even for a particular innovation, predicting the nature of the shift is very difficult. Assuming that canola oil is a homogeneous commodity for consumers all over the world, it is hypothesized that canola oil demand in Canada and the ROW (but not Japan) shifts upward by the same absolute amount. Thus, the total demand curve for oil shifts upward from the *ex ante* to *ex post* health information demand curve (from D_O^T to $D_O^{T'}$), resulting in a higher international price, P_O', and a higher quantity demanded, Q_O'. The increased demand for canola oil implies an upward shift in the derived demand curve for canola processing inputs and canola seed. Because canola oil is produced with a fixed proportion of processing input and seed, whenever the demand for canola oil increases, the processing input and seed must also increase by exactly the same amount. Consequently, the quantity supplied and the prices of canola processing input and canola seed are higher.

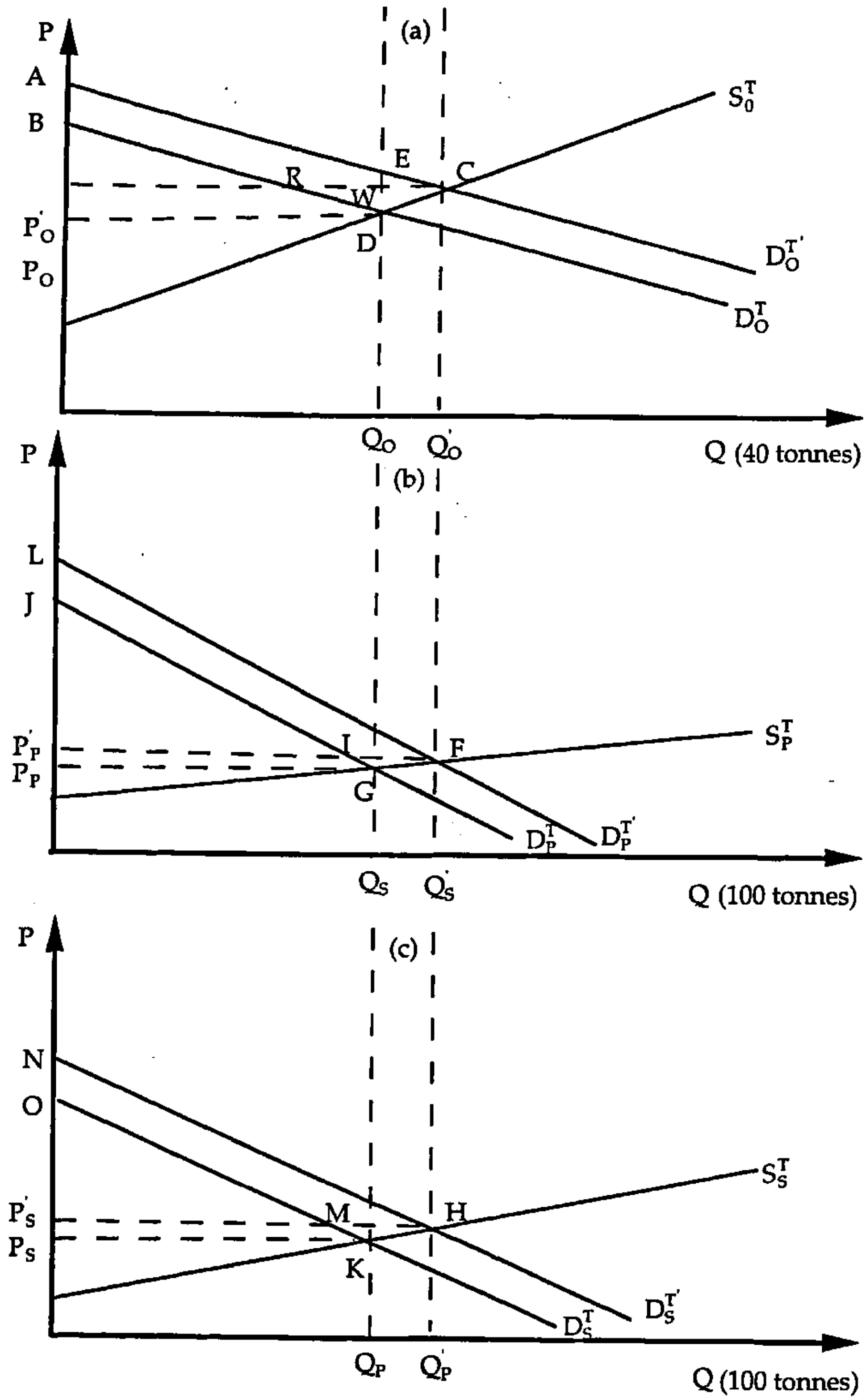

Figure 4.2. Sectoral Distribution of the Increased Demand for Canola Oil Resulting from Health Information.

In terms of welfare analysis, producers in the canola oil market should benefit from health research in Canada and the ROW. The change in the producer surplus in the canola oil sector is equal to $P_0'P_0DC$, which is unambiguously positive. The change in producer surplus in the canola oil sector includes changes in producer surplus of the processing services and a change in producer surplus of the canola seed. Notice also that this economic surplus includes the producer surplus of the suppliers of both processing input and canola seed (Just and Hueth, 1979).

Canada and ROW canola oil consumers are not necessarily better off with the health information. As we state earlier (section 3.2.2.3), improved health information on canola oil changed consumers' preferences and increased the demand for canola oil, for a given price and income.[5] Hence, the conventional welfare estimate can not be apply in this case, as its core assumption does not hold. Consequently, the Dixit and Norman (1978) methodology, which allows tastes to change, will be followed. They suggested that, in the case where the taste standard is not fixed, the conventional welfare measurement is applicable only if either the *ex post* or the *ex ante* demand curve is used in the estimation of the welfare benefit. In our case, the *ex post* health preference will be used as the standard because consumers are better informed after the health information, which in turn will yield a better estimate of the health benefit. Thus, the initial consumer surplus was equal to the area P_0DEA (the area beneath the *ex post* demand curve less the cost of consumption at the initial quantity). After the health information, the consumer

[5] This is opposite of the case of quality-improvement where tastes remain constant and quality changes.

surplus is equal to the area $P_O'CA$ (the area beneath the *ex post* demand curve less the cost of consumption at the new quantity). This assumes that the willingness-to-pay for canola oil, after the information is revealed, represents the unknown value to the consumer before the information was revealed. Hence, the change in consumer surplus is equal to the area $EWC - P_O'P_ODW$, which is ambiguous because they now have the same health benefit as before, but at a higher price. Consequently, one cannot say with certainty whether consumers of canola oil, in Canada and the ROW, are better off with the health information.

Canola oil consumers in Canada and the ROW are better off when the conventional estimate of consumer surplus is used. The conventional estimate (as mentioned earlier) is unlikely to yield accurate results since the consumers' tastes for canola oil are not constant after the health information.[6] For the sake of comparison the conventional estimate of consumer surplus will be applied. The consumer surplus, before the health information, was equal to the area P_ODB (the area beneath the *ex ante* demand curve less the cost of consumption at the initial quantity). The consumer surplus, after the health information, was equal to the area $P_O'CA$ (the area beneath the *ex post* demand curve less the cost of consumption at the new quantity). Hence, the change in consumer surplus is equal to the area $ABRC - P_O'P_ORW$, which is positive since $Q_O' > Q_O$. Consequently, with the conventional estimate of

6 Dixit and Norman argue that a comparison can be made with either the pre-advertising (ex ante) or the post-advertising (ex post) demand curve rather than pre-advertising/post-advertising (ex ante/ex post) comparison used in conventional analysis.

consumer surplus, consumers are unambiguously better off with the health information.

Both ROW and Canadian suppliers of processing input benefit from health research into canola oil; this is the area $P_P'P_PFG$. The change in consumer surplus in the processing input market in Canada and the ROW is given by area $IJLF - P_P'P_PGI$, which is positive since $Q_S' > Q_S$. The change in consumer surplus in the processing input market includes change in consumer surplus of the canola oil and a change in producer surplus of the canola seed.

Similarly, in the seed sector, the gain to producers is equal to the area $P_S'P_SHK$ and the gain to consumers is equal to the area $NOHM - P_S'P_SMK$ ($NOHM > P_S'P_SMK$ since $Q_P' > Q_P$). The area $NOHM - P_S'P_SMK$ includes the change in the consumer surplus of canola oil and a change in producer surplus of the processing input.

Demand for canola oil in Japan has grown very slowly because Japanese consumers' diets have a low fat content, so they are not concerned about changing their diets or reducing their fat intake. However, the Japanese do use canola oil for reasons of flavor and palatability. The increased demand for canola oil in Canada and the ROW implies an upward shift in the excess supply (ES) of seed for Japanese crushers and an increase in the equilibrium price for seed. This reduces the Japanese demand for processing services and increases the Japanese price for oil and meal. Due to this change in demand, the equilibrium quantity is reduced in all sectors. Consequently, Japanese consumers and processors both experience a loss in economic surplus.

4.6.2 External Social Benefits

The consumption of canola oil due to medical/nutritional research creates not only internal/private benefits (as shown earlier), but also external/social benefits. Specifically, as discussed in Chapter II, the substitution of canola oil for a portion of the fat in regular diet reduces the level of total serum cholesterol, which in turn reduces the CHD risk. The reduction in CHD due to the consumption of canola oil will also reduce the social health care cost. Consequently, the canola industry creates an external (or social) benefit from the canola oil consumption. This external/social benefit was not included in the previous graphical illustration.

In Figure 4.3, the benefit from the reduction in CHD cost due to the consumption of canola oil in Canada is depicted. Specifically, this graph combines the private and the external social benefits from the consumption of canola oil. The social demand curve is denoted as D_S and shows the marginal external social benefits to the canola industry. D_P represents the private demand curve to the canola industry and shows the marginal internal/private benefits. The external economies cause the marginal social value to differ from the private value or market price. In the case of the canola industry, the marginal social value is greater than the marginal private value. The supply curve is denoted as S. The intersection of a private demand curve and a supply curve gives the price P_0 and the quantity supplied Q_P of canola oil.

In the above graphical illustration and throughout this thesis, there is an implicit assumption that governments pay the price of health

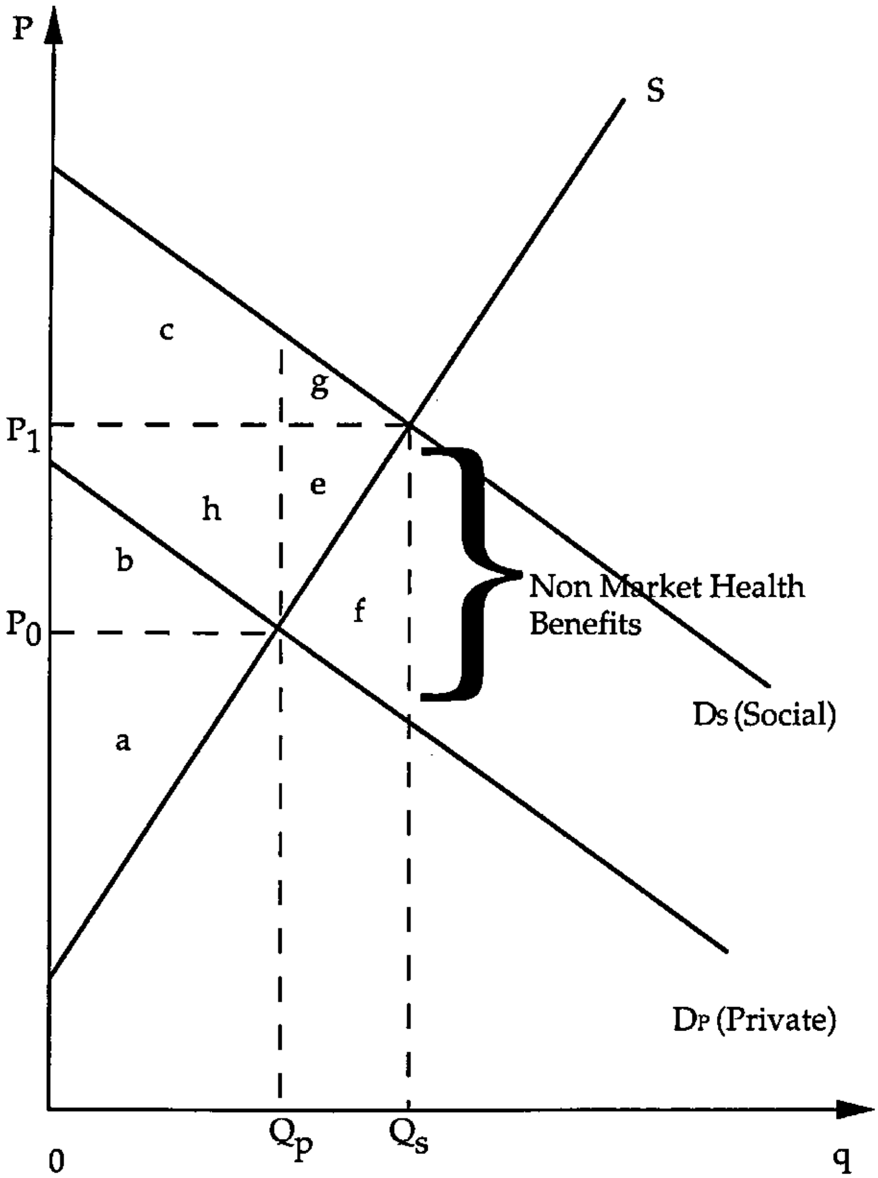

Figure 4.3. Private and Social Benefit from the Increased Demand in the Canola Oil Market

care costs. This situation is representative of the health care system in Canada. On the other hand, in a case where individuals themselves pay the health care costs (like in the U.S), the social and private demand curves could roughly coincide. However, where there is no government health care policy, private medical insurance creates a potential for the practice of moral hazard. Since fat consumption is difficult to monitor, individuals will consume fat knowing the insurance will pick up most of the costs of CHD. Again, this effect will be external to the borne by the individual.

In terms of welfare analysis, the external social benefits from the reduction in health care costs is equal to the area h+c. The internal/private benefit of the consumption of canola oil is equal to the sum of the benefits of consumers and producers. The consumer surplus is equal to the area b and the producer surplus is equal to the area a. Hence, the total internal/private benefits is equal to the area a+b. Consequently, the total benefit from the consumption of canola oil, which is equal to the sum of private and public benefits, are equal to the area a+b+h+c. Therefore, these results show that the external/social benefits from the consumption of canola oil exceed the internal/private benefits.

The correction of the externality, from the reduction in health care costs, results in a greater demonstrated total benefit to the canola industry. For the moment, assume that the government subsidizes the consumption of canola oil. This would result in an upward shift in the private demand curve so as to become equal to the social demand curve. The intercept of the new private demand curve (equal to the social demand curve) and the supply curve increases the equilibrium price from P_0 to P_1 and the equilibrium quantity from Q_P to Q_S. Health care savings are increased, too. The health care savings are now equal to the area c+g+e+f+h. The increased total internal/private benefits are equal to the area a+b+h+e+c+g (the area a+b+h+e captured by the producer and the area c+g captured by the consumer). On the other hand, the government's subsidy cost is equal to the area c+g+h+e+f. Consequently, the total derived external/social benefits are now equal to a+b+h+e+c+g, which is greater than the total benefit without the subsidy.

4.7 Graphical Illustration of Yield Reducing Technical Change in the Canola Market

4.7.1 Proportional Marginal Cost Increasing Supply Shift

The effect of the yield reduction in the canola industry due to switching to the quality characteristic of canola products, or in other words the effects of the switch from rapeseed to canola, in Canada is depicted in Figure 4.4. Specifically, this figure illustrates the two consequences of the switch from rapeseed to canola. The first is the reduction in yield due to sacrificing potential yield for better quality products. The second is the increase in demand for canola oil due to canola products being better quality than rapeseed products. To keep the analysis simple, only the total supply and demand curves are examined. The reduction in yield is depicted by a proportional upwards shift of the supply curve for canola seed ("marginal-cost-increasing"). A marginal-cost-increasing supply shift assumes that the effect of the yield reduction is larger, the greater the quantity supplied. The marginal cost is increased

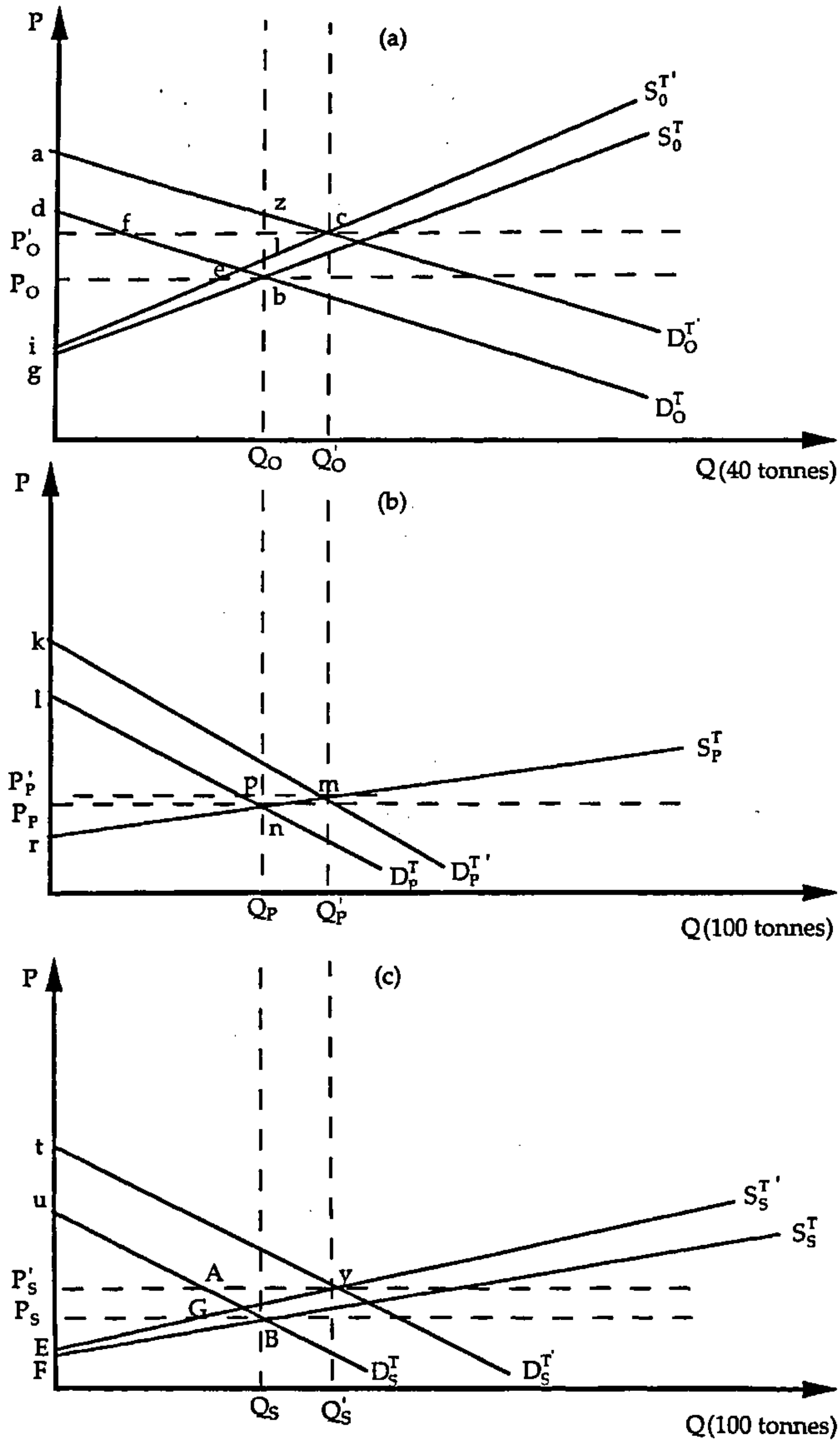

Figure 4.4. Proportional Increase in Marginal Cost for Improved Quality Canola Products

by a constant proportion at all the points along the supply curve. Hence, the two supply curves converge at the Q-axis. On the other hand, the increase in demand for canola oil is depicted by an upward parallel shift of the demand curve for canola oil. The parallel demand shift assumes that the willingness to pay a higher price for canola oil than for rapeseed oil is the same for all consumers at all prices. In this model, the increase in yield takes place only in Canada because the Canadian canola industry decided to switch from rapessed to canola. However, as mentioned earlier, the total supply curve of rapeseed/canola seed is the horizontal summation of the Canadian, ROW and Japan supply. Hence, the total supply curve for canola seed is shifted upward as a result of a reduction in Canadian yield. Conversely, the increase in demand for canola oil takes place in Canada and the ROW. Hence, the total demand curve for canola oil is shifted upward because it is the summation of the Canadian, ROW and Japan demand.

The reduction in the total supply of canola seed implies an upward marginal-cost-increasing shift in the total supply curve for oil (as it is given by the vertical sum of total supply of processing input and the total supply of canola seed) and a downward marginal-cost-increasing shift in the total derived demand for processing input (as it is given by the vertical difference between the total demand for canola oil and the total supply of canola seed). On the other hand, the increase in the total demand for canola oil implies an increase by exactly the same amount in the total demand of canola processing input and canola seed (since canola oil is produced with a fixed proportion of processing input and seed). Consequently, the total quantities supplied and demanded are higher

($Q_P^{'}, Q_S^{'}, Q_O^{'}$ in canola seed, processing and oil sector respectively).[7] Additionally, the price is increased in the canola seed sector, the canola processing sector and the canola oil sector as the demand shift is bigger than the supply shift.

In terms of welfare analysis, the effect of switching from rapeseed to canola is ambiguous for canola seed producers. The change in their total producer surplus is equal to $P_S P_S^{'} Gy - EFGB$, which is positive only if $EFGB > P_S P_S^{'} Gy$. The total consumer surplus in the canola seed sector is equal to the area $utyA - P_S P_S^{'} BA$, which is also ambiguous. Essentially, the consumers will gain if $P_S P_S^{'} BA > utyA$.

The suppliers of processing input benefit from a reduction in yield of canola seed and an increase in demand for canola oil. The benefit to suppliers of processing inputs is equal to $P_P P_P^{'} nm$. The change in consumer surplus in the processing input sector is given by area $klpm - P_P P_P^{'} pm$, which is positive only if $P_P P_P^{'} pm > klpm$.

Finally, in the canola oil sector the effect on consumers, from a supply-reducing and demand-increasing technical change, is ambiguous with both the *ex post* and conventional measures of consumer surplus. Specifically, the change in the total consumer surplus, using the *ex post* measure of consumer surplus, is equal to $lzc - P_O P_O^{'} lb$. On the other hand, the change in consumer surplus, using the conventional estimate, is equal to the area $adfc - P_O P_O^{'} bf$. The change in the total producer surplus is equal to $P_O P_O^{'} ce - igbe$, which is also ambiguous.

[7] The total quantities supplied and demanded are higher if the demand shift is bigger than the supply shift.

4.7.2 Parallel Supply Shift

The distribution and the magnitude of the total research benefit is mainly affected by the type of supply shift. In the previous section, the case of marginal-cost-reducing supply shift was examined. In this section the effect of the switch from rapeseed to canola will be simulated by using a parallel supply shift, which is the more widely applied assumption. Specifically, the reduction in yield will be depicted as an upward parallel supply shift. The increase in demand for canola oil will be depicted as an upward parallel shift of the demand curve for canola oil (Figure 4.5). Consequently, this analysis will reveal the different implications of the two kinds of supply shifts.

The parallel supply shift has a positive impact on the equilibrium quantities and prices. Specifically, the quantities supplied in the canola seed sector and processing sector, and the quantity demanded in the canola oil sector, are increased (only if the demand shift is bigger than the supply shift) from Q_S to Q_S', Q_P to Q_P' and Q_O to Q_O'. Similarly, the equilibrium prices increased from P_S to P_S', P_P to P_P' and P_O to P_O' for canola seed, canola processing and canola oil sector.

In terms of welfare analysis, the effect of the focus on the quality characteristic of canola products is ambiguous in the canola seed sector. The change in total producer surplus is given by the area $P_SP_S'Gy - EFGB$, which is positive only if $EFGB > P_SP_S'Gy$. The change in total consumer surplus is given by the area $utyA - P_SP_S'BA$, which is also positive if $P_SP_S'BA > utyA$.

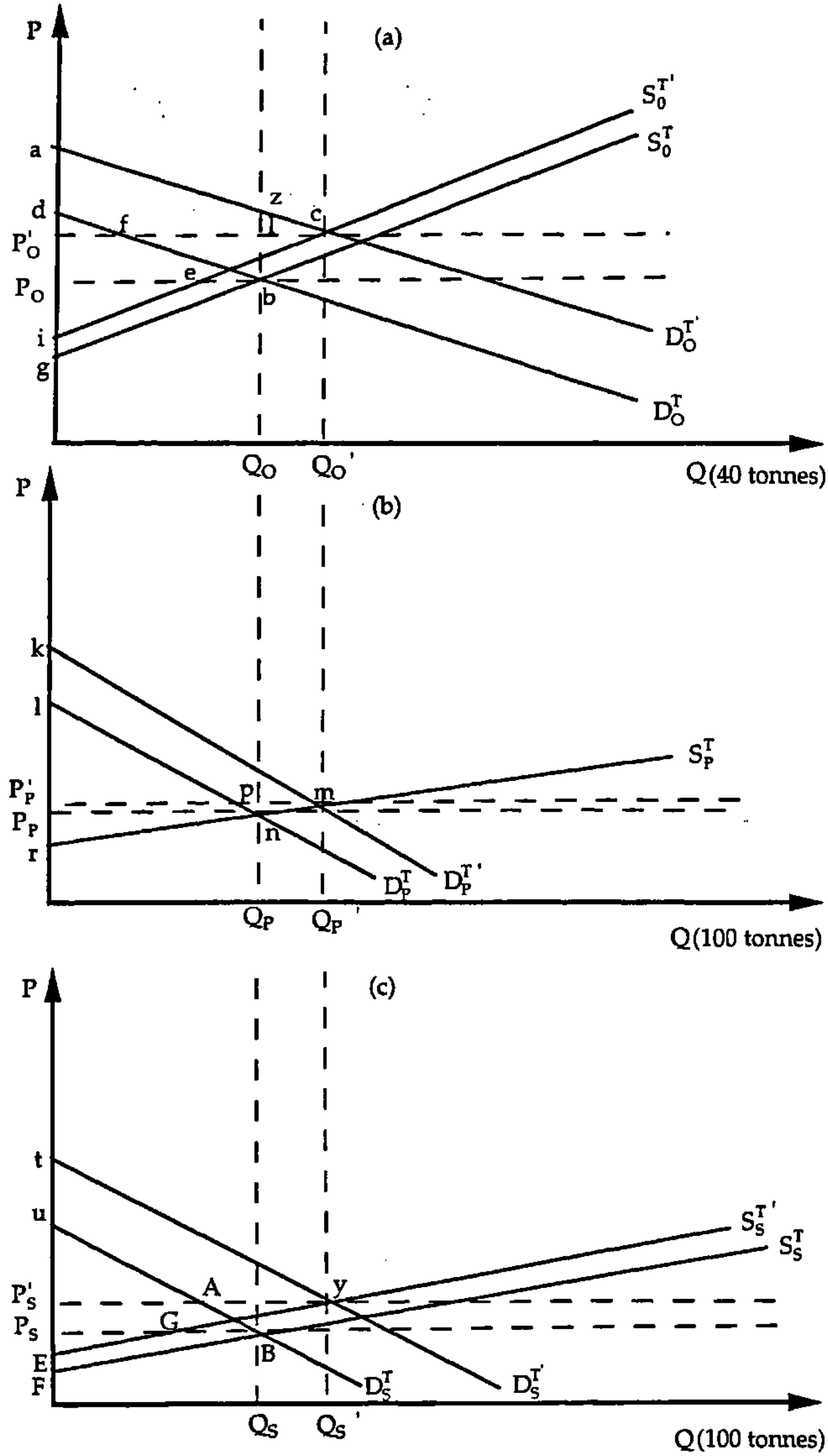

Figure 4.5.Parallel Supply Reduction for Improved Quality Canola Products

In the processing sector, the suppliers of processing input are better off with the switch from rapeseed to canola. Specifically, the welfare gain to suppliers of processing inputs is equal to $P_P P_P^{'} nm$. The change in total consumer surplus in the processing input sector is equal to $klpm - P_P P_P^{'} pm$, which is positive if $P_P P_P^{'} pm > klpm$.

Finally, with a parallel supply shift, whether or not the consumers of canola oil are better off from the decision of the canola industry, the benefits of focusing on the quality characteristic of a product at the expense of yield remains ambiguous. Specifically, using the *ex post* measure of consumer surplus, the change in the total consumer surplus is given by $lzc - P_O P_O^{'} lb$, which is positive if only if $P_O P_O^{'} lb > adfc$. Using the conventional estimate of consumer surplus, the change in the total consumer surplus is given by $adfc - P_O P_O^{'} bf$, which is also ambiguous. The change in producer surplus, in the canola oil sector, is given by the area $P_O P_O^{'} ce - igbe$.

4.8 Mathematical Form of the Model

Mathematically, these graphs can be represented by the following set of linear equations:

Seed Sector

Supply Equations

$$QS_S^C = a + bP_S \tag{4.1.1}$$

$$QS_S^R = c + dP_S \tag{4.2.1}$$

$$QS_S^J = e + fP_S \tag{4.3.1}$$

$$QS_S^T = QS_S^C + QS_S^R + QS_S^J \tag{4.4}$$

Processing Sector

Supply Equations

$$QS_P^C = g + hP_p \tag{4.5}$$

$$QS_P^R = i + jP_p \tag{4.6}$$

$$QS_P^J = k + lP_p \tag{4.7}$$

$$QS_P^T = QS_P^C + QS_P^R + QS_P^J \tag{4.8}$$

Oil Sector

Demand Equations

$$QD_O^C = m - nP_O \tag{4.9.1}$$

$$QD_O^R = o - pP_O \tag{4.10.1}$$

$$QD_O^J = q - rP_O \tag{4.11.1}$$

$$QD_O^T = QD_O^C + QD_O^R + QD_O^J \tag{4.12}$$

Meal Sector

Demand Equations

$$QD_m^C = s - tP_m \tag{4.13.1}$$

$$QD_m^R = u - vP_m \tag{4.14.1}$$

$$QD_m^J = w - xP_m \tag{4.15.1}$$

$$QD_m^T = QD_m^C + QD_m^R + QD_m^J \qquad (4.16)$$

Trade

Seed Sector

$$x_S^C / m_S^C = QS_S^C - QS_P^C \qquad (4.1.2)$$

$$x_S^R / m_S^R = QS_S^R - QS_P^R \qquad (4.2.2)$$

$$x_S^J / m_S^J = QS_S^J - QS_P^J \qquad (4.3.2)$$

Oil Sector

$$x_O^C / m_O^C = 0.4QS_P^C - QD_O^C \qquad (4.9.2)$$

$$x_O^R / m_O^R = 0.4QS_P^R - QD_O^R \qquad (4.10.2)$$

$$x_O^J / m_O^J = 0.4QS_P^J - QD_O^J \qquad (4.11.2)$$

Meal Sector

$$x_m^C / m_m^C = 0.58QS_p^C - QD_m^C \qquad (4.13.2)$$

$$x_m^R / m_m^R = 0.58QS_p^R - QD_m^R \qquad (4.14.2)$$

$$x_m^J / m_m^J = 0.58QS_p^J - QD_m^J \qquad (4.15.2)$$

Restrictions

$$QS_S^T = QS_P^T \qquad (4.17)$$

$$0.4QS_P^T = QD_O^T \qquad (4.18)$$

$$0.58QS_P^T = QD_m^T \qquad (4.19)$$

$$(0.4P_O + 0.58P_m) - P_S = P_P \qquad (4.20)$$

$$0.4Q_P^J = Q_0^J \qquad (4.21)$$

With Quality Improving Technical Change

$$QD_O^{C'} = m + nk - nP_O \qquad (4.9.1)'$$

$$QD_O^{R'} = o + pk - pP_O \qquad (4.10.1)'$$

With Yield Reducing Technical Change

$$QS_S^{C'} = a + b(1 - x)P_S \qquad (4.1.1)'$$

$$QS_S^{C'} = a + bx + bP_S \qquad (4.1.1)''$$

$$QD_O^{C'} = m + nk - nP_O \qquad (4.9.1)'$$

$$QD_O^{R'} = o + pk - pP_O \qquad (4.10.1)'$$

where P is price; QS and QD are quantity supplied and demanded; b, d,..., x are demand and supply price slopes; a, c,..., w are the intercept terms; the subscripts s, p, o, m denote the seed, processing, oil and meal sectors; and the superscripts C, R, J, T refer to Canada, the ROW, Japan and the total.

The supply equations for the seed and the processing sector are given by equations (4.1.1)-(4.8). Equations (4.9.1)-(4.16) are the demand equations for oil and meal. The equilibrium clearing conditions are given by equations (4.17)-(4.22). Finally, the equations (4.1.2)-(14.15.2) refer to the trade sector.

With the introduction of a demand shift caused by medical research, the equations (4.9.1) and (4.10.1) become (4.9.1)' and (4.10.1)'. The letter k denotes the exogenous demand shift. With the introduction of a supply shift caused by breeding research, the equations (4.1.1), (4.9.1) and (4.10.1) become (4.1.1)', (4.9.1)' and (4.10.1)', with a marginal-cost-increasing supply shift. Likewise, the equations (4.1.1), (4.9.1) and (4.10.1) become (4.1.1)'', (4.9.1)' and (4.10.1)', with a parallel supply shift. The letter x denotes the exogenous supply shift. Note also that x is a positive number with a marginal-cost-increasing supply shift.

Algebraically, the gain for producers with a negative quantity intercept, is G_P^N. The gain for producers with a negative quantity intercept and a marginal-cost-increasing supply shift is G_P^{NS}. The gain for producers with a negative quantity intercept and a parallel supply shift is G_P^{PP}. Conversely, the gain for producers with a positive quantity intercept is G_P^P. The gain for consumers, using the conventional estimate, is G_C; and the gain for Canadian and ROW consumers, based on the *ex post* health information standard, is $G_C^{C,R}$. These can be expressed as:

$$G_P^N = \frac{1}{2}(P + \frac{a}{b})Q,$$

$$G_P^{NS} = \frac{1}{2}\left(P + \frac{a}{b(1-x)}\right)Q,$$

$$G_P^P = 1/2(Q - a)P + Pa = 1/2(Q + a)P,$$

$$G_P^{PP} = \frac{1}{2}(P + \frac{a}{b} - x)Q$$

$$G_C = \frac{1}{2}(-\frac{a}{b} - P)Q,$$

$$G_C^{C,R} = \left[\frac{1}{2}(-\frac{a}{b} - k - P)Q\right] + Qk, \text{ and}$$

where a and b denote the intercept and slope terms of the inverse supply and demand function.

4.9 Summary

This chapter has developed both a graphical and a mathematical model of the canola industry. Specifically, this model is a trade displacement fixed proportion model containing three regions and four sectors. The three regions are Canada, Japan and the ROW. The four sectors are the canola seed sector, the processing sector, the oil sector and the meal sector. In using this modeling technique, the welfare implications of a technically induced demand shift/supply shift can be easily associated with the various industry stockholders.

Chapter V

Results and Discussion

5.1 Introduction

The previous chapter developed the empirical model which will be used as a framework to test the hypothesis developed in the thesis. This chapter provides the analysis and the results of estimation. Specifically, the model is used to measure the economic impact of the two main historical issues in the canola industry: the change in demand for canola oil and the change in the yield of canola seed. The model also determines the distribution of benefits between the social groups: consumers of canola oil and meal, processors and canola producers, in Canada, the ROW and Japan.

This chapter has two parts. The first part examines the case of a demand shift. The demand shift discussion begins with an estimate of the shift in demand due to health information using OLS regression. It is followed by an analysis of the market effects and welfare implications from the shift in the demand for canola oil. The discussion concludes with a sensitivity analysis of the critical assumptions regarding: the elasticities of supply and demand, *ex ante* and *ex post* measures of consumer surplus and the type of supply shift. The second part examines the net benefit/loss in the case of a supply shift. The supply shift section uses the same reporting structure as the demand shift section.

5.2 The Case of Demand Shift

In this section, the model is used to estimate the economic gain from medical research and the accompanying health information about canola oil in Canada, Japan and the ROW. The empirical procedure was to first derive the premium for canola oil due to the health information by running an OLS regression. Then, estimates of the demand for canola oil with this health benefit are included. After, to create the demand for canola oil without health information, the estimated demand was reduced appropriately by the premium. The calculations were performed over a range of different elasticities of supply and demand. Finally, the public benefit was estimated from the positive externality created by the reduction of CHD cost, which resulted inadvertently from the increased demand of canola oil.

The data used for the study was obtained from various sources. Price data on canola oil and meal for Canada was obtained from various issues of Statistics Canada, Cereals and Oilseed Review, catalogue no. 22-007. The price of canola oil and meal in Canada was expressed in Canadian dollars per metric tonne and grain prices were on a cash basis. The price data on soybean oil was obtained from various issues of the United States Department of Agriculture, Economic Research Service, Agricultural Outlook. The cash price of soybeans was in US dollars per metric tonne. US dollars were converted to Canadian dollars by the exchange rate obtained from various issues of the Bank of Canada Review. The price of canola seed in Canada was obtained from Saskatchewan Agriculture and Food, Agricultural Statistics 1992. The price of canola seed in Saskatchewan was used because the centrally located province provides an average representation of the price of seed.[8] The price of canola seed was in Canadian dollars per metric tonne and was the farm price. The farm price, or price received by the farmer, is important because this study estimates the benefits captured by the farmer due to the technical change. The data for the consumer price index (CPI) was obtained from Statistics Canada, Direct Cansim Time Series: CPI and All Goods for Canada (1994). Finally, all the quantity data used in this study was obtained from the United States Department of Agriculture, Production, Supply and Disposition Data Base 1994. The various elastisities used in this study are shown in Table 5.1. The elasticities were taken from various sources (reported in the table) and cover a range of low/average/high elasticities of supply for canola seed and the processing sector, and the elasticity of demand for canola oil and meal, for Canada, the ROW and Japan. The supply elasticity of the processing sector was available only for the short run. Hence, the value of the average and long run elasticity of processing sector was assumed. The world quantity of canola oil consumed was used instead of the Canadian quantity because the world supply and demand determined the equilibrium price of canola oil.

5.2.1 Result of Regression

The price of canola oil in Canada is determined primarily by the price of US soybean oil. Empirical estimation (Storey et. al., 1993) shows that the price of canola oil in Canada is positively and significantly related to the price of US soybean oil, as expressed in Canadian dollars.

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[8] Vancouver is a primary export point of canola seed. Hence, Alberta (west of Saskatchewan) has the higher canola seed price, while Manitoba (east of Saskatchewan) has the lower price.

Table 5.1. Elasticities*

	LOW	AVERAGE	HIGH
CANADA			
Elasticity of Supply for Canola seed	0.09 [1]	1.31	2.53 [2]
Elasticity of Supply for Processing	0.06 [3]	5.00	10.00 [18]
Elasticity of Demand for Canola Oil	-0.54 [4]	-2.44	-4.34 [5]
Elasticity of Demand for Canola Meal	-0.12 [6]	-0.71	-1.30 [7]
JAPAN			
Elasticity of Supply for Canola seed	0.00 [18]	0.00	0.00 [18]
Elasticity of Supply for Processing	0.06 [3]	5.00	10.00 [18]
Elasticity of Demand for Canola Oil	-0.31 [8]	-0.74	-1.17 [9]
Elasticity of Demand for Canola Meal	-0.20 [10]	-0.46	-0.71 [11]
ROW			
Elasticity of Supply for Canola seed	0.41 [12]	1.09	1.77 [13]
Elasticity of Supply for Processing	0.06 [3]	5.00	10.00 [18]
Elasticity of Demand for Canola Oil	-0.13 [14]	-2.05	-4.08 [15]
Elasticity of Demand for Canola Meal	-0.20 [16]	-1.03	-1.86 [17]

*Elasticities were taken from:
[9,17] Furtan, Nagy and Storey (1979);
[15] Furtan, Nagy and Storey (1978);
[4] Goddard and Glance (1988);
[11,13] Griffith (1979);
[7,8,10,16] Griffith and Meilke (1982);
[1] Liv and Roningen (1985);
[12] Meilke and Griffith (1983);
[5] Nagasa (1993);
[2] Nagy and Furtan (1978);
[3,6] Storey, Furtan, Rosaasen and Taylor (1993);
[14] Suryana (1986); and
[18] assumed.

Initially, the canola oil price was determined at a discount to the US soybean oil price. However, for the late 1980s, with the recognition of canola oil as "healthy" oil, mainly by the US market, the price of canola oil was determined at a premium to US soybean oil.

The estimation of the premium due to the quality characteristics of canola oil was determined by the following equation[9]:

$$P_{Ct} = \alpha + \beta_1 P_{St} + \beta_2 D_t + \beta_3 Q_t^{CONS} + \varepsilon_t$$

where:

P_{Ct} is Canadian canola oil price deflated by the consumer price index (1990=100) and P_{St} is the US soybean oil price (expressed in Canadian dollars) deflated by the consumer price index (1990=100).

D_t is an intercept-shifting dummy variable which is zero before the 1988 crop year and one after the 1987 crop year, reflecting the influence of health information.

Q_t is the world quantity of canola oil consumed[10]

The regression was corrected for autocorrelation using the standard Cochrane-Orcutt type of procedure. Specifically, the regression was corrected for second-order autocorrelation, since the correction for first-order autocorrelation still resulted in evidence (D-W=1.306) of

[9] In the estimation of the premium received by canola oil, a system of demand equations method was not used for two reasons. First, while a demand system may give more efficient estimates, it is complex, time consuming, and beyond the scope of this thesis. Second, in the current situation (average for 1991 to 1994 crop years) world production of canola oil represents a very small portion of the world total oilseeds production (4.4 percent) (United States Department of Agriculture, Foreign Agriculture Service, Production, Supply and Distribution Data Base, 1995). Hence, canola oil production does not have a significant impact on the world price of oil.

[10] The world quantity of canola oil consumed was used instead of the Canadian quantity consumed because the world supply and demand determined the equilibrium price of canola oil.

positive first-order autocorrelation. The procedure converged after 8 iterations at RHO_1=1.348 and RHO_2=-0.406. The asymptotic t-ratios for RHO_1 and RHO_2 were 15.966 and -4.807 respectively which were statistical significant at 95% confidence interval. The computed Durbin-Watson coefficient, after the correction for second-order autocoreletion (D-W=1.645), lies between the lower and the upper limit; hence, there is inclusive evidence regarding the presence or absence of positive higher order autocorrelation.

The regression results are shown in Table 5.2. In this table, the sign of the estimated coefficient indicates whether an increase in the independent (explanatory) variable increases (+) or decreases (-) the dependent variable. Furthermore, for a one-tailed test of significance, the results must have a t-ratio of at least 1.29, to fall within an 80% confidence interval. A one-tailed test of significance is used because only one hypothesis is examined. The proposed null hypothesis is: the coefficient on intercept-shifting dummy variable is less than or equal to zero, which is the same as saying there is no canola premium due to health information. Therefore, if the computed t-value reported exceeds the critical value of (1.29), with 113 degrees of freedom, then one would reject the null hypothesis. We can therefore select the hypothesis with 80% confidence. Finally, the coefficient of determination, R^2, indicates what proportion of the variation in the dependent variable that is explained by the explanatory variable.

Table 5.2. Demand Increase: OLS Regression Results

	R^2=0.959	$\overline{R^2}$=0.958		
Variable	Estimated Coefficient	Standard Error	t-Ratio	Elasticity (At Means)
Intercept	419.780	81.912	5.125*	0.806
Price of Soybean	0.210	0.4807E-01	4.376*	0.220
Dummy	32.254	20.284	1.590	0.2804E-01
World Quantity Consumed	-4.0866	10.530	-0.381	-0.5569E-01

* The estimated coefficient is significant within a 95% confidence interval.

The regression results indicate the following general conclusions. If all the explanatory variables are zero, the average or mean value of the price of canola oil is estimated at approximately +$419.78/t, in 1991 dollars. The intercept-shifting dummy coefficient 32.254 means that, holding all other variables constant, as the dummy variable increases from zero to one the price of canola oil increases by about +$32.254/t. The other explanatory variables can be explained similarly. The R^2 of 0.959 shows that the three explanatory variables explain about 95.9 percent of the variation in quarterly price of canola oil in Canada over the period 1983-1992. The $\overline{R^2}$ shows that after taking into account the degrees-of-freedom, the explanatory variable still explain about 95.8 percent of the variation in price of canola. Finally, each of the estimated coefficients, except for the coefficient on the world quantity consumed, are individually statistically significant. Consequently, we would reject the proposed null hypothesis that: the coefficient on the intercept-shifting dummy variable is less than or equal to zero with 80% confidence.

Furthermore, as can be observed in Table 5.2, the coefficient on the intercept-shifting dummy variable is greater than zero, which means that there is a premium due to medical/nutritional research. The regression results show the best point estimate of the premium to be +$32.254/t.

5.2.2 Market Effects and Welfare Implications

The mathematical model used to simulate the market equilibrium with and without a shift in demand, shows that the health/nutritional research, and consequently the demand shift, affects the quantity demanded/supplied and the prices in the various sectors. The mathematical model was solved by using the average elasticities of supply for canola seed and the processing sector, and the average elasticities of demand for canola oil and meal. As expected, health information had a positive impact on the quantity of oil (+3.89% in Canada and +3.19% in the ROW) and the quantity of meal (+2.06% in Canada and +2.91% in the ROW) demanded. The same effect was found for the quantity of seed (+3.20% in Canada and +2.65% in the ROW) and processing input (+3.25% in Canada and +3.23% in the ROW) supplied in Canada and ROW. Health information also had a positive impact on the price of canola oil (+4.28%), processing input (+0.64%) and seed (+2.43%). The price of canola meal fell (-2.82%) as the increased demand for oil caused an increased supply of canola meal, which forced meal prices downward (Table 5.3.).

Conversely, and as anticipated, a different situation arises in the Japanese canola market. Since the rest of the canola industry sectors adjusted around them, the price in the Japanese processing sector and

Table 5.3. Canola Model Parameters: Base Prices and Quantities, and Changes due to Medical/Nutritional Research.

	Elasticities	Prices		Quantities	
	Average	Base($/t)	Change($/t)	Base($/t)	Change($/t)
CANADA					
Supply of Canola seed	1.310	261.250	6.353	3.343	0.107
Supply of Processing Inputs	5.000	56.791	0.366	1.510	0.049
Demand of Canola Oil	-2.439	552.720	23.636	0.385	0.015
Demand of Canola Meal	-0.710	167.160	-4.715	0.339	0.007
JAPAN					
Supply of Canola seed	0.000	261.250	6.353	0.000	0.000
Supply of Processing Inputs	5.000	56.791	-0.333	1.820	-0.053
Demand of Canola Oil	-0.740	552.720	21.888	0.728	-0.021
Demand of Canola Meal	-0.460	167.160	-4.715	1.242	0.016
ROW					
Supply of Canola seed	1.090	261.250	6.353	19.297	0.512
Supply of Processing Inputs	5.000	56.791	0.366	19.310	0.623
Demand of Canola Oil	-2.045	552.720	23.636	7.943	0.254
Demand of Canola Meal	-1.030	167.160	-4.715	11.551	0.336

Source: as calculated

meal sector decreased, while all other Japanese sectors saw an increase in price. In addition, the quantity demanded and supplied by all Japanese sectors, except from the meal sector, decreased (Table 5.3.).

The value of benefits resulting from medical research, as estimated by the model, are shown in Table 5.4 (Base case). This table depicts the change in welfare and the distribution of benefits between the social groups. A positive change indicates that a benefit is realized by the groups. Conversely, a negative change indicates that a loss is realized by the groups. The percentage change (in parentheses) indicates what proportion of the total internal/private benefits/loss accrued to a specific social group. The estimation was performed at average elasticities for both the supply equations and demand equations.

The impact of health information is shown in Table 5.4 (Base case). The results concur with what was expected from the graphical analysis. (1) Canadian canola seed producers, processors and meal consumers benefited from the health information (Base Case: +$M 20.90, +$M 0.54 and +$M 1.58 respectively). The total internal/private benefits were also positive in all the cases (Base Case: +$M 14.34). In contrast, using the *ex post* demand curve canola oil consumers lost from the health information (Base Case: -$M 8.69). (2) Similar nutrition/health research effects, as in Canada, occurred in the ROW. (3) Japanese canola seed producers, processors and consumers of oil lost benefits from the health information. The total internal/private benefits were also negative. Conversely, the consumers of canola meal experienced benefits from the health information.

Table 5.4. Welfare Impacts from the Health Information using the Ex post Demand Measure*

	BASE BASE($M)	CHANGE($M)
CANADA		
Canola Seed Producers	333.34	20.90 (145.78%)
Canola Processors	8.58	0.54 (3.80%)
Canola Oil Consumers	43.61	-8.69 -(60.61%)
Canola Meal Consumers	39.91	1.58 (11.04%)
Total Internal/Private Benefit		14.34
Total External/Social Benefit		29.77
JAPAN		
Canola Seed Producers	0.00	0.00 (0.00%)
Canola Processors	10.34	-0.61 (5.60%)
Canola Oil Consumers	271.88	-16.17 (147.43%)
Canola Meal Consumers	225.59	5.82 -(53.03%)
Total Internal/Private Benefit		-10.97
ROW		
Canola Seed Producers	2312.54	120.98 (12598.99%)
Canola Processors	109.66	6.96 (724.67%)
Canola Oil Consumers	1070.79	-180.64 -(18812.75%)
Canola Meal Consumers	937.28	53.67 (5589.10%)
Total Internal/Private Benefit		0.96
Total External/Social Benefit		504.13

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total external/Social Benefit" indicates the social welfare .
benefits from the increased consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

Source: as calculated

The medical/nutritional research mainly benefited producers. Specifically, the producers' share of the gain in total private return from the health information is, in the base case, 145.78%. The producers' share of the total internal/private benefits follows the canola meal consumers' with a share of the gain (in a base case) of 11.04%, and the canola processors with 3.80% (in a base case) of the total internal/private benefits. Finally, canola oil consumers' portion of the total private returns is the lowest of all the social groups, which is -60.61% in the base case. Consequently, contrary to what is generally believed, the health information increased the demand for canola oil which mainly benefited the producers of canola oil and, surprisingly, not the consumers of canola oil. The consumers of canola oil have less benefit; in fact they have lost some previous benefit from the medical/nutrition research because they had the health benefit from the consumption of canola oil even before the health information. Hence, now for the same benefit they used to enjoy, they have to pay an extra amount of money.

5.2.3 Sensitivity Analysis on Critical Assumptions Imposed

5.2.3.1 The Elasticities of Supply and Demand

The assumptions concerning supply and demand elasticities have an impact on the welfare measurements. In this section, the analysis uses the lowest and highest reported estimates of the elasticities of supply and demand to calculate a range of benefits/losses, which may accrue to the different social groups.

The results of the different simulations are reported in Tables 5.4.1-5.4.4. The results can be summarized as follows:

Table 5.4.1. Welfare Impacts from the Health Information using the Ex post Demand Measure*

	BASE		1st. Case		2nd. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	20.90 (145.8%)	834.06	31.76 (141.5%)	172.60	15.57 (150.1%)
Canola Processors	8.58	0.54 (3.8%)	8.58	0.30 (1.3%)	8.58	0.67 (6.4%)
Canola Oil Consumers	43.61	-8.69 -(60.6%)	43.61	-10.39 -(46.3%)	43.61	-7.85 -(75.7%)
Canola Meal Consumers	39.91	1.58 (11.04%)	39.91	0.77 (3.43%)	39.91	1.99 (19.14%)
Total Internal/Private Benefit		14.34		22.44		10.38
Total External/Social Benefit		29.77		15.68		35.72
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-0.61 (5.6%)	10.34	-0.74 (4.3%)	10.34	-0.55 (7.1%)
Canola Oil Consumers	271.88	-16.17 (147.4%)	271.88	-19.34 (112.1%)	271.88	-14.59 (186.2%)
Canola Meal Consumers	225.59	5.82 -(53.0%)	225.59	2.82 -(16.4%)	225.59	7.31 -(93.3%)
Total Internal/Private Benefit		-10.97		-17.25		-7.83
ROW						
Canola Seed Producers	2312.54	120.98 (12599.0%)	4007.87	182.28 -(6393.4%)	1424.11	90.53 (3250.4%)
Canola Processors	109.66	6.96 (724.7%)	109.66	3.79 -(132.9%)	109.66	8.53 (306.2%)
Canola Oil Consumers	1070.79	-180.64 -(18812.8%)	1070.79	-215.10 (7544.4%)	1070.79	-163.55 -(5872.4%)
Canola Meal Consumers	937.28	53.67 (5589.1%)	937.28	26.18 -(918.1%)	937.28	67.28 (2415.7%)
Total Internal/Private Benefit		0.96		-2.85		2.79
Total External/Social Benefit		504.13		272.27		619.96

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total external/Social Benefit" indicates the social welfare . benefits from the increased consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada:
elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
Japan: elasticity of canola meal demanded=-0.71
elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
ROW: elasticity of canola meal demanded=-0.46
elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
In 1st. Case all parameters are elasticity of canola meal demanded=-1.03
In 2nd. Case all parameters are at base value except for the elasticity of canola seed supplied in Canada and ROW(2.53 and 1.77 respectively).

Source: as calculated

Table 5.4.2. Welfare Impacts from the Health Information using the Ex post Demand Measure*

	BASE		3rd. Case		4th. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	20.90 (145.8%)	333.34	6.65 (70.6%)	333.34	21.19 (146.8%)
Canola Processors	8.58	0.54 (3.8%)	83.18	13.56 (144.2%)	4.29	0.28 (1.9%)
Canola Oil Consumers	43.61	-8.69 -(60.6%)	43.61	-11.30 -(120.2%)	43.61	-8.63 -(59.8%)
Canola Meal Consumers	39.91	1.58 (11.04%)	39.91	0.50 (5.33%)	39.91	1.60 (11.11%)
Total Internal/Private Benefit		14.34		9.41		14.44
Total External/Social Benefit		29.77		8.53		29.57
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-0.61 (5.6%)	100.26	-3.96 (117.4%)	5.17	-0.32 (2.9%)
Canola Oil Consumers	271.88	-16.17 (147.4%)	271.88	-1.25 (37.1%)	271.88	-16.71 (150.1%)
Canola Meal Consumers	225.59	5.82 -(53.0%)	225.59	1.84 -(54.5%)	225.59	5.90 -(53.0%)
Total Internal/Private Benefit		-10.97		-3.37		-11.13
ROW						
Canola Seed Producers	2312.54	120.98 (12599.0%)	2312.54	38.39 -(807.3%)	2312.54	122.64 (11239.2%)
Canola Processors	109.66	6.96 (724.7%)	1063.73	173.43 -(3647.2%)	54.83	3.53 (323.7%)
Canola Oil Consumers	1070.79	-180.64 -(18812.8%)	1070.79	-233.63 (4912.9%)	1070.79	-179.49 -(16448.7%)
Canola Meal Consumers	937.28	53.67 (5589.1%)	937.28	17.05 -(358.5%)	937.28	54.41 (4985.8%)
Total Internal/Private Benefit		0.96		-4.76		1.09
Total External/Social Benefit		504.13		149.03		511.61

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total external/Social Benefit" indicates the social welfare . benefits from the increased consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada:
elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan:
elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW:
elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 3rd. Case all parameters are at base value except for the elasticity of canola processing inputs supplied in Canada, Japan and ROW(0.06, 0.06 and 0.06 respectively).
In 4th. Case all parameters are at base value except for the elasticity of canola processing inputs supplied in Canada, Japan and ROW(10, 10 and 10 respectively).

Source: as calculated

Table 5.4.3. Welfare Impacts from the Health Information using the Ex post Demand Measure*

	BASE		5th. Case		6th. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	20.90 (145.8%)	333.34	4.95 (141.0%)	333.34	23.83 (145.9%)
Canola Processors	8.58	0.54 (3.8%)	8.58	0.12 (3.5%)	8.58	0.65 (4.0%)
Canola Oil Consumers	43.61	-8.69 -(60.6%)	197.03	-1.94 -(55.1%)	24.52	-9.95 -(60.9%)
Canola Meal Consumers	39.91	1.58 (11.04%)	39.91	0.37 (10.62%)	39.91	1.81 (11.06%)
Total Internal/Private Benefit		14.34		3.51		16.33
Total External/Social Benefit		29.77		20.04		31.15
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-0.61 (5.6%)	10.34	-0.06 (2.4%)	10.34	-1.10 (8.6%)
Canola Oil Consumers	271.88	-16.17 (147.4%)	649.00	-3.82 (152.1%)	171.96	-18.29 (143.4%)
Canola Meal Consumers	225.59	5.82 -(53.0%)	225.59	1.37 -(54.5%)	225.59	6.64 -(52.1%)
Total Internal/Private Benefit		-10.97		-2.51		-12.75
ROW						
Canola Seed Producers	2312.54	120.98 (12599.0%)	2312.54	28.61 -(78766.6%)	2312.54	138.00 (8707.9%)
Canola Processors	109.66	6.96 (724.7%)	109.66	1.57 -(4335.1%)	109.66	8.27 (522.0%)
Canola Oil Consumers	1070.79	-180.64 -(18812.8%)	16885.60	-42.92 (118178.4%)	538.02	-205.90 -(12992.2%)
Canola Meal Consumers	937.28	53.67 (5589.1%)	937.28	12.70 -(34976.7%)	937.28	61.21 (3862.2%)
Total Internal/Private Benefit		0.96		-0.04		1.58
Total External/Social Benefit		504.13		98.03		604.48

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total external/Social Benefit" indicates the social welfare. benefits from the increased consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada:
elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan:
elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW:
elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 5th. Case all parameters are at base value except for the elasticity of canola oil demanded in Canada, Japan and ROW(-0.54, -0.31 and -0.13 respectively).
In 6th. Case all parameters are at base value except for the elasticity of canola oil demanded in Canada, Japan and ROW(-4.34, -1.17 and -4.08 respectively).

Source: as calculated

Table 5.4.4. Welfare Impacts from the Health Information using the Ex post Demand Measure*

	BASE		7th. Case		8th. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	20.90 (145.8%)	333.34	11.37 (199.8%)	333.34	23.11 (141.4%)
Canola Processors	8.58	0.54 (3.8%)	8.58	0.32 (5.7%)	8.58	0.60 (3.6%)
Canola Oil Consumers	43.61	-8.69 -(60.6%)	43.61	-10.20 -(179.2%)	43.61	-8.34 -(51.1%)
Canola Meal Consumers	39.91	1.58 (11.04%)	236.11	4.20 (73.81%)	21.80	0.98 (5.97%)
Total Internal/Private Benefit		14.34		5.69		16.34
Total External/Social Benefit		29.77		17.06		31.75
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-0.61 (5.6%)	10.34	-0.72 (16.5%)	10.34	-0.59 (4.7%)
Canola Oil Consumers	271.88	-16.17 (147.4%)	271.88	-19.00 (434.0%)	271.88	-15.51 (124.0%)
Canola Meal Consumers	225.59	5.82 -(53.0%)	518.86	15.34 -(350.5%)	146.16	3.59 -(28.7%)
Total Internal/Private Benefit		-10.97		-4.38		-12.51
ROW						
Canola Seed Producers	2312.54	120.98 (12599.0%)	2312.54	65.73 (5299.1%)	2312.54	133.77 (14554.2%)
Canola Processors	109.66	6.96 (724.7%)	109.66	4.13 (333.3%)	109.66	7.61 (828.2%)
Canola Oil Consumers	1070.79	-180.64 -(18812.8%)	1070.79	-211.34 -(17038.4%)	1070.79	-173.53 -(18879.4%)
Canola Meal Consumers	937.28	53.67 (5589.1%)	4827.00	142.72 (11506.0%)	519.03	33.06 (3597.0%)
Total Internal/Private Benefit		0.96		1.24		0.92
Total External/Social Benefit		504.13		297.28		552.09

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total external/Social Benefit" indicates the social welfare.
benefits from the increased consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada:
elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
Japan: elasticity of canola meal demanded=-0.71
elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
ROW: elasticity of canola meal demanded=-0.46
elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 7th. Case all parameters are at base value except for the elasticity of canola meal demanded in Canada, Japan and ROW(-0.12, -0.20 and -0.20 respectively).
In 8th. Case all parameters are at base value except for the elasticity of canola meal demanded in Canada, Japan and ROW(-1.30, -0.71 and -1.86 respectively).

Source: as calculated

(1) Canadian canola seed producers' gains from health research in canola oil are greater with a more inelastic supply of canola seed;

(2) Canadian canola processors' gains are greater with a more inelastic supply of processing inputs;

(3) Canadian canola meal consumers' gains are greater with a more inelastic demand for canola meal;

(4) Canadian canola oil consumers' losses are greater with a more elastic demand for canola oil; and

(5) similar effects of the health information as in Canada, occurred in the ROW.

The results indicate a positive (private) impact from the health information. In general, the aggregate total internal/private benefits are positive for health-related canola research. For Canada and the ROW (countries which increase their demand due to the health-related research), the benefits to any one sector are greater the more inelastic its supply curve is relative to the other sector. The gain (loss) to consumers of canola meal is greater (less) than the gain to producers the more elastic (inelastic) the supply curve is relative to the demand curve. Conversely, the gain (loss) to consumers of canola oil is greater (less) than the gain to producers, the more elastic the demand curve is relative to the supply curve. In the case of canola oil, consumer surplus results were found to be opposite to the other social groups. Specifically, the results revealed that consumers in Canada and the ROW were better off before the health information because they were already receiving the additional health benefit without paying for it. Hence, the initial estimation of the consumer surplus, prior to the health information, initiated a shift in the demand curve, which included the health benefit, which explains the adverse consequences of health information for Canadian consumers.

5.2.3.2 Conventional versus ex post Measures of Consumers Surplus

The consumer's welfare position and consequently the total internal/private benefits are influenced by whether the conventional or the *ex post* measurement of consumer surplus is used. Specifically, the conventional estimate of the consumer surplus includes the area beneath the demand curve less the cost of consumption. The *ex post* measure of consumer surplus (as discussed in section 3.2.2.3) includes the area beneath the *ex post* health information demand curve less the area under the supply curve. The conventional estimate's core assumption is that taste remains constant before and after the health information. This assumption does not hold though, since the health information has definitely changed taste (at given set of price and income demand will change). Hence, the conventional estimate is unlikely to produce an accurate result. On the other hand, the *ex post* measurement of consumer surplus allows tastes to vary. For the sake of comparison between the two estimates of consumer surplus (conventional and *ex post*), this section will estimate the consumer surplus using the conventional estimate only (Tables 5.5.1-5.5.4). Consequently, this comparison should reveal the welfare implications of the two consumer measures.

Using the conventional estimate of consumer surplus, the analysis reveals that consumers benefit from the health information. Specifically, the Canadian and ROW consumers' benefit is equal to +\$M3.25 and

Table 5.5.1. Welfare Impacts from the Health Information using the Conventional Welfare Measure*

	BASE		1st. Case		2nd. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	20.90 (79.5%)	834.06	31.76 (91.8%)	172.60	15.57 (70.1%)
Canola Processors	8.58	0.54 (2.1%)	8.58	0.30 (0.9%)	8.58	0.67 (3.0%)
Canola Oil Consumers	43.61	3.25 (12.4%)	43.61	1.77 (5.1%)	43.61	3.99 (17.9%)
Canola Meal Consumers	39.91	1.58 (6.02%)	39.91	0.77 (2.23%)	39.91	1.99 (8.94%)
Total Internal/Private Benefit		26.28		34.60		22.21
Total External/Social Benefit		29.77		15.68		35.72
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-0.61 (5.6%)	10.34	-0.74 (4.3%)	10.34	-0.55 (7.1%)
Canola Oil Consumers	271.88	-16.17 (147.4%)	271.88	-19.34 (112.1%)	271.88	-14.59 (186.2%)
Canola Meal Consumers	225.59	5.82 -(53.0%)	225.59	2.82 -(16.4%)	225.59	7.31 -(93.3%)
Total Internal/Private Benefit		-10.97		-17.25		-7.83
ROW						
Canola Seed Producers	2312.54	120.98 (48.6%)	4007.87	182.28 (73.2%)	1424.11	90.53 (36.4%)
Canola Processors	109.66	6.96 (2.8%)	109.66	3.79 (1.5%)	109.66	8.53 (3.4%)
Canola Oil Consumers	1070.79	67.36 (27.1%)	1070.79	36.67 (14.7%)	1070.79	82.56 (33.2%)
Canola Meal Consumers	937.28	53.67 (21.6%)	937.28	26.18 (10.5%)	937.28	67.28 (27.0%)
Total Internal/Private Benefit		248.96		248.92		248.90
Total External/Social Benefit		504.13		272.27		619.96

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total external/Social Benefit" indicates the social welfare . benefits from the increased consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada:
elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
Japan: elasticity of canola meal demanded=-0.71
elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
ROW: elasticity of canola meal demanded=-0.46
elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 1st. Case all parameters are at base value except for the elasticity of canola seed supplied in Canada and ROW(0.09 and 0.41 respectively).
In 2nd. Case all parameters are at base value except for the elasticity of canola seed supplied in Canada and ROW(2.53 and 1.77 respectively).

Source: as calculated

Table 5.5.2. Welfare Impacts from the Health Information using the Conventional Welfare Measure*

	BASE		3rd. Case		4th. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	20.90 (79.5%)	333.34	6.65 (30.6%)	333.34	21.19 (80.3%)
Canola Processors	8.58	0.54 (2.1%)	83.18	13.56 (62.5%)	4.29	0.28 (1.0%)
Canola Oil Consumers	43.61	3.25 (12.4%)	43.61	0.98 (4.5%)	43.61	3.30 (12.5%)
Canola Meal Consumers	39.91	1.58 (6.02%)	39.91	0.50 (2.31%)	39.91	1.60 (6.08%)
Total Internal/Private Benefit		26.28		21.68		26.37
Total External/Social Benefit		29.77		8.53		29.57
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-0.61 (5.6%)	100.26	-3.96 (117.4%)	5.17	-0.32 (2.9%)
Canola Oil Consumers	271.88	-16.17 (147.4%)	271.88	-1.25 (37.1%)	271.88	-16.71 (150.1%)
Canola Meal Consumers	225.59	5.82 -(53.0%)	225.59	1.84 -(54.5%)	225.59	5.90 -(53.0%)
Total Internal/Private Benefit		-10.97		-3.37		-11.13
ROW						
Canola Seed Producers	2312.54	120.98 (48.6%)	2312.54	38.39 (15.4%)	2312.54	122.64 (49.3%)
Canola Processors	109.66	6.96 (2.8%)	1063.73	173.43 (69.6%)	54.83	3.53 (1.4%)
Canola Oil Consumers	1070.79	67.36 (27.1%)	1070.79	20.15 (8.1%)	1070.79	68.39 (27.5%)
Canola Meal Consumers	937.28	53.67 (21.6%)	937.28	17.05 (6.8%)	937.28	54.41 (21.9%)
Total Internal/Private Benefit		248.96		249.02		248.97
Total External/Social Benefit		504.13		149.03		511.61

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total external/Social Benefit" indicates the social welfare.
benefits from the increased consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada:
elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan:
elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW:
elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 3rd. Case all parameters are at base value except for the elasticity of canola processing inputs supplied in Canada, Japan and ROW(0.06, 0.06 and 0.06 respectively).
In 4th. Case all parameters are at base value except for the elasticity of canola processing inputs supplied in Canada, Japan and ROW(10, 10 and 10 respectively).

Source: as calculated

Table 5.5.3. Welfare Impacts from the Health Information using the Conventional Welfare Measure*

	BASE Base($M)	BASE Change($M)	5th. Case Base($M)	5th. Case Change($M)	6th. Case Base($M)	6th. Case Change($M)
CANADA						
Canola Seed Producers	333.34	20.90	333.34	4.95	333.34	23.83
		(79.5%)		(31.7%)		(84.4%)
Canola Processors	8.58	0.54	8.58	0.12	8.58	0.65
		(2.1%)		(0.8%)		(2.3%)
Canola Oil Consumers	43.61	3.25	197.03	10.16	24.52	1.96
		(12.4%)		(65.1%)		(6.9%)
Canola Meal Consumers	39.91	1.58	39.91	0.37	39.91	1.81
		(6.02%)		(2.39%)		(6.39%)
Total Internal/Private Benefit		26.28		15.61		28.25
Total External/Social Benefit		29.77		20.04		31.16
JAPAN						
Canola Seed Producers	0.00	0.00	0.00	0.00	0.00	0.00
		(0.0%)		(0.0%)		(0.0%)
Canola Processors	10.34	-0.61	10.34	-0.06	10.34	-1.10
		(5.6%)		(2.4%)		(8.6%)
Canola Oil Consumers	271.88	-16.17	649.00	-3.82	171.96	-18.29
		(147.4%)		(152.1%)		(143.4%)
Canola Meal Consumers	225.59	5.82	225.59	1.37	225.59	6.64
		-(53.0%)		-(54.5%)		-(52.1%)
Total Internal/Private Benefit		-10.97		-2.51		-12.75
ROW						
Canola Seed Producers	2312.54	120.98	2312.54	28.61	2312.54	138.00
		(48.6%)		(11.2%)		(55.7%)
Canola Processors	109.66	6.96	109.66	1.57	109.66	8.27
		(2.8%)		(0.6%)		(3.3%)
Canola Oil Consumers	1070.79	67.36	16885.60	211.66	538.02	40.47
		(27.1%)		(83.2%)		(16.3%)
Canola Meal Consumers	937.28	53.67	937.28	12.70	937.28	61.21
		(21.6%)		(5.0%)		(24.7%)
Total Internal/Private Benefit		248.96		254.55		247.95
Total External/Social Benefit		504.13		98.03		604.48

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total external/Social Benefit" indicates the social welfare . benefits from the increased consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada:
elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
Japan: elasticity of canola meal demanded=-0.71
elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
ROW: elasticity of canola meal demanded=-0.46
elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 5th. Case all parameters are at base value except for the elasticity of canola oil demanded in Canada, Japan and ROW(-0.54, -0.31 and -0.13 respectively).
In 6th. Case all parameters are at base value except for the elasticity of canola oil demanded in Canada, Japan and ROW(-4.34, -1.17 and -4.08 respectively).

Source: as calculated

Table 5.5.4. Welfare Impacts from the Health Information using the Conventional Welfare Measure*

	BASE		7th. Case		8th. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	20.90 (145.8%)	333.34	11.37 (199.8%)	333.34	23.11 (141.4%)
Canola Processors	8.58	0.54 (3.8%)	8.58	0.32 (5.7%)	8.58	0.60 (3.6%)
Canola Oil Consumers	43.61	-8.69 -(60.6%)	43.61	-10.20 -(179.2%)	43.61	-8.34 -(51.1%)
Canola Meal Consumers	39.91	1.58 (11.04%)	236.11	4.20 (73.81%)	21.80	0.98 (5.97%)
Total Internal/Private Benefit		14.34		5.69		16.34
Total External/Social Benefit		29.77		17.06		31.75
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-0.61 (5.6%)	10.34	-0.72 (16.5%)	10.34	-0.59 (4.7%)
Canola Oil Consumers	271.88	-16.17 (147.4%)	271.88	-19.00 (434.0%)	271.88	-15.51 (124.0%)
Canola Meal Consumers	225.59	5.82 -(53.0%)	518.86	15.34 -(350.5%)	146.16	3.59 -(28.7%)
Total Internal/Private Benefit		-10.97		-4.38		-12.51
ROW						
Canola Seed Producers	2312.54	120.98 (12599.0%)	2312.54	65.73 (5299.1%)	2312.54	133.77 (14554.2%)
Canola Processors	109.66	6.96 (724.7%)	109.66	4.13 (333.3%)	109.66	7.61 (828.2%)
Canola Oil Consumers	1070.79	-180.64 -(18812.8%)	1070.79	-211.34 -(17038.4%)	1070.79	-173.53 -(18879.4%)
Canola Meal Consumers	937.28	53.67 (5589.1%)	4827.00	142.72 (11506.0%)	519.03	33.06 (3597.0%)
Total Internal/Private Benefit		0.96		1.24		0.92
Total External/Social Benefit		504.13		297.28		552.09

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total external/Social Benefit" indicates the social welfare.
benefits from the increased consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada:
elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
Japan: elasticity of canola meal demanded=-0.71
elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
ROW: elasticity of canola meal demanded=-0.46
elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 7th. Case all parameters are at base value except for the elasticity of canola meal demanded in Canada, Japan and ROW(-0.12, -0.20 and -0.20 respectively).
In 8th. Case all parameters are at base value except for the elasticity of canola meal demanded in Canada, Japan and ROW(-1.30, -0.71 and -1.86 respectively).

Source: as calculated

+$M67.36 respectively. The share of the gain in total private return from the health information is +12.38% for Canada and +27.06% for ROW.

The conventional estimate yields a high estimate of the total internal/private benefits. Specifically, the conventional estimate of consumer surplus results in a positive change in the consumers' benefit. This positive change in consumers' surplus in turn results in an always positive change in total internal/private benefits. The total internal/private benefits is +$M 163.58 for Canada and +$M 2820.03 for the ROW.

There are three different outcomes revealed when using the conventional, rather than the *ex post* measurement of the consumer benefit. First, the conventional estimate results in a net benefit to consumers from the health information which is opposite to the *ex post* measures findings. Second, the conventional estimate results in consumers receiving the second largest share of the gain in total internal/private benefits, after the producers. Conversely, when the *ex post* health information preference is taken as the standard, consumers had a negative return. Finally, the estimated total internal/private benefits is higher using the conventional estimate.

Regardless of whether or not the conventional or the *ex post* measurement of consumer surplus is used, producers are the social group who benefit more from the health information. Specifically, the canola producer's share of the gain in total private return is the highest of all the social groups. The producers' share accounts for 79.58% of total welfare when using the conventional estimate (base case) and 145.78%

(base case) of total welfare when using the *ex post* health information standard. Consequently, the increase in demand for canola oil due to medical/nutrition research benefits mainly the producers.

5.2.4 The Effects of Canola Use on the Costs of Health Care

In addition to the benefits of canola oil related to the increase in demand due to the health information, there is a perhaps larger benefit which is derived from the improved health of an entire population. These benefits come in the form of reduced social health care costs, especially those related to treatment and prevention of coronary heart disease. As this section will show, the result of substituting canola oil in traditional diets can have a very large positive effect on the cost of health care in Canada. Hence, the increase in canola consumption creates a positive externality.

Table 5.6 reports the results of some studies where the relationship between canola oil usage and serum cholesterol was tested. Studies were chosen that kept the total fat, as a percentage of energy, constant before and after the canola diet. In all the studies, canola oil replaced a portion of the saturated fat sources in the regular diet, such that no additional fat was added to the diet. Hence, the reported studies can be directly compared. Most of the studies published were controlled diets except for two, where subjects consumed their regular diets except for the change in type of oil. The study population ranged from 8 to 59 persons The change in monounsaturated fatty acid (MOFAs) in each study varied from 14g/d to 27.5g/d. The baseline total serum cholesterol ranged from 4.4 to 7.1 mmol/L. Consequently, the range covers all levels of baseline

Table 5.6. Reduction in Total Cholesterol (TC) Given Canola Consumption, Various Studies.

Paper	Year	Diet Characteristics	Change in MOFAs(gm)	Baseline Cholesterol (mmol/L)	% Change in Cholesterol	% Change in TC/10g MOFAs	% Change in TC/10g Canola
Bierenbaum et al.	1991	replacement not controlled n=36	15.4	6.56	-2.30%	-1.49%	-1.12%
Wardlaw et al.	1991	replacement controlled n=16	26.4	4.36	-8.80%	-3.33%	-1.99%
Chan et al.	1991	replacement controlled n=8	17.8	4.4	-18.40%	-10.30%	-6.17%
McDonald et al.	1989	replacement controlled n=8	16.7	4.41	-16.60%	-9.90%	-5.93%
Miettined et al.	1994	replacement not controlled n=18	27.5	7.1	-9%	-3.27%	-1.96%
Valsta et al.	1992	replacement controlled n=59	14.5	5.35	-15.50%	-10.68%	-6.40%

Source: as calculated

serum cholesterol, which can be categorized as: light risk (most desirable, less than 5.2 mmol/L), moderate risk (5.2 to 6.2 mmol/L) and high risk (greater than 6.2 mmol/L) (Reeder et al., 1995).

In Canada about 46% of the population have total serum cholesterol levels above the desirable level of 5.2 mmol/L. According to a recent survey of nine Canadian provinces, with a study population of 16,582 men and women ages 18 to 74 from 1986 to 1990, 48% of men and 43% of women have total serum cholesterol above 5.2 mmol/L. Accordingly, the majority of the Canadian population, 52% of men and 55% of women, had a desirable level of total serum cholesterol (less than 5.2 mmol/L) (Connelly et al., 1992).

In each of the dietary intervention studies, there is an effect on total serum cholesterol level (Table 5.6.). Specifically, the percentage reduction in the total serum cholesterol level ranged between 2.3% and 18.4% in all the examined canola diets. Converting this to a reduction for a uniform level of canola consumed, the percentage reduction in total serum cholesterol level per 10 grams of canola oil ranged between 1.12% and 6.40%. Interestingly, when the effect of canola oil on total serum cholesterol is related to the initial cholesterol values, it is obvious that the effect on total serum cholesterol is independent of how high cholesterol was initially. For example, 10g of canola oil with a starting cholesterol of 7.1 mmol/L resulted in a percentage change in cholesterol of -1.96%. On the other hand, 10g canola oil with a starting cholesterol of 4.36 mmol/L resulted in a percentage change in cholesterol of -1.99%. This has not been found to be the case with other cholesterol-lowering agents, such as oat bran (Stephen, 1989). On average, the substitution of

10g of canola oil for other saturated sources of fat (like fats/oils of animal origin and some vegetable oils like coconut oil and palm oil) resulted in the reduction of the total serum cholesterol level by 3.93%.

A change in edible oil consumption patterns could result in a reduction in total serum cholesterol levels in Canada. According to a nutrition survey in Nova Scotia, with a representative sample of 3,684 men and women, ages 18 to 74 years in 1993, it is estimated that the average per person total energy obtained by fats and oils is 12% of energy daily, which is 30 grams per day (g/d) (Nova Scotia Heart Health Program, 1993). The Nova Scotia Nutrition Survey is the only up-to-date survey presently available in Canada which shows the actual amount of fats and oils consumed. For this study, it is assumed that 30 g/d fats and oils is the average per person consumption for adults in Canada. By substituting 10g of canola oil for more saturated sources of fat, or a third of the total consumption of fats and oils, the total serum cholesterol can be significantly reduced.

Canola oil can be effective in reducing CHD. It was shown that CHD can be significantly reduced by a relatively modest lowering of total serum cholesterol level for most adult Canadians (Yusuf and Furberg, 1987; Yusuf and Culter, 1987; Tyroler, 1985; and Tyroler, 1987). Since a 1% reduction in cholesterol level reduces the risk for CHD by 2%, then an average reduction in the total serum cholesterol level by 3.93% is likely to reduce the risk for CHD by an average of 7.86%. As an aside, the reduction in CHD risk ranges from a low of 2.24% to a high of 12.8%. The effect in total serum cholesterol levels would be less than the average 3.93% and the reduction in CHD risk would be lower than the average

7.86%, if 10g canola oil was substituted for a polyunsaturated source of fat (like soybean, sunflower, maize or safflower oil).

The above results suggest the need for a systematic strategy to address the cholesterol issue. According to Rose (1981), most cases of CHD due to elevated total serum cholesterol levels originate in people in the moderate-risk categories. The relationship between cholesterol level and CHD is positive and curvilinear, not a plateau at the low cholesterol level (MRFIT Research Group, 1991). Hence, the high correlation between CHD and total serum cholesterol exists even in the desirable cholesterol range, where the majority of the population can be found. Consequently, the public health approach which attempts to reduce, for the entire population, the total serum cholesterol is likely to be the most effective at the community and population level in Canada. This approach is also supported by the outcome of the Cholesterol Consensus Conferences in Canada and the United States (McDonald, 1994). On the other hand, the clinical approach mostly benefits only the individuals at the higher total serum cholesterol level and is a very costly approach. Canola oil, in the context of the public health approach, can be recommended as a dietary modification for reducing total serum cholesterol levels and CHD risk because canola oil can effectively reduce the total serum cholesterol and CHD within the whole range of the baseline cholesterol levels (desirable or elevated).

Canola oil diets may reduce the health care costs associated with CHD cost. Canola oil has been shown on average to reduce the risk of CHD by 7.86% (the reduction in CHD risk ranges from a low of 2.24% to a high of 12.8%). Reducing the CHD risk by 7.86% means that the total cost of CHD is also reduced. This reduction in CHD risk is expected to have great economic impact, as CHD is the most expensive disease category. In 1993, the cost of CHD was $8.3 billion in Canada (Reeder et al., 1995). Consequently, the total Canadian reduction of CHD cost, demonstrated by substituting 10 g of canola oil for saturated sources of fat, on average is $652 million. The range of the total reduction in CHD cost is between $186 million and $1.062 billion (Table 5.7.). This represents a potential CHD cost of $8.114 billion to $7.238 billion, with an average total cost of $7.6 billion. The per capita reduction of CHD cost, on average, is $24. The per capita reduction of CHD cost ranges from a low of $7 to a high of $39. Consequently, the total Canadian health care savings, per kg consumption of canola oil, given an annual total consumption of 99,645 tonnes of canola oil, ranges from $1.8 to $10.7, with an average per kg reduction of $6.5. This would add an extra economic benefit from the consumption of canola oil. This health/medical benefit is probably the most significant economic impact from canola research, because the impact is so widespread.

When calculating gains from dietary changes it is important to note exactly how much monounsaturated fats/oils (canola) purchased for consumption is actually consumed. As mentioned earlier, the average per person total energy obtained from fats and oils is 30g/d (Nova Scotia Heart Health Program, 1993). The consumption of monounsaturated fats/oils represents only 38% of this 30g/d. In other words, the average per person total consumption, or total energy obtained from monounsaturated fats/oils, is 11.4g/d. Hence, the total annual Canadian consumption of monounsaturated fats/oils is 113 Mt, which represents

Table 5.7. Estimated Economic Impact of 10g/day Canola Oil Consumption on Health Care Cost in Canada*.

	Total Canadian			Per Capita		
	Low	Average	High	Low	Average	High
Health Care Savings	$186 million	$652 million	$1,062	$7	$24	$39
Daily Increase in Canola Intake	273 t	273 t	273 t	10g	10g	10g
Annual Canola Consumption	99,645 t	99,645 t	99,645 t	3.65kg	3.65kg	3.65 kg
Health Saving/kg Consumption	$1.8/kg	$6.5/Kg	$10.7/kg	$1.8/kg	$6.5/kg	$10.7/kg

* Consumption of canola oil is roughly 30% of quanity dissaperrance

Source: as calculated

only about 30% of the quantity of oil purchased for consumption. Therefore, in calculating the external/social benefits from the consumption of canola oil, we will use the 30% figure rather than the total volume purchased for consumption.

The total external social benefits from the reduction in CHD cost is enormous. Specifically, the consumption of canola oil generates a positive level of welfare and external benefits (positive externality, or external economy) for an entire society by reducing the CHD cost. As estimated earlier, consumption of canola oil reduces, on average, the CHD cost by $654.3 per tonne consumed. Using this estimate, in the case of Canada, the increase in quantity of canola oil consumed due to health information, results in health savings ranging from $8.53 Million to $35.72 Million. For similar reasons, the health savings in the ROW ranged from $98.03 Million to $619.56 Million. These results show that the external/social benefits from health information may be greater than the total internal/private benefits, in both in Canada and the ROW (Tables 5.4.1. - 5.4.4. and 5.5.1-5.5.4).

5.3 The Case of Supply Shift

In this section the model is used to estimate the net economic benefit/loss from the change in potential yield for improved quality canola products. To measure the size of this effect the empirical procedure began by converting the relative yield index of different canola varieties to the same variety base (torch) (1976=100). The yield index for each variety is obtained from the last available observation because it is thought to be more accurate estimation of the yield performance. The yield index was weighted by the seeded acreage. Adding up the products of this computation, for all the varieties grown in a given year, produces the annual weighted average yield index. The cumulative effect of the change in yield growth is derived by running an OLS regression. To measure the economic impact of the reduction in potential yield for the sake of producing varieties with higher quality characteristics, the first supply function is represented as it is in the present production situation with the historical reduction in yield included. The demand for canola oil is also represented as it is in the present production situation with the premium of canola oil included. Then, to simulate the net benefit from switching from rapeseed to canola, the first supply function was increased by a proportion of the cumulative yield change and the demand function was reduced by the premium of canola oil. These calculations were performed over a range of different supply and demand elasticities.

The data on the relative yield of different varieties used for this study were obtained from various issues of Saskatchewan Agriculture and Food, Varieties of Grain Crops in Saskatchewan. Unfortunately, the whole series was not available from other provinces. Hence, the data from Saskatchewan is used as a national proxy.[11]

The data on the relative yield of different canola varieties is based on the research station yield trials at a number of locations across Saskatchewan.[12] The canola varieties were sown and harvested in

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[11] It should be resonable close given Saskatchwan is located in the center of the canola growing region.

[12] Research station yield trial data was used in this estimation. Actual yield data was not used because it would be extremely difficult to isolate the genetic affects on actual yields from the non-genetic factors such as weather, soil type, weeds, diseases, and nutrients.

multiple small plots of 30 square ft. to 45 square ft. Agriculture Canada and the University of Saskatchewan conducted the research station yield trials. The yield potential of different canola varieties is calculated by estimating the weight of grain produced per unit area. The variability of non-genetic factors (e.g., weeds, moisture) is minimized in this estimation of the potential yield. The design of the experiment is such that replication and randomization were used. Hence, the research station yield trials measure varietal performance of that is due mainly to genetic causes.

The data on the percentage acreage of each canola variety were obtained from various issues of Prairie Pools Inc., Prairies Grain Variety Survey.

5.3.1 Result of Regression

Historically, improvements in canola quality have been attained at the expense of seed yield. Plotting the annual weighed average yield index over time (Figure 5.1) reveals a reduction in yield from 1978 to 1982. This result is similar to others findings, which found that the combined yield of Argentine and Polish type canola varieties decreased from the middle 1970s to the beginning of the 1980s (e.g., Forhan (1993)). In addition, Dr. Downey believes that "if the research effort had been given to rapeseed instead of canola varieties, today's potential yield would probably be higher." (personal communication).

In order to estimate the change in yield due to the preference for quality, the following OLS regression was designed.

$$Y_t = \alpha_0 + \alpha_1 T_t + \beta_1 D_{1t} + \beta_2 D_{1t} T_t + \beta_{3t} D_{2t} + \beta_4 D_{2t} T_t + \varepsilon_t$$

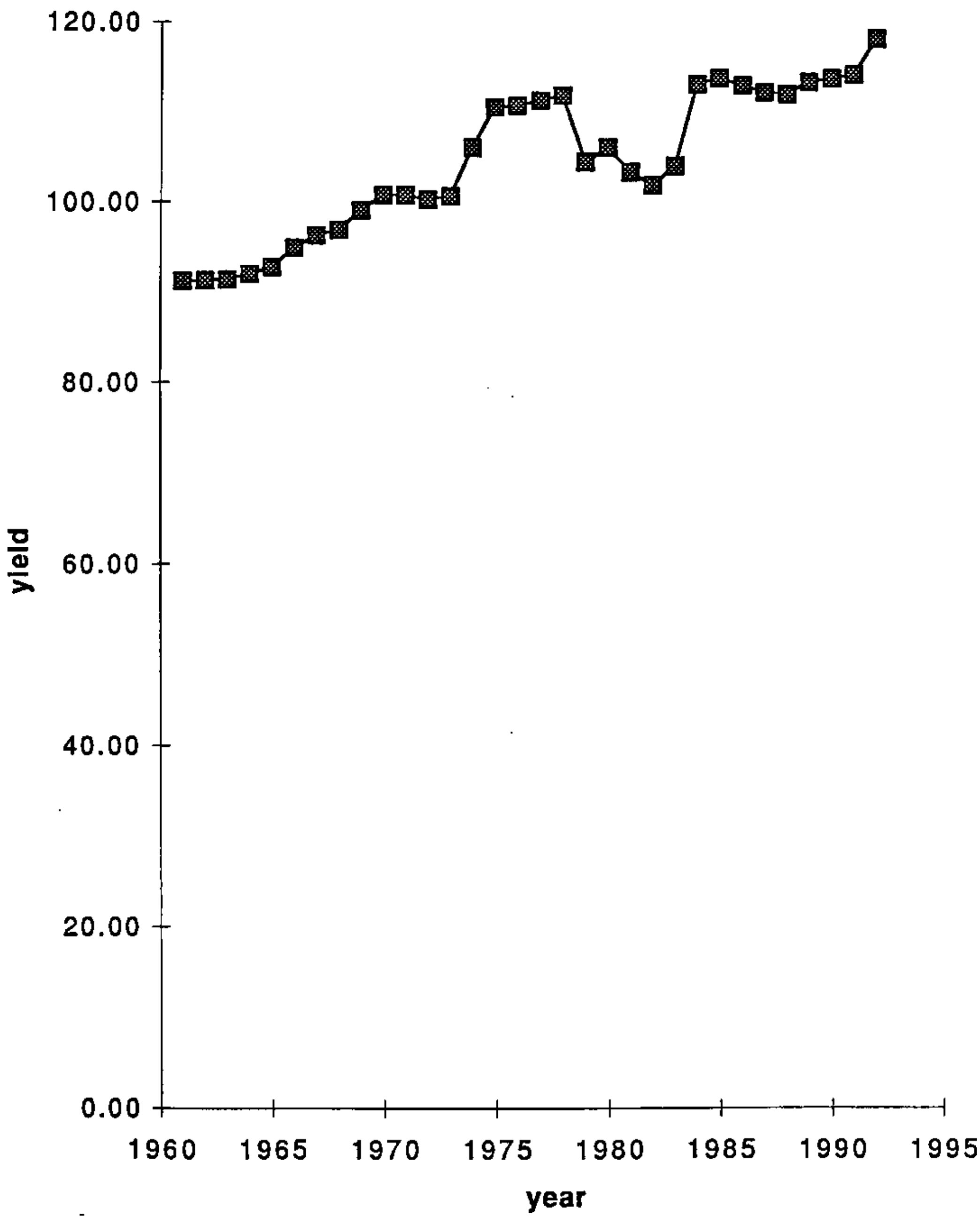

Figure 5.1. Weighted Average Yield Index of Rapeseed/Canola Seed

where:

Y_t is the annual weighted average yield index for each year.

T_t is a time variable which is 1,2,3,..,33.

D_{1t} is an intercept dummy variable which is zero before the 1979 and one from 1979 to 1983.

$D_{1t}T_t$ is a slope dummy variable which is the product of the time variable (T_t) and the first dummy variable (D_{1t}).

D_{2t} is an intercept dummy variable which is zero before 1983 and one from 1983 to 1992.

$D_{2t}T_t$ is a slope dummy variable which is the product of the time variable (T_t) and the second dummy variable (D_{2t}).

The yield regression includes two slope-shifting dummy variables and two intercept-shifting dummy variables, resulting in estimatation of three regression lines. The first regression segment has an intercept equal to α_0 and a slope equal to α_1. This segment represents the situation when only rapeseed was grown. The second regression segment has an intercept equal to $\alpha_0+\beta_1$ and a slope equal to $\alpha_1+\beta_2$. The second regression segment captures the impact on yields of switching from rapeseed to canola varieties. The third regression segment has an intercept equal to $\alpha_0+\beta_3$ and a slope equal to $\alpha_1+\beta_4$. This segment determines whether the yield potential in the period following the introduction of canola, which is characterized by yield loss due to the quality research focus, has changed from the rapeseed period. In other words, one might find that the sacrifice of temporary yields for quality-improvements may have resulted in a permanent disruption of the potential yield trend established by rapeseed varieties.

The regression was corrected for autocorrelation using the standard Cochrane-Orcutt type of procedure. The correction of first-order autocorrelation resulted in inconclusive evidence regarding the presence or absence of positive first-order autocorrelation (D-W=1.375). Hence, the regression was corrected for second-order autocorrelation which still resulted in inconclusive evidence regarding the presence or absence of autocorrelation (D-W=1.4975). However, the computed D-W value was closer to the upper limit.

The regression results are shown in Table 5.8. For a two-tailed test of significance, results must have a t-ratio of at least 2.05 within a 95% confidence interval and 27 degrees of freedom. Significant variables are marketed with an asterisk.

The regression results show the reduction in yield due to switching from rapeseed to canola varieties. Specifically, using the first regression segment coefficients and setting the variable time equal to 1990, which represents the center of the data time period (1988-1992), we found that the yield was 126.05 index points (1976=100) for the first period. Using the same procedure for the third time period (114.57 index points (1976=100)), the difference between the first (original yield) and third (current yield situation) regression segments represents the reduction in yield potential, which is equal to 11.22 index points (1976=100). Thus, the yields of canola varieties are 11.22 index points below the trend established by rapeseed varieties. Stated another way, if research on rapeseed varieties had been maintained yield would have been 9.10% higher in 1990.

Table 5.8. Yield Reduction: OLS Regression Result*

	R^2=0.978		$\overline{R^2}$=0.974	
Variable	Estimated Coefficient	Standard Error	t-Ratio	Elasticity (At Means)
T	1.272	0.8331E-01	15.269*	0.208
D_1	12.319	11.020	1.118	0.17990E-01
D_1T	-1.054	0.518	-2.035*	-0.3387E-01
D_2	8.936	7.528	1.187	0.23487E-01
D_2T	-0.658	0.268	-2.454*	-0.50185E-01
Constant	86.616	0.966	89.604*	0.834

* The estimated coefficient is significant within a 95% confidence interval.

where: Y_t is the annual weighted average yield index for each year.

T_t is a time variable which is 1,2,3,..,33.

D_{1t} is an intercept dummy variable which is zero before the 1979 and one from 1979 to 1983.

$D_{1t}T_t$ is a slope dummy variable which is the product of the time variable (T_t) and the first dummy variable (D_{1t})

D_{2t} is an intercept dummy variable which is zero before 1983 and one from 1983 to 1992.

$D_{2t}T_t$ is a slope dummy variable which is the product of the time variable (T_t) and the second dummy variable (D_{2t}).

The F-test was used to test if there was temporary reduction in yield, and this in turn resulted in long term reduction in potential yield. In other words, the first part of the hypothesis is: the intercept and the slope-shifting dummy coefficient, for the second regression segment, is equal to zero, which means that the first and second regression segments are identical. The computed F value for this test was 36.7, far in excess of the 5% critical value of 4.28, leading one to the conclusion the introduction of canola varieties had a temporary effect on yield. The second and more critical hypothesis is that after a period of adjustment canola yields still lag behind those consistent with the growth of rapeseed varieties. The derivation in yield in the 1983-1992 period from the rapeseed yield base will be the intercept shift plus the slope shift multiplied by the time variable. The year 1990 was chosen as the time variable it is the midpoint of the simulation period. Specifically, it was tested whether $\beta_3 + \beta_4 * T_{1990}$ was equal to zero. This regression restriction resulted in an F value of 33.61, which was far in excess of 5% critical value of 4.2. Thus we can safely reject the hypothesis that there was no lasting drop in yield. We will therefore use the point estimate of a drop of 11.22 index points in our analysis. The above argument can also be graphically shown in Figure 5.2 which illustrates the expected yield index over time. It is obvious from the graph that there is reduction in yield for the second regression segment and the third regression segment does not have the same trend as the first regression segment.

5.3.2 Market Effects and Welfare Implications

The results of the mathematical model show that the conversion to canola quality research, which results in a drop in potential yield, affects the quantities demanded and supplied, and the prices in the various sectors. The mathematical model was simulated by using the average elasticities of supply for canola seed and the processing sector, and the average elasticities of demand for canola oil and meal. As expected from the theoretical development of the model (graphical illustration), the reduction in yield and the increase in demand for canola oil have a positive impact in the total quantities demanded and supplied and a positive impact on the prices in the canola oil, processing input and seed sectors. Specifically, in Canada the switch from rapeseed to canola has a positive impact on the quantity of canola oil and meal demanded

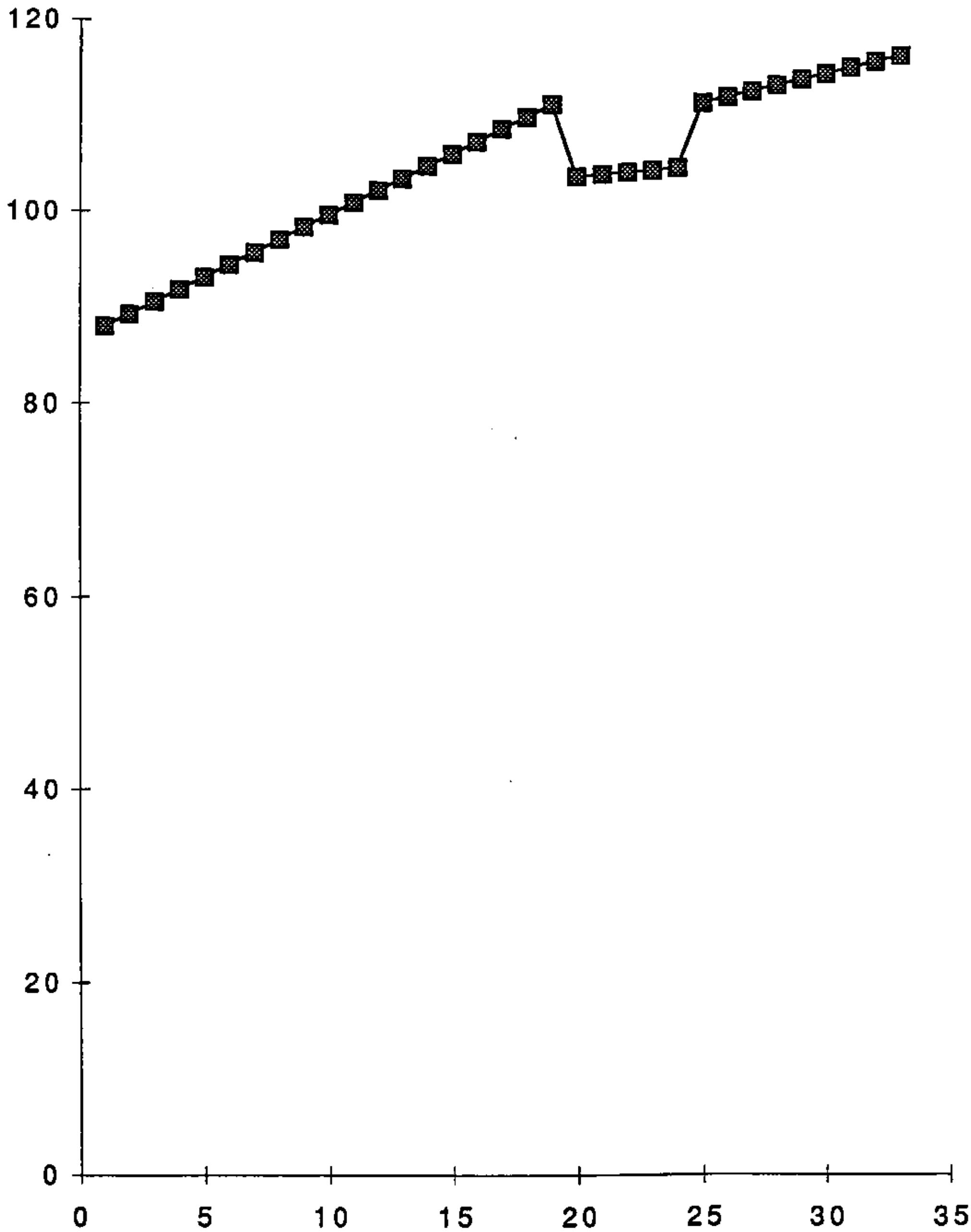

Figure 5.2. Trend in Weighted Average Yield Index of Rapeseed/Canola Seed

(+2.86% and +1.47% respectively). The same effect was found for the quantity of processing input supplied (+2.32%). Conversely, the quantity of canola seed supply fell (-7.29%) as the yield fell. The price effect is positive for canola oil (+4.71%), processing input (+0.46%) and canola seed (+3.17%). The price of canola meal fell (-1.93%) as the demand for canola oil increased, causing an excess supply of canola meal, which forced meal price downward. A similar effect occurred in the ROW except for the quantity of canola seed supplied. The ROW, as mentioned, does not experience the reduction in yield but does experience an increase in the demand for canola oil. The quantity of seed supplied in the ROW is increased as the supply of Canadian canola seed is reduced, resulting in an increase in the world price of canola seed (Table 5.9.).

A different situation arises in the Japanese canola market. The quantity of processing input supplied is reduced because less is exported from Canada, which results in a reduction in the canola processing input price. The quantity of canola oil demanded decreases when the quantity available for crushing decreases. Therefore, because the Japanese do not import canola oil, the canola oil price increases. However, the quantity of canola meal imported to Japan increases since more canola meal supply is available due to increased crushing in Canada. Consequently, the price of canola meal is reduced (Table 5.9.).

The welfare implications of the reduction in yield due to the preference in quality characteristics of canola products are reported in Table 5.10 (Base case). This table depicts the change in welfare and the distribution of benefit between the social groups. A positive change indicates a benefit is realized by the groups and a negative change

Table 5.9. Canola Model Parameters: Base Prices and Quantities, and Changes Due to Reduction in Potential Yield for Improved Quality Canola Products. The Case of Proportional-Marginal-Cost-Increase

	Elasticities	Prices		Quantities	
	Average	Base($/t)	Change($/t)	Base($/t)	Change($/t)
CANADA					
Supply of Canola seed	1.31	261.250	8.280	3.343	-0.243
Supply of Processing Inputs	5.00	56.791	0.264	1.510	0.035
Demand of Canola Oil	-2.44	552.7200	26.048	0.385	0.011
Demand of Canola Meal	-0.71	167.160	-3.233	0.339	0.005
JAPAN					
Supply of Canola seed	0.00	261.250	8.280	0.000	0.000
Supply of Processing Inputs	5.00	56.791	-0.372	1.820	-0.060
Demand of Canola Oil	-0.74	552.720	24.459	0.728	-0.024
Demand of Canola Meal	-0.46	167.160	-3.233	1.2416	0.011
ROW					
Supply of Canola seed	1.09	261.250	8.280	19.297	0.667
Supply of Processing Inputs	5.00	56.791	0.264	19.310	0.448
Demand of Canola Oil	-2.05	552.720	26.048	7.943	0.183
Demand of Canola Meal	-1.03	167.160	-3.233	11.5506	0.230

Source: as calculated

indicates a loss is realized by the groups. The percentage change (in parentheses) indicates the proportion of the total benefit/loss that accrues to specific social groups. The estimation was performed using average elasticities for both the supply equations and demand equations (Table 5.1.).

The net impact of the reduced yield due to quality research goals was, as expected from the graphical analysis, supported by the results in Table 5.10. (Base case). Canadian canola seed producers, processors and the consumers of canola meal experienced a benefit from the reduction in yield for better quality canola varieties (Base Case: +$M 0.61, +$M 0.39 and +$M 1.09 respectively). In contrast, canola oil consumers lost from the technical change (Base Case: -$M 9.72). The similar effect, as in Canada, occurred in the ROW. Finally, in Japan, the overall total internal/private benefits decreased; while only the canola meal consumers gained.

Although the net effect on the total Canadian canola industry is negative, in the base case, the research focus chosen in the 1970s was "absolutely necessary" for the survival of the total industry. There was evidence which showed that rapeseed oil might not be appropriate for human consumption. After 1956, there was growing evidence that the consumption of fatty acids was associated with myocardial lessions in laboratory animals. These findings started to concern the Department of National Health and Welfare. The rapeesed/canola industry realized that it would not be allowed to supply the market with an oil which may be hazardous to human health. Hence, the rapeseed/canola industry would collapse.

Table 5.10 Ex post Welfare Impacts from the Proportional Increase in Marginal Cost and Increase in Demand*.

	BASE BASE($M)	CHANGE($M)
CANADA		
Canola Seed Producers	333.34	0.61 -(7.95%)
Canola Processors	8.58	0.39 -(5.16%)
Canola Oil Consumers	43.61	-9.72 (127.37%)
Canola Meal Consumers	39.91	1.09 -(14.26%)
Total Internal/Private Benefit		-7.63
JAPAN		
Canola Seed Producers	0.00	0.00 (0.00%)
Canola Processors	10.34	-0.69 (4.65%)
Canola Oil Consumers	271.88	-18.10 (122.37%)
Canola Meal Consumers	225.59	4.00 -(27.02%)
Total Internal/Private Benefit		-14.79
ROW		
Canola Seed Producers	2312.54	157.03 -(6182.57%)
Canola Processors	109.66	5.03 -(198.18%)
Canola Oil Consumers	1070.79	-201.57 (7936.51%)
Canola Meal Consumers	937.28	36.97 -(1455.76%)
Total Internal/Private Benefit		-2.54

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total external/Social Benefit" indicates the social welfare . benefits from the increased consumption of canola oil due to the reduction in Coronary Heart Disease
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

Source: as calculated

Even if the rapeseed/canola industry had managed to survive without quality-improvements, it would never have achieved the present profile in the market. The rapeseed/canola with high erucic acid content had very little chance of being granted the status of GRAS in the US. Consequently, without the GRAS status it could not enter to the US market nor probably other markets like the EU and Mexico. Additionally, canola oil would never have become a premium product and the Canadian canola industry would never have become "the industry leader" in the development of canola products. On the other hand, the rapeseed/canola industry might have explored more industrial uses for the rapeseed/canola products. However, the market for industrial uses for the canola oil and meal was limited by that time.

5.3.3. Sensitivity Analysis an Critical Assumptions Imposed.

5.3.3.1 The Elasticities of Supply and Demand

The assumptions regarding the elasticities of supply for canola seed and the processing sector, and the elasticities of demand for canola oil and meal do affect welfare measurements. Tables 5.10.1-5.10.4 report the impact of reduction in yield due to preferences for quality characteristics in rapeseed/canola products. The estimation was performed over a range of elastisities (low and high) for both the supply equation and demand equation. The net welfare effects of switching from rapeseed to canola are the following.

Table 5.10.1. Ex post Welfare Impacts from the Proportional Increase in Marginal Cost and Increase in Demand*.

	BASE		1st. Case		2nd. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	0.61	834.06	29.14	172.60	16.29
		-8.0%		148.3%		187.9%
Canola Processors	8.58	0.39	8.58	0.28	8.58	0.45
		-(5.16%)		(1.43%)		(5.18%)
Canola Oil Consumers	43.61	-9.72	43.61	-10.49	43.61	-9.34
		127.4%		-53.4%		-107.7%
Canola Meal Consumers	39.91	1.09	39.91	0.72	39.91	1.27
		-(14.26%)		(3.66%)		(14.66%)
Total Internal/Private Benefit		-7.63		19.65		8.67
Total External/Social Benefit						
JAPAN						
Canola Seed Producers	0.00	0.00	0.00	0.00	0.00	0.00
		0.0%		0.0%		0.0%
Canola Processors	10.34	-0.69	10.34	-0.74	10.34	-0.66
		4.7%		4.2%		4.9%
Canola Oil Consumers	271.88	-18.10	271.88	-19.54	271.88	-17.38
		(122.37%)		(110.74%)		(129.96%)
Canola Meal Consumers	225.59	4.00	225.59	2.64	225.59	4.67
		-27.0%		-15.0%		-34.9%
Total Internal/Private Benefit		-14.79		-17.64		-13.38
ROW						
Canola Seed Producers	2312.54	157.03	4007.87	186.03	1424.11	142.32
		-6182.6%		-5826.7%		-5448.8%
Canola Processors	109.66	5.03	109.66	3.59	109.66	5.75
		-198.2%		-112.4%		-220.0%
Canola Oil Consumers	1070.79	-201.57	1070.79	-217.26	1070.79	-193.83
		7936.5%		6804.9%		7420.9%
Canola Meal Consumers	937.28	36.97	937.28	24.45	937.28	43.15
		-1455.8%		-765.8%		-1652.1%
Total Internal/Private Benefit		-2.54		-3.19		-2.61
Total External/Social Benefit						

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total Social Benefit" indicates the external/social welfare benefits from the increa consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 1st. Case all parameters are at base value except for the elasticity of canola seed supplied in Canada and ROW(0.09 and 0.41 respectively).
In 2nd. Case all parameters are at base value except for the elasticity of canola seed supplied in Canada and ROW(2.53 and 1.77 respectively).

Source: as calculated

Table 5.10.2. Ex post Welfare Impacts from the Proportional Increase in Marginal Cost and Increase in Demand*.

	BASE		3rd. Case		4th. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	0.61 -8.0%	333.34	-9.85 84.5%	333.34	0.82 -10.9%
Canola Processors	8.58	0.39 -(5.16%)	83.18	9.49 -(81.43%)	4.29	0.20 -(2.65%)
Canola Oil Consumers	43.61	-9.72 127.4%	43.61	-11.64 99.8%	43.61	-9.68 128.2%
Canola Meal Consumers	39.91	1.09 -(14.26%)	39.91	0.34 -(2.88%)	39.91	1.10 -(14.63%)
Total Internal/Private Benefit		-7.63		-11.66		-7.55
Total External/Social Benefit						
JAPAN						
Canola Seed Producers	0.00	0.00 0.0%	0.00	0.00 0.0%	0.00	0.00 0.0%
Canola Processors	10.34	-0.69 4.7%	100.26	-8.16 85.9%	5.17	-0.35 2.4%
Canola Oil Consumers	271.88	-18.10 (122.37%)	271.88	-2.57 (27.10%)	271.88	-18.61 (124.83%)
Canola Meal Consumers	225.59	4.00 -27.0%	225.59	1.23 -13.0%	225.59	4.05 -27.2%
Total Internal/Private Benefit		-14.79		-9.50		-14.91
ROW						
Canola Seed Producers	2312.54	157.03 -6182.6%	2312.54	101.28 -1601.6%	2312.54	158.19 -6458.1%
Canola Processors	109.66	5.03 -198.2%	1063.73	121.37 -1919.3%	54.83	2.56 -104.4%
Canola Oil Consumers	1070.79	-201.57 7936.5%	1070.79	-240.40 3801.7%	1070.79	-200.70 8193.7%
Canola Meal Consumers	937.28	36.97 -1455.8%	937.28	11.43 -180.8%	937.28	37.51 -1531.2%
Total Internal/Private Benefit		-2.54		-6.32		-2.45
Total External/Social Benefit						

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total Social Benefit" indicates the external/social welfare benefits from the increa consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 3rd. Case all parameters are at base value except for the elasticity of canola processing inputs supplied in Canada, Japan and ROW(0.06, 0.06 and 0.06 respectively).
In 4th. Case all parameters are at base value except for the elasticity of canola processing inputs supplied in Canada, Japan and ROW(10, 10 and 10 respectively).

Source: as calculated

Table 5.10.3. Ex post Welfare Impacts from the Proportional Increase in Marginal Cost and Increase in Demand*.

	BASE Base($M)	Change($M)	5th. Case Base($M)	Change($M)	6th. Case Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	0.61 -(8.0%)	333.34	-11.21 (70.5%)	333.34	2.80 -(46.0%)
Canola Processors	8.58	0.39 -(5.2%)	8.58	0.09 -(0.5%)	8.58	0.48 -(7.8%)
Canola Oil Consumers	43.61	-9.72 (127.4%)	197.03	-5.02 (31.6%)	24.52	-10.60 (174.3%)
Canola Meal Consumers	39.91	1.09 -(14.3%)	39.91	0.24 -(1.5%)	39.91	1.25 -(20.5%)
Total Internal/Private Benefit		-7.63		-15.91		-6.08
Total External/Social Benefit						
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-0.69 (4.7%)	10.34	-0.15 (1.7%)	10.34	-1.17 (7.3%)
Canola Oil Consumers	271.88	-18.10 (122.4%)	649.00	-9.58 (108.1%)	171.96	-19.51 (121.2%)
Canola Meal Consumers	225.59	4.00 -(27.0%)	225.59	0.87 -(9.8%)	225.59	4.58 -(28.4%)
Total Internal/Private Benefit		-14.79		-8.86		-16.10
ROW						
Canola Seed Producers	2312.54	157.03 -(6182.6%)	2312.54	94.00 -(3175.8%)	2312.54	168.73 -(8245.1%)
Canola Processors	109.66	5.03 -(198.2%)	109.66	1.11 -(37.4%)	109.66	6.09 -(297.6%)
Canola Oil Consumers	1070.79	-201.57 (7936.5%)	16885.60	-106.16 (3586.7%)	538.02	-219.20 (10711.4%)
Canola Meal Consumers	937.28	36.97 -(1455.8%)	937.28	8.09 -(273.4%)	937.28	42.33 -(2068.6%)
Total Internal/Private Benefit		-2.54		-2.96		-2.05
Total External/Social Benefit						

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total Social Benefit" indicates the external/social welfare benefits from the increased consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 5th. Case all parameters are at base value except for the elasticity of canola oil demanded in Canada, Japan and ROW(-0.54, -0.31 and -0.13 respectively).
In 6th. Case all parameters are at base value except for the elasticity of canola oil demanded in Canada, Japan and ROW(-4.34, -1.17 and -4.08 respectively).

Source: as calculated

Table 5.10.4. Ex post Welfare Impacts from the Proportional Increase in Marginal Cost and Increase in Demand*.

	BASE		7th. Case		8th. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	0.61 -(8.0%)	333.34	-6.34 (45.3%)	333.34	2.23 -(36.2%)
Canola Processors	8.58	0.39 -(5.2%)	8.58	0.24 -(1.7%)	8.58	0.43 -(7.0%)
Canola Oil Consumers	43.61	-9.72 (127.37%)	43.61	-10.77 (76.94%)	43.61	-9.48 (154.10%)
Canola Meal Consumers	39.91	1.09 -(14.3%)	236.11	2.87 -(20.5%)	21.80	0.67 -(10.9%)
Total Internal/Private Benefit		-7.63		-14.00		-6.15
Total External/Social Benefit						
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-0.69 (4.7%)	10.34	-0.76 (7.4%)	10.34	-0.67 (4.2%)
Canola Oil Consumers	271.88	-18.10 (122.37%)	271.88	-20.05 (194.57%)	271.88	-17.64 (111.35%)
Canola Meal Consumers	225.59	4.00 -(27.0%)	518.86	10.51 -(102.0%)	146.16	2.47 -(15.6%)
Total Internal/Private Benefit		-14.79		-10.30		-15.84
ROW						
Canola Seed Producers	2312.54	157.03 -(6182.6%)	2312.54	119.94 -(5771.7%)	2312.54	165.67 -(6285.2%)
Canola Processors	109.66	5.03 -(198.2%)	109.66	3.07 -(148.0%)	109.66	5.49 -(208.3%)
Canola Oil Consumers	1070.79	-201.57 (7936.5%)	1070.79	-222.85 (10723.4%)	1070.79	-196.61 (7458.8%)
Canola Meal Consumers	937.28	36.97 -(1455.8%)	4827.00	97.75 -(4703.8%)	519.03	22.81 -(865.3%)
Total Internal/Private Benefit		-2.54		-2.08		-2.64
Total External/Social Benefit						

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total Social Benefit" indicates the external/social welfare benefits from the increa consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 7th. Case all parameters are at base value except for the elasticity of canola meal demanded in Canada, Japan and ROW(-0.12, -0.20 and -0.20 respectively).
In 8th. Case all parameters are at base value except for the elasticity of canola meal demanded in Canada, Japan and ROW(-1.30, -0.71 and -1.86 respectively).

Source: as calculated

(1) Canadian canola processors' gains are greater with a more inelastic supply of processing inputs.

(2) Canadian canola meal consumers' gains are greater with a more inelastic demand of canola meal.

(3) Canadian canola oil consumers' losses are greater with a more inelastic demand of canola oil.

(4) The net effect to Canadian canola seed producers is ambiguous. Under some circumstances (scenarios) they benefit from the reduction in yield and increase the quality of the canola products, but this is not the case. In general, Canadian canola seed producers benefit more with inelastic supply of canola seed.

(5) The total internal/private benefits are ambiguous and depend on the elasticities of supply and demand. Effect similar to those in Canada occurred in the ROW, except for the canola seed producers' surplus, which is positive and greater with a more inelastic supply of canola seed.

In general, the benefit (loss) to any one sector (e.g., the canola seed sector or the canola processing sector) are greater (smaller), the more inelastic (elastic) its supply curve is relative to that of the other sector. The gain (loss) to consumers (e.g., in the canola oil sector and the canola meal sector) is larger (smaller) than the gain to producers, the more elastic (inelastic) the supply curve is relative to the demand curve.

The reduction in canola yield, due to the focus on the improved quality varieties, that determines which social group benefits is very ambiguous. Specifically, the share of the gain in total private return to each social group depends on the elasticities of supply and demand. For example producers' share of the benefit ranges from -36.20% to +187,86%. Producers' share of the benefit fluctuates because producers lose from the reduction in yield which results in a lower price for canola seed and a lower quantity supplied, but producers gain from the increase in demand for canola oil which increases the equilibrium price and quantity. The net impact to producers depends on which of the two effects is greater the supply effect or the demand effect.

5.3.3.2 Conventional versus ex post Measures of Consumers' Surplus

The use of the conventional rather than the *ex post* estimate of consumer surplus affects the welfare estimate. The method of estimating the consumer benefit, as applied thus far, uses the *ex post* health information preference (the area beneath the *ex post* demand curve less the cost of consumption), while the conventional estimate use both the *ex post* and *ex ante* health information preference (or the demand curves). It is not appropriate to use both the *ex post* and *ex ante* demand curves because the health information changed consumers' tastes. As previously discussed, this means that one of the basic assumptions of the conventional estimate does not hold any more. For the sake of comparison between the two estimates of consumer surplus, the model in this section will be estimated using the conventional estimate of the consumers' surplus (Tables 5.11.1-5.11.4). Consequently, the different implications arising from the comparison of the conventional measure of consumer surplus to the one applied previously, can be revealed.

The results of the conventional estimates of consumer surplus are described in the following scenarios. Results show that consumers

Table 5.11.1. Conventional Welfare Impacts from the Proportional Increase in Marginal Cost and Increase in Demand*.

	BASE		1st. Case		2nd. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	0.61 (13.7%)	834.06	29.14 (91.6%)	172.601	16.29 (78.7%)
Canola Processors	8.58	0.39 (8.9%)	8.58	0.28 (0.9%)	8.575	0.45 (2.2%)
Canola Oil Consumers	43.61	2.36 (53.0%)	43.61	1.68 (5.3%)	43.606	2.69 (13.0%)
Canola Meal Consumers	39.91	1.09 (24.5%)	39.91	0.72 (2.3%)	39.91	1.27 (6.1%)
Total Internal/Private Benefit		4.45		31.82		20.70
Total External/Social Benefit						
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.000	0.00 (0.0%)
Canola Processors	10.34	-0.69 (4.7%)	10.34	-0.74 (4.2%)	10.336	-0.66 (4.9%)
Canola Oil Consumers	271.88	-18.10 (122.4%)	271.88	-19.54 (110.7%)	271.878	-17.38 (130.0%)
Canola Meal Consumers	225.59	4.00 -(27.0%)	225.59	2.64 -(15.0%)	225.59	4.67 -(34.9%)
Total Internal/Private Benefit		-14.79		-17.64		-13.38
ROW						
Canola Seed Producers	2312.54	157.03 (63.4%)	4007.87	186.03 (74.8%)	1424.108	142.32 (57.7%)
Canola Processors	109.66	5.03 (2.0%)	109.66	3.59 (1.4%)	109.663	5.75 (2.3%)
Canola Oil Consumers	1070.79	48.72 (19.7%)	1070.79	34.75 (14.0%)	1070.794	55.62 (22.5%)
Canola Meal Consumers	937.28	36.97 (14.9%)	937.28	24.45 (9.8%)	937.28	43.15 (17.5%)
Total Internal/Private Benefit		247.76		248.81		246.84
Total External/Social Benefit						

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total Social Benefit" indicates the external/social welfare benefits from the increas consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 1st. Case all parameters are at base value except for the elasticity of canola seed supplied in Canada and ROW(0.09 and 0.41 respectively).
In 2nd. Case all parameters are at base value except for the elasticity of canola seed supplied in Canada and ROW(2.53 and 1.77 respectively).

Source: as calculated

Table 5.11.2. Conventional Welfare Impacts from the Proportional Increase in Marginal Cost and Increase in Demand*.

	BASE		3rd. Case		4th. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	9.98 (141.9%)	333.34	-9.85 -(1482.1%)	333.34	0.82 (18.2%)
Canola Processors	8.58	0.72 (10.2%)	83.18	9.49 (1428.8%)	4.29	0.20 (4.4%)
Canola Oil Consumers	43.61	-5.70 -(81.0%)	43.61	0.68 (102.8%)	43.61	2.39 (52.9%)
Canola Meal Consumers	39.91	2.03 (28.9%)	39.91	0.34 (50.6%)	39.91	1.10 (24.4%)
Total Internal/Private Benefit		7.03		0.66		4.52
Total External/Social Benefit						
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-1.15 (4.8%)	100.26	-8.16 (85.9%)	5.17	-0.35 (2.4%)
Canola Oil Consumers	271.88	-30.28 (126.3%)	271.88	-2.57 (27.1%)	271.88	-18.61 (124.8%)
Canola Meal Consumers	225.59	7.47 -(31.1%)	225.59	1.23 -(13.0%)	225.59	4.05 -(27.2%)
Total Internal/Private Benefit		-23.97		-9.50		-14.91
ROW						
Canola Seed Producers	2312.54	249.50 (119.7%)	2312.54	101.28 (40.8%)	2312.54	158.19 (63.8%)
Canola Processors	109.66	9.21 (4.4%)	1063.73	121.37 (48.9%)	54.83	2.56 (1.0%)
Canola Oil Consumers	1070.79	-118.93 -(57.0%)	1070.79	14.10 (5.7%)	1070.79	49.50 (20.0%)
Canola Meal Consumers	937.28	68.73 (33.0%)	937.28	11.43 (4.6%)	937.28	37.51 (15.1%)
Total Internal/Private Benefit		208.50		248.18		247.75
Total External/Social Benefit						

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total Social Benefit" indicates the external/social welfare benefits from the increase consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 3rd. Case all parameters are at base value except for the elasticity of canola processing inputs supplied in Canada, Japan and ROW(0.06, 0.06 and 0.06 respectively).
In 4th. Case all parameters are at base value except for the elasticity of canola processing inputs supplied in Canada, Japan and ROW(10, 10 and 10 respectively).

Source: as calculated

Table 5.11.3. Conventional Welfare Impacts from the Proportional Increase in Marginal Cost and Increase in Demand*.

	BASE		5th. Case		6th. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	0.61 -(8.0%)	333.34	-11.21 (301.3%)	333.34	2.80 (46.9%)
Canola Processors	8.58	0.39 -(5.2%)	8.58	0.09 -(2.3%)	8.58	0.48 (8.0%)
Canola Oil Consumers	43.61	-9.72 (127.4%)	197.03	7.17 -(192.6%)	24.52	1.44 (24.2%)
Canola Meal Consumers	39.91	1.09 -(14.3%)	39.91	0.24 -(6.4%)	39.91	1.25 (20.9%)
Total Internal/Private Benefit		-7.63		-3.72		5.96
Total External/Social Benefit						
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-0.69 (4.7%)	10.34	-0.15 (1.7%)	10.34	-1.17 (7.3%)
Canola Oil Consumers	271.88	-18.10 (122.4%)	649.00	-9.58 (108.1%)	171.96	-19.51 (121.2%)
Canola Meal Consumers	225.59	4.00 -(27.0%)	225.59	0.87 -(9.8%)	225.59	4.58 -(28.4%)
Total Internal/Private Benefit		-14.79		-8.86		-16.10
ROW						
Canola Seed Producers	2312.54	157.03 -(6182.6%)	2312.54	94.00 (37.3%)	2312.54	168.73 (68.3%)
Canola Processors	109.66	5.03 -(198.2%)	109.66	1.11 (0.4%)	109.66	6.09 (2.5%)
Canola Oil Consumers	1070.79	-201.57 (7936.5%)	16885.60	148.91 (59.1%)	538.02	29.80 (12.1%)
Canola Meal Consumers	937.28	36.97 -(1455.8%)	937.28	8.09 (3.2%)	937.28	42.33 (17.1%)
Total Internal/Private Benefit		-2.54		252.10		246.95
Total External/Social Benefit						

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total Social Benefit" indicates the external/social welfare benefits from the incr consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 5th. Case all parameters are at base value except for the elasticity of canola oil demanded in Canada, Japan and ROW(-0.54, -0.31 and -0.13 respectively).
In 6th. Case all parameters are at base value except for the elasticity of canola oil demanded in Canada, Japan and ROW(-4.34, -1.17 and -4.08 respectively).

Source: as calculated

Table 5.11.4. Conventional Welfare Impacts from the Proportional Increase in Marginal Cost and Increase in Demand*.

	BASE		7th. Case		8th. Case	
	Base($M)	Change($M)	Base($M)	Change($M)	Base($M)	Change($M)
CANADA						
Canola Seed Producers	333.34	0.61 -(8.0%)	333.34	-6.34 (354.9%)	333.34	2.23 (37.8%)
Canola Processors	8.58	0.39 -(5.2%)	8.58	0.24 -(13.5%)	8.58	0.43 (7.3%)
Canola Oil Consumers	43.61	-9.72 (127.4%)	43.61	1.44 -(80.6%)	43.61	2.57 (43.6%)
Canola Meal Consumers	39.91	1.09 -(14.3%)	236.11	2.87 -(160.9%)	21.80	0.67 (11.4%)
Total Internal/Private Benefit		-7.63		-1.79		5.90
Total External/Social Benefit						
JAPAN						
Canola Seed Producers	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)	0.00	0.00 (0.0%)
Canola Processors	10.34	-0.69 (4.7%)	10.34	-0.76 (7.4%)	10.34	-0.67 (4.2%)
Canola Oil Consumers	271.88	-18.10 (122.4%)	271.88	-20.05 (194.6%)	271.88	-17.64 (111.3%)
Canola Meal Consumers	225.59	4.00 -(27.0%)	518.86	10.51 -(102.0%)	146.16	2.47 -(15.6%)
Total Internal/Private Benefit		-14.79		-10.30		-15.84
ROW						
Canola Seed Producers	2312.54	157.03 -(6182.6%)	2312.54	119.94 (47.9%)	2312.54	165.67 (67.0%)
Canola Processors	109.66	5.03 -(198.2%)	109.66	3.07 (1.2%)	109.66	5.49 (2.2%)
Canola Oil Consumers	1070.79	-201.57 (7936.5%)	1070.79	29.76 (11.9%)	1070.79	53.15 (21.5%)
Canola Meal Consumers	937.28	36.97 -(1455.8%)	4827.00	97.75 (39.0%)	519.03	22.81 (9.2%)
Total Internal/Private Benefit		-2.54		250.53		247.12
Total External/Social Benefit						

*The numbers in the column entitled "Base" indicate the initial welfare position of each social group.
The numbers in the column entitled "Change" indicate the change in welfare position of each social group and the total change in welfare.
The percentage change in parentheses indicates what proportion of the change in the total internal/private benefit/loss occur to the specific social group.
The number in the row entitled "Total Social Benefit" indicates the external/social welfare benefits from the incre consumption of canola oil due to the reduction in Coronary Heart Disease cost.
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

In 7th. Case all parameters are at base value except for the elasticity of canola meal demanded in Canada, Japan and ROW(-0.12, -0.20 and -0.20 respectively).
In 8th. Case all parameters are at base value except for the elasticity of canola meal demanded in Canada, Japan and ROW(-1.30, -0.71 and -1.86 respectively).

Source: as calculated

benefited under all the different scenarios/elasticities. Specifically, the consumers' surplus ranged from +$M0.09 to +$M9.48. This finding is contrary to the result that is found when the *ex post* health information standard was used to estimate the consumer surplus. In addition, the positive consumer surplus results in an increase of the total internal/private benefits. Although total internal/private benefits increased, they were still negative under some circumstances/scenarios. Finally, even with a positive consumer surplus, it is still inconclusive which social group benefits more or receives the higher share of the total external social benefits.

5.3.3.3 The Type of Supply Shift

The type of supply shift is the most important determinant of the distribution of benefits from research among the interested social groups and also affects the magnitude of R&D. In this section the net effect from the reduction in potential yield for canola quality research will be estimated with a parallel supply shift. A parallel shift is the most widely used kind of analysis shift, on either the demand side or the supply side. The estimation was performed using an average elasticity for both the supply equations and demand equations. The welfare measured in this study has been estimated using a proportional-marginal-cost-increasing supply shift, which is the middle case between the parallel and pivotal supply shift. Under some special circumstances, returns to research under a parallel supply shift are exactly twice those under a pivotal supply shift. Consequently, the different effects of the two kinds of supply shifts (parallel-proportional-marginal-cost-increasing) on the total benefits and the distribution between the social groups can be compared.

The estimation of the model with a parallel supply shift shows that the switch to canola quality research affects the quantities demanded and supplied, and the prices in the various sectors (Table 5.12). Specifically, in Canada the focus on agronomic research has had a positive impact on the quantity of canola oil and meal demanded (+2.86% and +1.47% respectively). The same effect was found for the quantity of processing input supplied (+2.45%). Conversely, the quantity of canola seed supply fell (-5.68%) as did the yield. The price effect is positive for canola oil (+4.65%), processing input (+0.49%) and canola seed (+3.06%). The price of canola meal fell (-2.07%). A similar effect occurred in the ROW market with the exception of the quantity of canola seed supplied.

The welfare implications of the agronomic research, which result in drop in potential yield for higher quality canola products, are reported in Table 5.13. The calculation of consumer welfare, used in this section, is based on the *ex post* health information standard. Canadian processors, and consumers of canola meal benefited from the research (+$M0.42 and +$M1.16 respectively). In contrast, canola seed producers, canola oil consumers and the total industry lost (-$M38.89, -$M9.56 and -$M46.88 respectively). Similar effects occurred in the ROW except for the case of canola seed producers who benefited. In Japan, the total industry and all the sectors except the canola meal sector experienced loss in welfare.

Table 5.14 reports the welfare estimates, which use the conventional estimate of the consumer surplus. Specifically, Canadian processors, consumers of canola oil and meal benefit. Consumers of

Table 5.12. Canola Model Parameters: Base Prices and Quantities, and Changes Due to Reduction in Potential Yield for Improved Quality Canola Products.

The Case of Parallel Supply Shift

	Elasticities	Prices		Quantities	
	Average	Base($/t)	Change($/t)	Base(Mt)	Change(Mt)
CANADA					
Supply of Canola seed	1.31	261.250	7.987	3.343	-0.190
Supply of Processing Inputs	5.00	56.791	0.279	1.510	0.037
Demand of Canola Oil	-2.44	552.7200	25.681	0.385	0.011
Demand of Canola Meal	-0.71	167.160	-3.459	0.339	0.005
JAPAN					
Supply of Canola seed	0.00	261.250	7.987	0.000	0.000
Supply of Processing Inputs	5.00	56.791	-0.366	1.820	-0.059
Demand of Canola Oil	-0.74	552.720	24.068	0.728	-0.023
Demand of Canola Meal	-0.46	167.160	-3.459	1.2416	0.012
ROW					
Supply of Canola seed	1.09	261.250	7.987	19.297	0.643
Supply of Processing Inputs	5.00	56.791	0.279	19.310	0.475
Demand of Canola Oil	-2.05	552.720	25.681	7.943	0.194
Demand of Canola Meal	-1.03	167.160	-3.459	11.5506	0.246

Source: as calculated

Table 5.13. Ex post Welfare Impacts from the Parallel decrease in Supply and Increase in Demand*

	BASE Base($M)	Change($M)
CANADA		
Canola Seed Producers	333.34	-38.89 (82.97%)
Canola Processors	8.58	0.42 -(0.89%)
Canola Oil Consumers	43.61	-9.56 (20.40%)
Canola Meal Consumers	39.91	1.16 -(2.48%)
Total Private Benefit		-46.88
JAPAN		
Canola Seed Producers	0.00	0.00 (0.00%)
Canola Processors	10.34	-0.68 (4.76%)
Canola Oil Consumers	271.88	-17.80 (125.32%)
Canola Meal Consumers	225.59	4.27 -(30.09%)
Total Private Benefit		-14.21
ROW		
Canola Seed Producers	2312.54	151.55 -(7712.01%)
Canola Processors	109.66	5.33 -(271.11%)
Canola Oil Consumers	1070.79	-198.37 (10094.4%)
Canola Meal Consumers	937.28	39.53 -(2011.31%)
Total Private Benefit		-1.97

*The numbers in the column entitled "Base" indicates the initial welfare position of each social group.
The numbers in the column entitled "Change" indicates the change in welfare position of each social group and the total change in welfare.
The percentage change in the brackets indicates what proportion of the change in the total benefit/loss occur to the specific social group.
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

Source: as calculated

Table 5.14. Conventional Welfare Impacts from the Parallel decrease in Supply and Increase in Demand*

	BASE Base($M)	Change($M)
CANADA		
Canola Seed Producers	333.34	-38.89 (111.70%)
Canola Processors	8.58	0.42 -(1.20%)
Canola Oil Consumers	43.61	2.49 -(7.16%)
Canola Meal Consumers	39.91	1.16 -(3.34%)
Total Private Benefit		-34.82
JAPAN		
Canola Seed Producers	0.00	0.00 (0.00%)
Canola Processors	10.34	-0.68 (4.76%)
Canola Oil Consumers	271.88	-17.80 (125.32%)
Canola Meal Consumers	225.59	4.27 -(30.09%)
Total Private Benefit		-14.21
ROW		
Canola Seed Producers	2312.54	151.55 (61.12%)
Canola Processors	109.66	5.33 (2.15%)
Canola Oil Consumers	1070.79	51.57 (20.8%)
Canola Meal Consumers	937.28	39.53 (15.94%)
Total Private Benefit		247.98

*The numbers in the colum entitled "Base" indicates the initial welfare position of each social group.
The numbers in the column entitled "Change" indicates the change in welfare position of each social group and the total change in welfare.
The percentage change in the brackets indicates what proportion of the change in the total benefit/loss occur to the specific social group.
Base case parameters value:

Canada: elasticity of canola seed supplied=1.31
elasticity of canola processing inputs supplied=5.0
elasticity of canola oil demanded=-2.44
elasticity of canola meal demanded=-0.71

Japan: elasticity of canola seed supplied=0.00
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-0.74
elasticity of canola meal demanded=-0.46

ROW: elasticity of canola seed supplied=1.09
elasticity of canola processing inputs supplied=5.00
elasticity of canola oil demanded=-2.05
elasticity of canola meal demanded=-1.03

Source: as calculated

canola oil benefit by +$M2.49. Conversely, Canadian canola seed producers, and the total industry lost. Similar effects occurred in the ROW, except for the canola seed producers and the total industry who benefited.

There is one important difference between the results of the proportional-marginal-cost-increasing and the parallel supply shift. Specifically, the Canadian producers of canola seed lose benefits with a parallel supply shift; but gain with a proportional-marginal-cost-increasing supply shift. On the other hand, the magnitude of the benefits for other social groups is about the same with a parallel and proportional-marginal-cost-increasing supply shift. Finally, both the proportional-marginal-cost-increasing and parallel supply shift were inconclusive about which social group benefited more from the reduction in yield, for better quality canola products.

5.4 Conclusion

This chapter estimates the economic benefits to the total canola industry and to the social groups from two main historical events. First, the increased demand for canola oil benefits the canola producers, the processors and the consumers of canola meal. Conversely, using an *ex post* measure of consumer surplus, consumers of canola oil are worse off with the health/nutrition research because now they have almost the same benefit as before but at the higher price. The total internal/private benefit to the canola industry is also positive and significant in all the scenarios. The increased consumption of canola oil also generates external social benefits due to the reduction in CHD cost. The magnitude of the external social benefits is enormous (at least twice that of internal/private benefits). Finally, the net benefit from the reduction in potential yield for improved quality canola products is estimated. The net impact affecting canola producers, processors and consumers of canola meal is ambiguous. The impact depends on the elasticity of supply/demand. However, consumers of canola oil lose under all the scenarios. Nevertheless, as discussed earlier, the switch was "absolutely necessary" to the long term survival of the industry. Finally, the analysis examined the sensitivity of the welfare results when there was a change in the critical assumptions. Specifically, the assumptions regarding the elasticities of demand and supply, consumers surplus measures and the type of supply shift were examined.

CHAPTER VI

Summary and Conclusion

6.1 Summary

This thesis began by looking at the historical development and utilization of rapeseed/canola products. Many important issues were discussed in that section, two of which are relevant to this study's hypotheses. The first historical issue, related to the first hypothesis, is the findings of the medical/nutritional research. Specifically, medical/nutritional research showed that monounsaturated fatty acids are healthier sources of fats than the polyunsaturated or saturated fatty acids. These findings prompted an increased preference for canola oil and consequently an increased demand for canola oil. In addition, the medical/nutritional research showed that replacing other saturated edible oils with canola oil can reduce the total cholesterol, which in turn reduces the CHD risk. Hence, the consumption of canola oil may be an effective way to reduce the cost of CHD in society. The second historical issue is about the second hypothesis, the economic impact of agronomic research. Specifically, from the beginning of the 1970s, when research revealed that the consumption high erucic of rapeseed oil can cause "fatty hearts" in rats, the focus of the canola breeding program was the improvement of the quality characteristics of the rapeseed/canola products. This research, which focused on quality "canola" products, resulted in a drop in the potential yield. Evidence showed that yield reduction took place from the middle of the 1970s to the beginning of the 1980s as these varieties were adopted.

The theoretical framework developed in this thesis provides an environment in which the two main historical issues can be analyzed. This framework introduces a number of approaches which have been used to estimate the economic effect(s) of the agricultural research. For the purpose of this study, the economic surplus approach was very applicable because it could focus on one part of the economy at a time (e.g., a specific industry) by considering all the other economic variables as exogenous (i.e., a partial-equilibrium framework). Specifically, this approach could trace the magnitude and the distribution of the gross annual flow of economic benefit(s) which occur due to research-driven technological change. By using this approach, though, the magnitude of research benefits is sensitive mainly to the type of shift, while the distribution of research benefits is sensitive to the type of shift and the elasticity of demand and supply.

Conventional welfare economics typically require an assumption that taste or preference remain constant. The preferences and taste for canola oil have changed with introduction of the health information. Therefore, it is inappropriate to use the conventional estimate of consumer surplus. Dixit and Norman (1978) suggested a modification of the conventional method, which allows tastes to vary. Hence, following the Dixit and Norman methodology, the estimation of consumer surplus is based on the *ex post* health information standard (or *ex post* health information demand curve).

The research efforts and literature seem to be focused on the type of research which results in a shift of the supply curve. Conversely, there has been a substantial lack of attention to the demand side, which is evident in the limited number of sources in the literature. Furthermore, there has been little empirical work done on developing a comparative static model or equilibrium displacement model, which incorporates the case of multimarket tradable commodities and technical change (shifting the supply curve (reduction in yield) or shifting the demand curve (increase in demand)).

Next, a graphical and a mathematical model of the canola industry was developed. Specifically, the model developed is a trade displacement model (a set of linear supply and demand equations and the equilibrium clearing conditions) containing three regions and four sectors. The three regions are Canada, Japan and the ROW. The four sectors are the canola seed sector, the processing sector, the oil sector and the meal sector. In using this modeling technique, the welfare implications of a technically induced demand shift/supply shift can be easily associated with the various industry stakeholders. Hence, the distribution of benefits between the social groups can be determined. In addition, this modeling technique allowed the estimation of benefits/losses for foreign markets with which Canada trades. For the sake of comparison, the consumer surplus in Canada and the ROW was represented both with the *ex post* and conventional measure. Additionally, the shift in the supply curve was represented both with a proportional-marginal-cost-increasing supply shift and parallel supply shift.

Having completed the empirical estimation, the analysis and the results of the two main historical issues in canola industry, the change in demand for canola oil and the change in the potential yield for canola seed were reported. First, the estimation revealed that the increased demand for canola oil, due to the nutrition/health findings, benefits canola producers, processors and consumers of canola meal. The demand increased by $32/t. On the other hand, the domestic consumers of canola oil were not found to be better off when using the *ex post* measurement of consumer surplus, but they were found to be better off when using the conventional estimate. The total internal/private benefits to the canola industry is positive in all the different scenarios. The total external social benefit of health care saving, due to the reduction in CHD cost, are large and greater than the internal/private benefits from the increased consumption of canola oil.

Finally, the study reveals that, when a marginal-cost-increasing supply shift is applied, the net effect on the total industry of the focus on the quality characteristics of canola products at the expense of the potential yield is ambiguous. The analysis showed that there has a permanent reduction in yield of 9%. The net effect depends on the elasticities of supply and demand. Canola oil consumers lose when the *ex post* measurement of consumer surplus is used, but gain with a conventional estimate. On the other hand, when a parallel supply shift is used, the magnitude, of the benefits to social groups, is about the same to all the social groups and the total industry, except for the canola seed producers. Canola seed producers lose with a parallel supply shift.

6.2 Conclusions and Suggestion for Further Study

The purpose of this study was to examine a recent and pronounced example of an industry which has developed as the result of research and development. This is the case in the canola industry in Canada. The Canadian canola industry, through intensive research and development, has established a leading position in the world market and the domestic market. Canadian canola oil has also gained recognition as a "healthy" oil from the US market and other global markets.

To achieve the objectives of this study, a welfare analysis framework was engaged to estimate the economic effects of two kinds of research and development in the canola industry: the economic implications of the change in demand for canola oil due to the nutrition/health research and/or the change in potential yield due to the agronomic research. This study determined the total benefit and the distribution of benefits between the various social groups.

Two hypotheses were formally examined in this thesis. The first hypothesis is that the canola industry, as a whole, and the producer, processor and consumer groups within it, were better off with the health/nutrition research which increased the demand for canola oil. The second hypothesis is that the net effect for the canola industry as a whole, and the producer, processor and consumer groups, gained from the decision to switch to agronomic research, which reduced the potential yield of the canola seed for better quality characteristic of the canola products.

The study examined the above hypotheses in an equilibrium displacement trade model, which provides a multi-sector and open-economy environment. This partial equilibrium framework is adequate for this thesis.

As far as the first hypothesis is concerned, the total canola industry is better off with the health/nutrition research. However, not all social groups are better off. Consumers of canola oil are worse off due to health/nutritional news. Thus we reject the first hypothesis. In addition, society as a whole experiences a large benefit from the reduction in CHD cost.

As far as the second hypothesis is concerned, the net effect on the total canola industry and the consumers of canola meal, producers and processors, is ambiguous. The overall effect on the industry is dependent on parameter values. The sensitivity analysis showed net gains in some simulations and net losses in others. Consumers of canola oil are worse off from the change in yield due to the preference in quality. However, the research focus on canola oil quality was "absolutely necessary" for the survival of the total industry and, moreover, the canola industry's present status in the oil market. Consequently, we fail to reject the second hypothesis because of an ambiguous result.

The canola industry has a large potential to capture more dividends through further oilseed research. Transgenetic processes have created the potential to produce a wide variety of enzymes and pharmaceuticals from canola. Other research offers the possibility of developing canola properties in mustard, a crop which is more drought tolerant than canola, thereby increasing the effective growing area of the crop. Selective herbicide resistance also affords greater potential for the crop.

The positive externality in the canola industry may suggest the need for agricultural policy. The external economies cause the marginal social value to differ from the private value or market price. Consumption is difficult to monitor. There is no effective way of reducing moral hazard even in private insurance. In the case of canola oil, subsidies for canola consumption or taxation of the consumption of substitute oil could be an efficient way to correct the external economies. This tax/subsidy would align the marginal internal/private benefits (value) equal to the marginal external social benefits (value). The problem with the subsidy, as a means of correcting the externality, is that the amount to be paid as subsidy is enormous. Hence, it is preferable to use a combination of the two policies, a subsidy on canola oil and a tax encouraging consumers to change to canola oil, so as to reduce the subsidy burden. It is clear that this area requires further investigation to determine the optimal combination of the two policies needed to correct the externality. The estimation of the optimal combination of agricultural policy is recommended for further study.

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