PRODUCER RETURNS TO HYBRID CANOLA RESEARCH:

THE WESTERN GRAIN RESEARCH FOUNDATION PROGRAM

by

ANNE S. KOLODY

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ABSTRACT

From 1985-90, the Western Grain Research Foundation (WGRF) has continued to fund hybrid canola breeding research conducted by Dr. P.B.E. McVetty at the University of Manitoba. The research found that substantial yield increases over Regent were possible using the cytoplasmic male sterility (CMS) system of pollination control to produce F_1 hybrids. In addition, the research has resulted in students trained in hybrid canola breeding and a pool of genetic material and information for distribution to hybrid canola breeding programs. In 1988, the WGRF funded a study to estimate the benefits and costs to producers associated with hybrid canola breeding and to recommend a framework for assessing benefits and costs associated with subsequent project proposals. The results of a preliminary analysis are reported in a draft journal article.[i]

In general, previous models evaluating returns to agricultural research investment have focussed on the issue of social costs and returns. These models require modification for the WGRF case because the WGRF represents the private interests of agricultural producers.

In this thesis, previous models and results are reviewed, modified and re-estimated using social criteria from a producer-investment perspective. Using the theory of producer and consumer surplus, the benefit/cost technique of evaluating returns to research is undertaken in addition to an estimation of canola supply and demand curves and analysis of actual producer costs and returns. Results indicate substantially higher benefits in comparison to costs for

i. J.A. MacMillanet al., "Evaluating Producer Returns to WGRF Research Project Investments," Canadian Journal of Agricultural Economics. (future issue).

canola research at the University of Manitoba. Using the index number approach a favorable conservative benefit/cost ratio was obtained. Using a discount rate of 15 percent, sensitivity analysis of the results to economic and technical factors were positive with the lower limit of the range of benefit/cost ratio being over 1. An examination of the production practices of a select number of canola producers indicates low-cost producers will likely be positively affected by the newly developed variety. Additional research is required to more accurately estimate the benefits to producers over a longer time period to include the effects of low prices, unfavorable weather conditions, etc. Overall, the results indicate that producer-funded research provides substantial returns even when the benefit set is constrained to those attained within the producer sector.

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Chapter I

INTRODUCTION

Canola has been called a Canadian success story. The crop was originally known as rapeseed, a crop high in erucic acid and glucosinolates and undesirable for both human and animal consumption. During the war, rapeseed was grown on small acreages for its oil which served as an excellent lubricant. In 1974, the first canola variety, Tower, was released. The change in name from rapeseed to canola occurred to reflect the low level of undesirable properties in the new variety. This was a major accomplishment for Canadian plant breeders. By 1984, the change-over from rapeseed to canola varieties in Canada was almost 100 percent. The value of the crop grew from almost $0 in 1950 to over $1 billion in 1987. Canada is second only to China in world production (Canola Council of Canada, 1988).

Canola is an important crop to prairie grain producers. It is a valuable alternative since land, tillage, harvesting, storage and transportation equipment and facilities are virtually identical to that required by major grains grown on the Prairies (Kramer, Sauer and Pigden, 1983). Research has been the key to success of canola and with competition from other crops such as soybeans, oil palm, cottonseed, peanuts, groundnuts and sunflowers for the oilseed market, research is necessary to keep production competitive and consumer demands fulfilled.

The amount invested in canola research in Canada has increased significantly over the last few years with much taking place in the private sector.

With respect to varietal development, an investment survey by the Canadian Seed Trade Association found that approximately $7 million were being spent annually by its members in 1987. This represents 50 percent of private investment in crop varietal development (CSTA, 1987). In 1987, public funding administered by the Canola Council of Canada approximated $1.3 million with $700,000 directed toward breeding efforts and the remainder directed toward product utilization (Canola Council of Canada, 1988).

Numerous Canadian studies provide estimates of returns to investment in agricultural research (Nagy and Furtan (1978), Kerr (1980), Zentner (1982), Ulrich, Furtan and Downey (1984), Ulrich, Furtan and Schmitz (1985), Farrell and Funk (1985), Widmer, Fox and Brinkman (1988)). As illustrated in Table 1.1, results, in general, have been favorable. With respect to the issue of publicly-funded research, the information is useful; however, it is inadequate for evaluating private investment projects such as those funded by the Western Grain Research Foundation (WGRF) on behalf of prairie grain producers.

1.1 BACKGROUND TO THE WESTERN GRAIN RESEARCH FOUNDATION

The Western Grain Research Foundation (WGRF) is a producer-controlled, research-funding organization. In 1983, the WGRF program was initiated with $9.06 million in funds remaining after the termination of the Prairie Farm Assistance Act (PFAA) program. Its purpose is to help improve the productivity and profitability of grain and oilseed production in the prairie provinces through assistance in expansion of research and extension of research results on:

1. production including the development of new grain crops and varieties, weed and insect control, harvesting techniques and soils management and

2. alternative methods of using grains and oilseeds and the potential for new markets.

The WGRF is administered by the Executive Secretary operating under the direction of the Board of Directors. Directors are elected annually from each member organization. Directors and a representative from the Research Branch of Agriculture Canada supervise the annual program of the WGRF. At annual or general meetings, delegates nominated annually, give general direction to the Foundation. Membership includes the three Wheat Pools, United Grain Growers, Western Canadian Wheat Growers Association, Western Barley Growers Association, Flax Growers of Western Canada, Prairie Canola Growers Association, Unifarm, Keystone Agricultural Producers and the Canadian Federation of Agriculture.

Financially, the WGRF is administered with the income earned from investment of its $9.06 million sinking fund. In the future, annual producer levies on all deliveries of cereals and oilseeds to the elevators and processors is hoped to finance the Foundation's activities. Pedigreed seed sales may also be assessed. The proposed check-off by the WGRF on canola will be in addition to the levy collected by the Canola Council of Canada and its use is intended to be co-ordinated with the Canola Council program.

A single research and technical advisory committee including producers and scientists receives, reviews and priorizes research proposals and submits recommendations to the Board of Directors. In 1984, $594,000 was allocated to 14 projects. Through 1987, 46 projects were supported with a total expenditure of $4.15 million. Over $1 million was allocated to 32 projects in 1988.

Member organizations, other producer organizations and research institutions in the prairie region submit research proposals to the Foundation. In 1986, researchers were requested by the WGRF to include an assessment of the benefits and costs associated with their projects in research proposals. In 1988, the WGRF funded this study to estimate the benefits and costs to producers associated with the hybrid canola research project conducted by Dr. P.B.E. McVetty at the University of Manitoba and to recommend a framework for assessing benefits and costs associated with subsequent project proposals.

1.2 HYBRID CANOLA RESEARCH AT THE UNIVERSITY OF MANITOBA

Under the direction of Dr. B.R. Stefansson, conventional canola breeding research at the University of Manitoba began in the mid 1950's. From the 1950's to 1980, efforts focussed strictly on quality improvement in order to convert rapeseed into canola, a crop with low levels of erucic acid in the oil and low levels of glucosinolates in the meal. Later, Sernyk and Stefansson (1983) discovered substantial heterosis or growth vigor (30 percent and greater) in Regent topcrosses. Further research, under the direction of Dr. P.B.E. McVetty, has focussed on the development of the pol cytoplasmic male sterility (CMS) system of pollination control to produce F_1 hybrids, combining ability assessment and F_1 hybrid seed production on a commercial scale. In addition to the

Canola Council of Canada, Agriculture Canada, the National Science and Engineering Research Council and the Canadian Wheat Board, the latter providing graduate student scholarships, the Western Grain Research Foundation was the primary source of research funds which led to the discovery of a workable pollination control mechanism permitting yield-enhanced variety growth.[1]

1.3 PURPOSE AND METHOD

The WGRF is a private organization whose main interest is the private concerns of prairie grain producers. In this respect, research investment decisions depend on costs and returns to producers rather than to society as a whole. The objectives of this study are two-fold: 1) to evaluate WGRF investment in canola research at the University of Manitoba, from a producer perspective, in terms of a benefit/cost ratio and through an analysis of producer-level returns and 2) to develop a general framework for economic analysis of WGRF investment in research projects.

The theory of economic surplus underlies the method of estimating the benefit/cost ratio. In the past, the benefits of research have been determined by estimating a supply and demand curve for canola for a scenario in which research has been undertaken. By shifting the supply curve backwards to represent a no-research scenario, the area between the no-research and with-research supply curves under the demand curve is believed to represent the benefits of research or economic surplus. One method of shifting the supply curve is the index number approach. With the index number approach, the supply curve

1. Personal communication with Dr. P.B.E. McVetty, Department of Plant Science, University of Manitoba.

shifts back at a rate determined by an index which accounts for the lower yield of the old rapeseed/canola varieties and the respective seeded acreage of each variety that would have been planted given the absence of new varieties. Shifting the supply curve back is classified as an ex post evaluation of research funding since the past performance of these funds is analysed. The majority of studies relating to agricultural research have been ex post evaluation of research. (See Table 1.1.) In this study the supply curve will be shifted forward and a potential hybrid variety of canola will be assumed to replace one current variety, Westar. This ex ante study will determine the potential benefits of the new variety. Summing and discounting annual benefits and dividing by discounted costs of the research project will result in a benefit/cost ratio. Sensitivity analysis will be conducted on economic and technical factors affecting the sum of producer benefits, in addition to an analysis of select producer returns from canola acreage. The model developed to estimate producer benefits from hybrid canola research will be a major component in an overall framework proposed for analysing research investments by the WGRF.

Table 1.1
Canadian Studies of Returns to Agricultural Research

Authors (Date)	Commodity	Type of Study	Results/Conclusions
Nagy and Furtan (1978)	rapeseed	ex post: index number approach	social IRR:* 101%
Kerr (1980)	beef cattle	ex post: production function approach	desirable traits of beef cattle resulting from technological change have a value
Zentner (1982)	wheat	ex post: index number approach production function approach	social IRR: 34% social IRR: 39%
Ulrich, Furtan and Downey (1984)	canola	ex post: index number approach ex ante: simulation	social IRR: 51% research costs could increase from 30-900% to maintain an IRR of 51%
Klein (1985)	livestock	ex ante: simulation	technological change can be induced efficiently upon examining possible research results
Ulrich, Furtan and Schmitz (1985)	malting barley	ex post: index number approach production function approach	social IRR: 51% private IRR: 35% social MRR:** 13:1
Farrell and Funk (1985)	plant biotechnology	ex ante: Delphi forecasting approach	social IRR: 15-40%
Widmer, Fox and Brinkman (1988)	beef cattle	ex post: production function approach	social IRR: 66% social MRR: 63%

* internal rate of return
** marginal rate of return

1.4 OUTLINE OF STUDY

In the following chapters, the theory behind a research investment evaluation model is developed and previous models are discussed. A model for the evaluation of WGRF research project investment is developed and data from Dr. McVetty's hybrid canola research project at the University of Manitoba is applied. The sensitivity of results to relevant factors is examined and an analysis of the Canola Council of Canada database of producers participating in the Attentive Crop Management Program is included. A general framework for evaluating WGRF investment follows.

Chapter II

HYPOTHESIS AND THEORETICAL FRAMEWORK

The general hypothesis of this study is that hybrid canola research investment funded by producers is beneficial to producers. Models of producer and consumer behavior, including the theories of demand and supply will be used to develop the analytical framework to test this hypothesis in addition to investment theory, research investment methodology and an explanation of benefit/cost estimation procedures.

2.1 DEMAND AND SUPPLY RELATIONSHIP

Models of producer and consumer behavior help to determine appropriate methods to estimate economic behavioral relationships. In order to explain the economic behavior of human beings two principles and a number of economic concepts are required. The first principle is the optimization principle or "'the quest for the best'".[2] Given constraints, the common criterion people use to choose among alternatives is the goal of maximization of profits or well-being or minimization of costs (Chiang, 1984). Secondly, the equilibrium principle states prices adjust until the quantity demanded for a good equals the quantity supplied (Varian, 1987). One economic concept which aids in simplifying matters is a competitive market. In a competitive market, many well-informed buyers and sellers of a homogeneous good may enter and exit the market without constraint. Sellers seek to maximize profit and buyers seek to be as well off

2. A.C. Chiang. Fundamental Methods of Mathematical Economics. 3rd ed. (New York: McGraw Hill Book Company, 1984), p. 232.

as possible (Tomek and Robinson, 1981).

Two other important concepts are the theories of demand and supply. The basic unit of demand theory is the consumer who is faced with a problem of choice among a number of wants and needs with a limited income. The utility approach is used by economists to define a consumer's attempt to maximize his utility or well-being. The approach, although good in theory, is difficult in empirical study; thus, the utility function remains a conceptual device in agricultural economics. One conclusion drawn from demand theory is that an inverse relationship exists between quantity demanded and price. The demand function, which defines the pure relationship between price and quantity, holding other factors constant, can be represented as a graph or algebraic function of price and quantities known as the demand curve (Tomek et al., 1981).

Market demand is defined in terms of the alternative quantities of a commodity which all consumers in a particular market are willing and able to buy as price varies and all other factors are held constant. A market demand curve can be thought of as a summation of individual demand relations.[3] However, since individual utility functions are not observable an alternate approach is needed to estimate the theoretical market demand curve. Data on sales and average prices can often be used to this end (Tomek et al., 1981).

In addition to a commodity's own price, factors influencing demand include: population, income, prices of substitutes and consumer tastes and preferences. Regression analysis provides a method of estimating the relationships

3. W. Tomek and K. Robinson. Agricultural Product Prices. (New York: Cornell University Press, 1981), p. 30.

between a dependent variable such as quantity demanded and explanatory variables such as the factors affecting demand. The demand curve can be represented as:

$$y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 \qquad (2.1)$$

where

y is a vector representing quantity of a commodity demanded,

x_1 is a vector allowing for an intercept term,

x_2 is a vector of commodity price,

x_3 is a vector of population size,

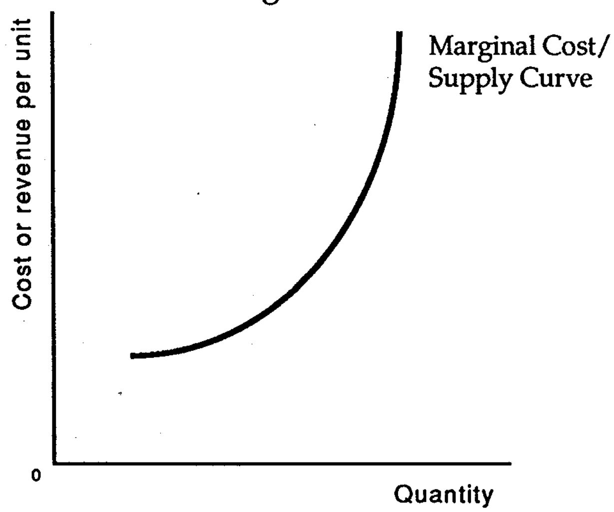
x_4 is a vector of substitutes,

x_5 is a vector of consumer income and

β_1, β_2, β_3, β_4 and β_5 are parameters indicating the relationship between variables. Two types of demand curve shifts are possible: a parallel shift and a structural shift. In equation (2.1) where quantity, price, population, substitutes and income are relevant variables, a parallel shift results from a change in x_5, consumer income, for example. A structural shift implies a change in the parameters which may result from a change in tastes and preferences (Tomek et al., 1981).

Similar to demand theory, supply theory is based on the assumption that producers seek to maximize net returns. A supply function can be derived from the underlying input-output relationship in a similar fashion to deriving a demand curve from individual utility functions. Cost curves can also be used to derive an individual firm's supply curve. For example, profit-maximizing behavior recognizes that the optimum output level is where marginal cost equals marginal revenue. In a competitive market, marginal revenue is the price a producer receives for his output. In Figure 2.1, the marginal cost curve represents physical production possibilities. Since the producer is a price taker, the marginal cost curve represents the individual firm's supply curve (Tomek et al., 1981).

Figure 2.1
A Marginal Cost Curve



Source: Tomek and Robinson (1981)

A market supply curve is defined as alternative quantities all producers are willing to sell as price changes and all other factors remain constant. Factors affecting supply include: prices of inputs, substitutes and joint products, technology and institutional constraints. Algebraically, the supply curve is represented in equation 2.2:

$$y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 \qquad (2.2)$$

where

y is a vector representing quantity of a commodity supplied,

x_1 is a vector allowing for an intercept term,

x_2 is a vector of commodity price,

x_3 is a vector of substitutes,

x_4 is a vector representing technology and

β_1, β_2, β_3 and β_4 are parameters indicating the relationship between variables. Like demand curves, supply curves are subject to parallel and structural shifts (Tomek et al., 1981).

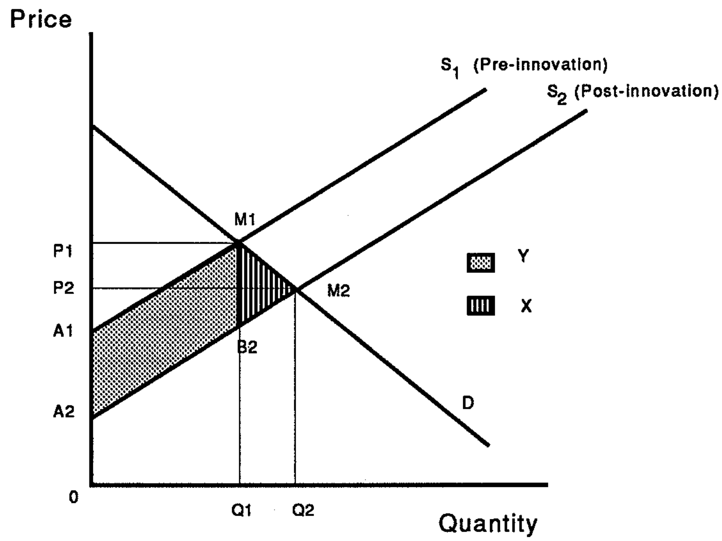
2.2 RESEARCH INVESTMENT EVALUATION METHODOLOGY

Norton and Davis (1981) reviewed major techniques in evaluating returns to agricultural research. They categorized studies into ex post and ex ante, the former evaluating returns to past research efforts and the latter evaluating possible returns to research. Two types of ex post study were found: 1) economic surplus analyses estimating an average return to research and 2) production function analyses estimating marginal returns. Ex ante approaches reviewed by Norton and Davis included: 1) scoring models, 2) benefit/cost analyses, 3) simulation and 4) mathematical programming. With scoring models , alternative research projects are ranked according to judgements of experts. In benefit/cost analysis, decisions are based on the present value of expected benefits divided by the present value of expected costs. The simulation method compares simulated system benefits and costs derived from introducing a new variety with system benefits and costs without the new variety. Mathematical programming methods rank alternative projects according to the estimate of marginal benefits associated with the addition of a new variety created by research in a farm production model. In this study, the nature of the problem, where costs are funds committed by the WGRF and benefits to producers are to be estimated, suggests that the ex ante benefit/cost method is most appropriate.

2.3 ESTIMATING BENEFITS AND COSTS

Using the theory of supply and demand, research benefits can be simulated using the concept of economic surplus. Technology change such as the introduction of a new, yield-increasing variety is represented by a shift of the supply curve, assuming all else remains constant. Diagrammatically, this is given in Figure 2.2. The 2 shaded areas identified by Rose (1980) as X and Y, between the pre- and post-innovation supply curves, S_1 and S_2, below the demand curve is the area of economic surplus or research benefits. This innovation model produces the opposite results to a supply management scheme which would reduce benefits and produce an X-like triangle of dead weight loss (Veeman, 1982).

Figure 2.2
Supply Curve Shift as a Result of Technology Change



A number of studies have used the Marshallian concept of economic surplus to measure change in social welfare from research activities. In their survey of the development of and debate over the concept of economic surplus, Currie et al. (1971) summarized the Marshallian concept of economic surplus by writing:

> The traditional conception of economic surplus is that in a transaction an individual generally gives up something which has a (direct or indirect) utility in exchange for something which has at least as great a (direct or indirect) utility. To the extent that the latter is greater, he receives an 'economic surplus' from this transaction.[4]

Recognizing the difficulty in measuring utility, they add, "the more operational monetary measure is the relevant area below the demand curve or above the supply line."[5] Inserting the word compensated before demand curve and supply line describes the contribution of Hicks to this area (Currie et al., 1971).

4. J.M. Currie, J.A. Murphy and A. Schmitz, "The Concept of Economic Surplus and Its Use in Economic Analysis," Economic Journal, 18(1971), p.764.

5. Ibid., p. 764.

Zentner (1985) commented that the Hicksian concept is theoretically correct; however, use of the Marshallian concept in estimating returns is justified because the proportion of consumers' budgets allocated to many agricultural commodities in the developed world is small.

Economic surplus can be broken into two components: 1) benefits accruing to consumers (consumer surplus) and 2) benefits accruing to producers (producer surplus). Numerous studies have used both concepts to determine annual research benefits and estimate a social rate of return to research funds (Nagy and Furtan (1978), Zentner (1982), Ulrich, Furtan and Downey (1984), Ulrich, Furtan and Schmitz (1985), Widmer, Fox and Brinkman (1988)). Benefits accruing to consumers are at most a secondary consideration to the WGRF; thus, producer surplus will be the focus of this study.

Empirical and theoretical issues which have arisen regarding the economic surplus approach to estimating research benefits include: (1) the functional form of the supply and demand curves, 2) the elasticity of the demand curve, 3) the type of supply curve shift and 4) the meaning of producer surplus. Differences in functional form of the demand and supply curve were considered by Lindner and Jarrett (1978) to be insignificant as they had less impact on results than assumptions about the magnitude and type of supply curve shift. Duncan and Tisdell (1971) found that the elasticity of the demand curve had a significant impact on producer surplus. They concluded that the more inelastic the demand curve, the lower the benefits accruing to producers. As illustrated in Table 2.1, a parallel supply curve shift with a perfectly inelastic demand curve results in zero producer benefits. Considering the international demand for Canada's canola, one would expect an elastic demand and positive benefits accruing to producers. In drawing attention to four types of supply curve shift: parallel, pivotal, proportional and convergent, Lindner and Jarrett (1978) argued that a substantial difference in research benefits results for different types of shifts. Rose (1980), however, argued that the areas being measured were only valid if the industry supply curve was both a marginal cost curve excluding factor rents and an average cost curve including factor rents which is generally not true in agriculture. Whenever there are two competing uses for land, Rose added, the supply curve for an agricultural commodity is not a marginal curve exclusive of rents because it includes marginal rents to land from alternative enterprises and marginal nonland costs. Further, it is virtually impossible to make an assumption about the type of supply curve shift unless evidence that links nonland costs with points on the supply curve exists. Rose noted that a proportional supply curve shift may be predicted for a yield-increasing innovation because demand for land and other inputs would be proportionately reduced for each unit of output. A sensible measure of the intercept terms, however, would not be likely. Thus, Rose concluded that since a single point estimate on the supply curve is generally the best information possible, a crude but useful approach to the estimation of research benefits is to assume the supply curve shift is parallel.

Table 2.1
Demand Elasticity and Effect on Producer Surplus

Type of Supply Shift	Nature of Demand Curve		
	Perfectly Elastic	Intermediate Elasticity	Perfectly Inelastic
Convergent	+	+	+
Parallel	+	+	0
Divergent	+	?	-

Source: Duncan and Tisdell (1971)

Support for Rose's conclusions can also be found in the work of Currie, Murphy and Schmitz (1971). These authors developed the theoretical basis for using the long-run supply curve in measuring economic surplus which is weakened because, theoretically, in the long term, with free entry and exit to the market, it is expected that producers would capitalize some surplus in the value of farm assets. Further, according to Currie et al., there must be two definitions of producer surplus: surplus accruing to owners of firms and surplus accruing to owners of factors of production. In the long term, surplus accruing to owners of firms is meaningless because in the long run, total revenue equals total cost and profit is capitalized in factors of production. In the long term, surplus accruing to owners of factors of production is meaningful only if the average cost curve (inclusive of rents) is the marginal cost curve (exclusive of rents). As Rose mentions, this is never the case for agricultural commodities with competing uses for land. Ulrich, Furtan and Schmitz (1985) point out that the conventional notion of producer and consumer surplus is a simplification of reality because benefits can be distributed to various sectors of the industry including producers, processors and marketing agencies. This reinforces Rose's conclusion that a parallel supply curve shift be assumed in estimating a crude approximation of research benefits.

In previous studies, costs of research have been estimated using a man-year method (Zentner, 1982). This method involves estimating the number of man years involved in research and multiplying by the cost per man-year. In this study, the expenditures by the WGRF for Dr. McVetty's research project will be used.

2.4 THEORY OF INVESTMENT

Similar to investment in equipment and machinery, investment in research involves an initial capital outlay with the expectation of a future stream of capital inflows. The concepts used in determining whether or not such investment is worthwhile are defined within the theory of capital budgeting.

According to Lusztig and Schwab (1983), the focus of capital budgeting is long-term projects requiring the commitment of funds in order to generate future returns. Because returns accrue over a number of years in the future, they must be transformed in such a way that allows comparison between the cost of the project and the returns. In general, if returns exceed the cost, the project is considered desirable.

As described by Lusztig and Schwab, interest is the price borrowers pay lenders for temporary use of money or capital. Because of interest, money has a "time value." In other words, the economic value or the amount money is worth to an individual or firm depends on the time it is received or disbursed. When the rate of interest is positive individuals prefer to receive money sooner than later because of the opportunity to earn the rate of interest on that money. Future cash flows are associated with an economic sacrifice in the form of a lost opportunity and should be charged an "opportunity cost." Thus, the value of money is a function of time and opportunity cost.

Discounting is a mathematical procedure whereby future cash flows can be adjusted for time and opportunity cost. The formula for discounting is:

$$PV = \sum_{t=0}^{n} \frac{FV_t}{(1+i)^t}$$

where

PV is the present value of a future cash flow,

FV is the future value of a cash flow,

i is the interest rate,

n is the number of years the future value is away from the present and

t is the time period.

In capital budgeting, discounting is used in the calculation of three criteria that are useful in investment evaluation. These criteria are net present value, internal rate of return and benefit/cost ratio.

Net present value (NPV) is defined as the sum of all cash flows generated by a project with each cash flow discounted back to the present.[6]

6. P. Lusztig and B. Schwab. Managerial Finance in a Canadian Setting. (Toronto: Butterworth & Co. Ltd., 1983), p. 161.

Mathematically, it is represented as:

$$NPV = \sum_{t=0}^{n} \frac{C_t}{(1+k)^t}$$

where

C_t is the net after-tax cash flow (benefits less costs) in period t,

k is the time value of money to the firm and

n is the number of periods in the expected life of the investment.

Only projects with positive net present values should be undertaken as " the net present value itself indicates the excess or shortfall of cash flows in present-value terms"[7] and when there are more than one project, the project/s with the highest NPVs (in descending order) should be selected.

The internal rate of return (IRR) is the "rate of discount that, when applied to the cash flows of an investment, will yield a net present value of zero."[8] Mathematically, the IRR is the discount rate, r, that satisfies the equation:

$$\sum_{t=0}^{n} \frac{Ct}{(1+r)^t} = 0$$

The internal rate of return measures the yield of an investment without consideration for financing charges. In other words, the IRR represents the level of interest at which funds could be borrowed without incurring a loss. If the IRR is greater than the borrowing rate, the investment is considered sound and projects with higher IRRs are preferred.

7. Ibid., p. 161.

8. Ibid., p. 163.

A third criteria is the benefit/cost ratio. Simply defined, it is "the ratio of discounted benefits over discounted costs."[9] Mathematically, it is represented as:

$$\sum_{t=0}^{n} \frac{FVB_t}{(1+i)^t} \Big/ \sum_{t=0}^{n} \frac{FVC_t}{(1+i)^t}$$

where

FVB is the future value of benefits in period t and

FVC is the future value of costs in period t.

Provided that the assumed benefits and costs represent all returns and costs, investment in projects with a benefit/cost ratio greater than 1 is desirable and larger ratios are preferred. When choosing from a number of projects, the project/s with the highest benefit/cost ratio should be selected.

Another investment evaluation criteria is the payback period. The payback period simply measures the time required for an investment's expected after-tax cash inflows to equal (and thereby recover) the original outlay.[10] One limitation of the payback period is that cash flows after the payback period are ignored; however, it is useful in indicating the length of time investors are exposed to the risk of not recapturing their initial capital outlay.

A number of factors are important in determining the validity of the investment criteria. The discount rate is not specified for the internal rate of return; however, it is required for the net present value and benefit/cost ratio.

9. Ibid., p. 184.

10. Ibid., p. 167.

The discount rate to be applied in investment evaluations is generally the firm's weighted average cost of capital.[11] An appropriate time horizon must be estimated and the effects of inflation must also be incorporated into the calculations.

The net present value, internal rate of return and benefit/cost ratio each evaluate discounted costs and benefits in a manner which, in the end, ranks a number of projects identically. Ranking and selecting projects on the basis of payback period may result in a different selection.

Previous studies evaluating returns to canola research have presented results in terms of an IRR. One objective of this study is to estimate the benefits to producers from a new canola variety. At a basic level, the cost of research is the amount invested by the WGRF. The availability of benefit and cost information suggests that the benefit/cost ratio be used in presenting the results of this study. Further, the results of this study are of interest to the decision-makers of the WGRF. In comparision to the internal rate of return, the benefit/cost ratio is a straightforward investment criteria requiring minimal background knowledge. In the interest of decision-makers, the use of the benefit/cost ration is favored.

11. Ibid., p. 192.

Chapter III

PREVIOUS STUDIES AND A MODEL FOR EVALUATING WGRF-FUNDED HYBRID CANOLA RESEARCH

Since the pioneering work of Schultz (1953) and Griliches (1958) on agricultural research in the United States numerous studies evaluating returns to agricultural research have been completed. In general, the focus of such study has been social returns to public expenditures and results of rates of return ranging from 11 to 110 percent have been reported (Evanson et al., 1979). Evaluations of research ranging from biological to mechanical and from industry-aggregate to commodity-specific have been documented to compare results by Evanson et al. (1979) and Hueth and Schmitz (1985). With respect to rapeseed/canola research, two major studies have been undertaken: Nagy and Furtan (1978) and Ulrich, Furtan and Downey (1984).

3.1 ECONOMIC MODELS FOR ESTIMATING RETURNS TO RESEARCH

In their review of the approaches to evaluation of agricultural research investment, Norton and Davis (1981) categorized studies into ex post and ex ante, the former evaluating returns to past research efforts and the latter, possible returns to research. The majority of studies are ex post with ex ante evaluation of investment remaining fairly unstudied. The work of Schultz (1953), Griliches (1958), Peterson (1967), Ayer and Schuh (1972), Akino and Hayami (1974) and Nagy and Furtan (1978) are examples of ex post evaluation using economic surplus models. Ulrich, Furtan and Downey (1984) included ex ante evaluation using a similar model. Using the concepts of economic surplus, the change in area between the pre-innovation and post-innovation supply curves and the change in area under the demand curve is a measure of research benefits or economic surplus. Production functions and productivity indexes are used to determine the supply curve shift.

The approach taken by Nagy and Furtan (1978) involved a productivity index which resulted in a 101 percent internal rate of return to rapeseed research for the period 1965-75. By using the index number approach, the supply curve for rapeseed was shifted back annually with an index number which accounted for the anticipated yield and acreage impact of old varieties replacing new research varieties. Research benefits were calculated for the area between the no-research (pre-innovation) and with-research (post-innovation) supply curves as shown in Figure 3.1 using the formulas of Akino and Hayami (1974). These formulas required an estimate for the price elasticity of supply and demand. Estimates of 1.96 and 2.85 for supply and demand were obtained by ordinary least squares regression of the following double log functions:

$$\ln RS_t = -1.71 + 1.96 \ln RP_{t-1} + 1.47 FP_{t-1} + 0.65 WS_{t-1} + 1.42T \qquad (3.1)$$

($R^2 = 0.92$, DW = 2.63, student t values significant at the 5 percent level)

$$\ln RD_t = -21.3 - 2.85 \ln RP_t + 1.13 SM_t + 2.66 SO_t + 5.38 WP_t \qquad (3.2)$$

($R^2 = 0.92$, DW = 1.79, student t values significant at the 5 percent level)

where

RS_t is total Canadian prairie rapeseed production in period t,

RP_t is Canadian prairie rapeseed price in year t,

FP_t is Canadian prairie flax farm price in year t,

WS_t is Canadian wheat stocks in year t,

T is a trend variable,

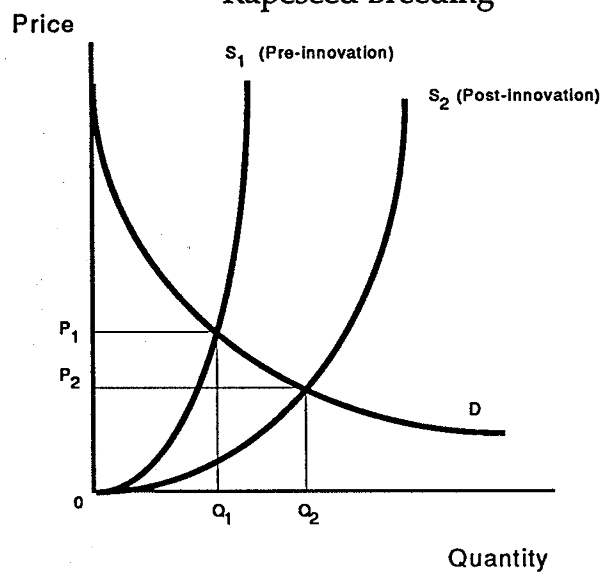
RD_t is Canadian exports + domestic demand for rapeseed in year t,

SM_t is soybean meal price in year t,

SO_t is soybean oil price in year t and

WP_t is world population in year t.

Figure 3.1
The Model of Nagy and Furtan (1978) for Returns to
Rapeseed Breeding



Annual research expenditures and annual research benefits were converted into 1961 constant dollars and a flow of funds was estimated by subtracting costs from benefits. Costs were assumed to begin in 1960 while returns began in 1964. Both costs and returns were arbitrarily assumed to end in 1995. This resulted in a social rate of return of 101 percent. Using a 10 percent discount rate, Nagy and Furtan obtained a benefit/cost ratio of 17.64:1. In this study, attempts to reproduce the results of Nagy and Furtan were successful.

The model used in this study is based on the work by Ulrich, Furtan and Downey (1984) on biotechnology in rapeseed breeding. Similar to Nagy and Furtan, Ulrich et al. used the index number approach to estimate annual ex post research benefits for the period 1951-82. Additional ex ante benefits were estimated under various scenarios up to 2002. Diagrammatically, the model used by Ulrich et al. is given in Figure 3.2. The formulas to calculate the area of economic surplus were based on the work of Rose (1980):

$$P1 = P2 / [1 - (K * e) / (e + n)] \qquad (3.3)$$

$$Q1 = Q2 / [1 + (K * e * n) / (e + n)] \qquad (3.4)$$

$$TS = .5 * Q1[K * P1 + (A1 - A2)] + .5 * K * P1(Q2 - Q1) \qquad (3.5)$$

where

K is a productivity index (weighted yield index - 100) / 100,

e is the price elasticity of supply,

n is the price elasticity of demand,

P2 is post-innovation price,

Q2 is post-innovation quantity,

P1 is pre-innovation price,

Q1 is pre-innovation quantity,

A2 is the post-innovation intercept,

A1 is the pre-innovation intercept and

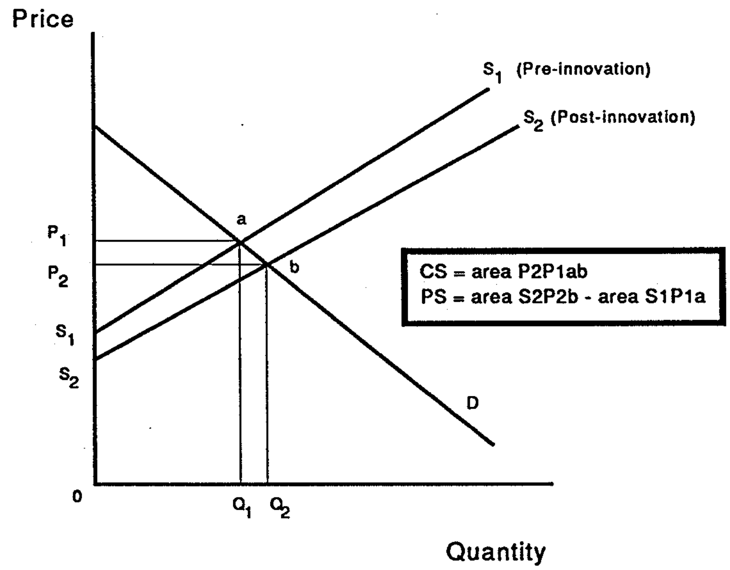
TS is total net producer plus consumer surplus.

The equation for consumer surplus was:

$$CS = Q1(P1 - P2) + .5(P1 - P2) * (Q2 - Q1). \qquad (3.6)$$

Both areas of total surplus and consumer surplus were estimated by Lindner and Jarrett (1978) based on the cross multiplication rule derived by Durrant and Kingston (1937). Producer surplus was obtained by subtracting consumer surplus from total surplus.

Figure 3.2
The Model of Ulrich et al. (1984) for Returns to Biotechnology in Rapeseed Breeding



Data on post-innovation prices and quantities were obtained from Statistics Canada while pre-innovation prices and quantities were calculated as above. The productivity index, K, was derived from a weighted yield index calculated from data reflecting the relative yield advantage of different varieties and the percentage of total rapeseed/canola acreage seeded to each variety. To calculate the weighted yield index, each variety's product (relative yield index X percentage acreage) was summed annually and divided by the sum of products for the base year 1960. The results indicated the increase in production due to new higher-yielding varieties. Elasticity estimates were obtained from the work of Nagy and Furtan (1978).

Annual research costs were estimated by multiplying the annual person-years devoted to rapeseed/canola variety research by a time series estimate of the annual person-year cost based on Zentner (1982). Annual research expenditures and annual research benefits were converted into 1971 constant dollars. A 10-year research lag was assumed which meant benefits in 1961 were the result of research performed 10 years earlier. A flow of funds was estimated by subtracting costs from benefits and an internal rate of return of 51 percent was calculated by Ulrich et al.

In reviewing Ulrich et al. (1984) for this study, three problems were discovered: 1) the definition of K in their model was a quantity-based horizontal supply shift measure which is not consistent with Rose's vertical shift and cost-based definition of k, 2) values for the intercept terms were not specified and 3) with a vertical cost-based shift, the elasticity of supply and demand, e and n, respectively, are not the same for both pre- and post-innovation supply curves and require annual re-calculation. In attempting to reproduce the results of Ulrich et al., the quantity-based K was converted into the cost-based k with equation (3.11) discussed later. Without values for the intercept term, the type of supply curve shift assumed by Ulrich et al. was not known. Based on previous arguments by Rose in favor of a parallel supply curve shift, equation (3.9), discussed later, was used and the need to calculate intercept terms was omitted. With annual re-calculations of the elasticities, an internal rate of return of 38 percent was obtained instead of 51 percent.

3.2 A MODEL FOR EVALUATING WGRF EXPENDITURES ON CANOLA RESEARCH

This study differs from the studies by Nagy and Furtan (1978) and Ulrich et al. (1984) in two ways. The first difference is in scope and level of applicability. The research cost data available to Nagy and Furtan included all (yield, quality and disease control) rapeseed breeding research undertaken by the federal and provincial governments, the Rapeseed Association of Canada and universities. They noted the research costs were biased upward because the research benefits they calcalulated were derived from yield increasing improvements only. Nevertheless, the rate of return was a social one reflecting the return to society as a whole, both producers and consumers. The cost data of Ulrich et al. also included all breeding research expenditures and social rates of return were estimated. In this study, WGRF expenditures on one specific research project will be examined and a social rate of return from a producer perspective will be estimated. Secondly, the previous studies were ex post and estimated benefits by shifting the supply curve backwards in time. Although Ulrich et al. calculated some ex ante benefits, these calculations were based on previous calculations of ex post benefits. In this study, the supply curve will be shifted forward based on the yield improvement demonstrated by the hybrid canola variety developed in the research project conducted by Dr. McVetty at the University of Manitoba.

Considering the arguments of Rose (1980), adjustments to the formulas used in the study by Ulrich et al. are necessary. The formulas used reflect a divergent shift of the supply curve; however, Rose discussed the impossibility of determining the nature of the supply curve shift and concluded with the availability of single point estimates on the supply curve, estimation of research benefits using a parallel supply curve shift is appropriate. It was also stressed that the results are crude but provide useful information. Thus, the formulas of Rose for a parallel curve shift will be used in this study. Further comment on the appropriateness of a parallel supply curve shift model is given in Appendix I. As illustrated in Figure 2.2, Rose divided the area of total surplus, TS, into two components, X and Y where:

$$TS = X + Y \qquad (3.7)$$

$$X = .5 * k * P1(Q2 - Q1) \qquad (3.8)$$

$$Y = k * Q1 * P1. \qquad (3.9)$$

$$Q2 = Q1 * [1 + (k * e * n) / (e + n)] \qquad (3.10)$$

and

k is a cost-based supply curve shifter,

e is the price elasticity of supply and

n is the price elasticity of demand.

In this case, since the supply curve is shifting forward, data on pre-innovation prices and quantities (P1 and Q1) are available and post-innovation quantity (Q2) requires calculation. In equations (3.8), (3.9) and (3.10) k refers to a cost decrease which is different from the quantity yield increase, K, used by Ulrich et al. According to Lindner and Jarrett (1978) K can be converted into k with the following formula:

$K = k * e$ (3.11).

Ex ante producer benefits will be estimated by subtracting consumer surplus calculated in equation (3.6) from total surplus calculated in equation (3.7). In order to calculate consumer surplus an estimate of post-innovation price, P2, is required. Rose's equation for P2 will be used:

$P2 = P1 * [1 - (k * e) / (e + n)].$ (3.12)

A benefit/cost ratio will be calculated by taking the present value of benefits over the present value of the WGRF expenditure on the hybrid canola research project. These values will be discounted to the year 1985, the year the decision to invest in this project was made using an assumed discount rate.

The sensitivity of producer benefits to changes in technical and economic variables can be summarized in the following function:

$B = f(k, e, n, r, p, u, P', I', M, O)$ (3.13)

where k, e and n are defined in the equations above and summarize the impact of yield increases and the rate of adoption of a new variety measured by seeded acres, and supply and demand factors. Together the real interest rate, r, and the rate of inflation, p, form the discount rate and affect the present value calculation in a manner similar to any capital investment project analysis. Larger values of the discount rate result in more conservative estimates of benefits. Inflating the discount rate is one method of accounting for the risk and uncertainty associated with a project's outcome; however, in this study, risk and uncertainty[12] is treated as another dimension associated with producer benefits requiring separate analysis. The returns to producers as a result of WGRF-funded hybrid canola research are expected to begin years after the decision to invest. Therefore, predictions of future benefits are estimated and subject to uncertainty. As the more distant future is often more difficult to predict, risk and uncertainty affect benefits negatively. Future product, P′, and input, I′, prices are likely to have a significant sensitivity impact on producer benefits given the likeliness of wide variation in crop prices over the 1985-94 investment planning period. With respect to a farm financial cash flow, rising canola prices could lead to increased demand for certain inputs and to rising input costs for hybrid canola seed and specific canola-related chemicals. The sensitivity of results to marketing margins, M, for commercial seed and chemicals, and other factors, O, require further analysis but are beyond the scope of this study. An analysis of the input costs and returns to a select number of producers enrolled in the Attentive Crop Management Program sponsored by the Canola Council of Canada will be completed to give a farm financial perspective to producer benefits.

12. Anderson et al. (1977) make a distinction between risk and uncertainty; however, in this study, the two will be used interchangeably.

Chapter IV

APPLICATION OF THE MODEL FOR EVALUATING WGRF-FUNDED HYBRID CANOLA RESEARCH AND RESULTS

The benefit/cost model discussed in the previous chapter is applied to the hybrid canola research project conducted by Dr. McVetty at the University of Manitoba to illustrate the potential for incorporating economic analysis in research allocation decisions being made by producer groups. The analysis is illustrative because the data available across WGRF projects will vary. Additional analysis of the sensitivity of results to the likely range in values for critical variables is presented.

4.1 ESTIMATION OF SUPPLY AND DEMAND FOR CANOLA

Two values required in the model for estimating returns to canola research are the price elasticity of demand and supply. Previous studies have used the values estimated by Nagy and Furtan (1978). In the study by Nagy and Furtan, the model for supply of rapeseed did not include research expenditures as a variable; thus, research effects were included in the error term. Nagy and Furtan suggested that the inclusion of such a variable would be an interesting exercise. Based on the approach used by Nagy and Furtan, new supply and demand curves are estimated using ordinary least squares regression.

4.1.1 Models for Supply and Demand of Canola

Theory does not indicate which functional form to use in specifying demand and supply relationships. For the period 1965-75, Nagy and Furtan obtained favorable results using a linear-in-logarithms formulation for both the supply and demand curves. Such specification permits a non-linear relationship to exist between variables while maintaining a linear form which is amenable for estimation techniques such as ordinary least squares (Varian, 1984). Since evidence has not been found to suggest curvilinear relationships are inappropriate for the supply and demand of canola, the functional form used by Nagy and Furtan is used in this study.

With rapeseed supply in period t as the dependent variable, the variables found by Nagy and Furtan to be significant in estimating the supply curve were rapeseed price, flaxseed price and wheat stocks all in period t-1. A trend variable was also found to be significant. (See equations 3.1 and 3.2.) By replacing the trend variable with a research expenditures variable in period t-10, the new supply model may be written as:

$$\ln CS_t = f(\ln CP_{t-1}, \ln FP_{t-1}, \ln WS_{t-1}, \ln RE_{t-10}) \qquad (4.1)$$

where

CS_t is total Canadian prairie rapeseed/canola production in period t,

CP_t is Canadian prairie rapeseed/canola price in year t,

FP_t is Canadian prairie flax farm price in year t,

WS_t is Canadian wheat stocks in year t,

RE_{t-10} is research expenditure in year t-10,

A research lag of 10 years was assumed as in the work of Ulrich et al. (1984). All variables are expected to have a positive effect on supply except flax price which is expected to have a negative impact. Tomek and Robinson (1981) found that many agricultural commodities have an inelastic supply elasticity. Thus, the price elasticity for canola supply is expected to be less than one.

The variables in the new model for demand are also different from those found in the study by Nagy and Furtan. In Table 4.1, the total 1987 value of canola exports is given, by province, in addition to the major importer. For each province, Japan was the major importer importing three-quarters of total exports. Considering the major role of Japan in importing Canadian canola, the strength of the Japanese economy as indicated by its gross domestic product and Canadian exchange rate is expected to have significant impact on canola demand. In addition to seed, canola oil and meal are important products associated with the canola industry. Thus, substitutes, soybean oil and soybean meal are expected to affect canola demand in addition to its own price. The new demand model for canola may be written as:

$$\ln CD_t = f(\ln CP_t, \ln JGDP_t, \ln ER_t, \ln SO_t, \ln SM_t) \qquad (4.2)$$

where

CD_t is total Canadian exports plus domestic demand for rapeseed/canola in year t,

CP_t is Canadian prairie rapeseed/canola price in year t,

$JGDP_t$ is Japanese gross domestic product in year t,

ER_t is Japanese/Canadian exchange rate in year t,

SM_t is soybean meal price in year t and

SO_t is soybean oil price in year t.

Canola price is expected to have a negative impact on quantity demanded while the remaining variables are expected to have positive effects. Considering the international influence on demand for canola and Canada's small market share, the price elasticity of demand is expected to be elastic or greater than 1.

Table 4.1
Value of Canola Exports and Major Importer By Province, 1987

Province	Total Exports $	Major Importer	Value of Imports $	% of Total
Alberta	189,991,429	Japan	143,935,850	75.8
Saskatchewan	203,628,877	Japan	154,267,423	75.5
Manitoba	94,480,656	Japan	71,577,706	76.6

Source: Statistics Canada, International Trade Domestic Exports By Province of Origin, By Class and By Country, Unpublished Data

4.1.2 Data

Data used in the regression of the supply and demand equations are summarized in Table A2.1 and Table A2.2 in Appendix II. The majority of data on canola prices, quantities and costs of canola research were obtained from Ulrich et al. (1984). Recent canola data and data for flax prices and wheat stocks were obtained from Statistics Canada in the Cereals and Oilseeds Review (22-007), Handbook of Agricultural Statistics (21-516) and Grain Trade of Canada (22-201). Until 1983, soybean data were available in the publication by the World

Bank, Commodity Trade and Price Trends. Subsequent soybean data were obtained from the Commodity Year Book. Soybean oil and meal prices were adjusted using the Canada-U.S. exchange rate. Data on exchange rates were obtained from the Bank of Canada Review. The International Journal of Financial Statistics provided data on Japan's annual gross domestic product and population. Data were collected for the time period 1962 to 1986.

4.1.3 Results and Discussion

Using ordinary least squares regression on the double log function presented in equation (4.1) resulted in the following supply curve:

$$\ln CS_t = -12.69 + \underset{(2.38)}{0.81\ln CP_{t-1}} + \underset{(4.82)}{1.39\ln WS_{t-1}} + \underset{(4.20)}{0.39\ln RE_{t-11}}. \qquad (4.3)$$

The student t values are given in parentheses and are significant at the 5 percent level. The R^2 value was 0.92 with a Durbin Watson value of 1.70 indicating indeterminant autocorrelation. The flax price variable was not significant possibly indicating the crop is not as prominent as in earlier times. This is a reasonable result given the popularity of canola on the prairies. The flax price variable was excluded from the regression. The research expenditures variable was found to be significant when lagged eleven years. As expected, the price elasticity of supply is inelastic with a value of 0.81.

Using ordinary least squares regression on the double log function presented in equation (4.2) resulted in the following demand curve:

$$\ln CD_t = -30.35 - \underset{(3.43)}{1.96\ln CP_t} + \underset{(9.30)}{2.09\ln JGDP_t} - \underset{(4.47)}{3.12\ln ER_t} + \underset{(1.35)}{0.63\ln SO_t} + \underset{(1.72)}{1.01\ln SM_t}. \qquad (4.4)$$

The student t values are given in parentheses and are significant at the 5 percent level with the exception of soybean oil price. The R^2 value was 0.93 with a Durbin Watson value of 1.52 indicating indeterminant autocorrelation. As expected, the price elasticity of demand is elastic with a value of 1.96.

The elasticity estimates obtained in this study differ from those estimated by Nagy and Furtan. In addition to the inclusion of different variables, one explanation for the difference is the time period under consideration. The time period used in this study extends 13 years past the time period of Nagy and Furtan. Changes in production practices and consumer demands are likely and are reflected in the new supply and demand models. For the purposes of this study, the most recent information will be used in calculating benefits.

Linear models were not attempted for regression purposes. As Coyle (1989) notes, "when linear consumer demand or output supply/factor demand equations are estimated using deflated price and income data, there can be no meaningful economic interpretation of econometric results."[13] Based on the approach of Widmer, Fox and Brinkman (1988), a polynomial distributed lag model was attempted for a double log canola supply function; however, results were generally insignificant.

4.2 ESTIMATION OF HYBRID CANOLA RESEARCH BENEFITS

Research benefits include many direct and indirect effects. Direct effects, the focus of this study, include the additional revenue from higher yielding varieties, the availability of genetic material and information and the research

13. B.T. Coyle. "A Comment on the Specification of Linear Equations for Consumer Demand, Output Supply and Factor Demand," Canadian Journal of Agricultural Economics. 37(1989), p. 263.

training component. Indirect effects, such as crop substitution, multiplier and distribution impacts will not be addressed. Although effects from research may be direct, they may not be easy to quantify, thus, the estimates of research benefits resulting from formulas must be viewed with care.

4.2.1 Quantified Benefits

The quantified benefits in this study result from the yield enhancing property of the new hybrid canola variety resulting from Dr. McVetty's research project and are estimated using equations (3.6) to (3.11). Benefits from the research project initiated from 1985-90 are assumed to occur from 1992-94. With the perpetual nature of research, new varieties are continually entering the market; therefore, it is unrealistic to assume a longer time period. Based on 5-year trials, the performance of three hybrid canola cultivars developed at the University of Manitoba exhibit considerable heterosis. Referring to Table 4.2, yield increases ranged from 20-44 percent over an existing variety, Regent. Currently, however, Westar, is the prominent Brassica napus canola variety on the prairies. For simplicity, comparisons will be made between a new hybrid variety, XXX, and Westar which has a yield index of 124 compared to Regent with 110. The yield performance results in Table 4.2 suggest that a new commericially available hybrid variety, XXX, will have at least a 15 percent yield increase over the canola variety, Westar. With this difference in yield, it is assumed the new variety will slowly penetrate the market, to be conservative, and optimistically replace 20, 35 and 50 percent of the 1985 canola acreage seeded to Westar in 1992, 1993 and 1994, respectively. These assumptions are necessary in determining a value for k in equations (3.8)-(3.10). With reference to Table 4.3, Westar is used as the base crop and given a yield index of 100. Given the results of Table 4.2, the yield index of the new variety, XXX, is 115 . The weighted yield index is obtained by multiplying the difference in yield index between Westar and the new variety by the proportion of acreage seeded to the new variety and adding 100. Referring to Table 4.3, cell E34, the weighted yield index of 103.0 results from 15 (yield index difference) X .2 (new variety acreage proprotion) + 100. Similar results are found in cells, F34 and G34, for the weighted yield index in 1993 and 1994. K, the productivity index, is obtained by subtracting 100 from the weighted yield index and dividing by 100. K is the quantity-based productivity index which is different from, k, the cost-based index required in equations (3.8)-(3.10). The conversion is made using equation (3.11). Statistics Canada reports for the year 1985 a value of \$7.22 for P1 and 154,280,000 bushels for Q1. Based on the regression detailed in section 4.1, values of 0.81 and 1.96 were used for elasticity estimates e and n, respectively.

Table 4.2
University of Manitoba Pol CMS Hybrid Canola Field Performance, Manitoba 1986-88

Hybrid	Yield* (t/ha)	Yield* (% of Regent)	% Oil*	% Protein*
M86001	2.67	130	44.3	26.4
M86002	2.45	120	43.6	26.0
M86003	2.96	144	44.8	25.8
Regent	2.05	100	45.0	25.1

*5 station years

Source: Dr. P.B.E. McVetty, Presentation at the 1988 Agri-Forum Conference, Winnipeg, December 13-14, 1988.

Based on the assumptions and data above, annual research benefits for the years 1992-94 are estimated and given in Table 4.3, cells B49 to D49. Of this total surplus, the benefits accruing to producers are obtained by subtracting the consumer surplus estimated from equation (3.6). Annual producer benefits are given in Table 4.3, cells B51 to D51. Summing the producer benefits from 1992-94 results in a total of $156,451,560. Assuming producers only capture 25 percent of these benefits due to marketing agents and competition for market share, producer benefits are reduced to $39,112,890.

4.2.2 Unquantified Benefits

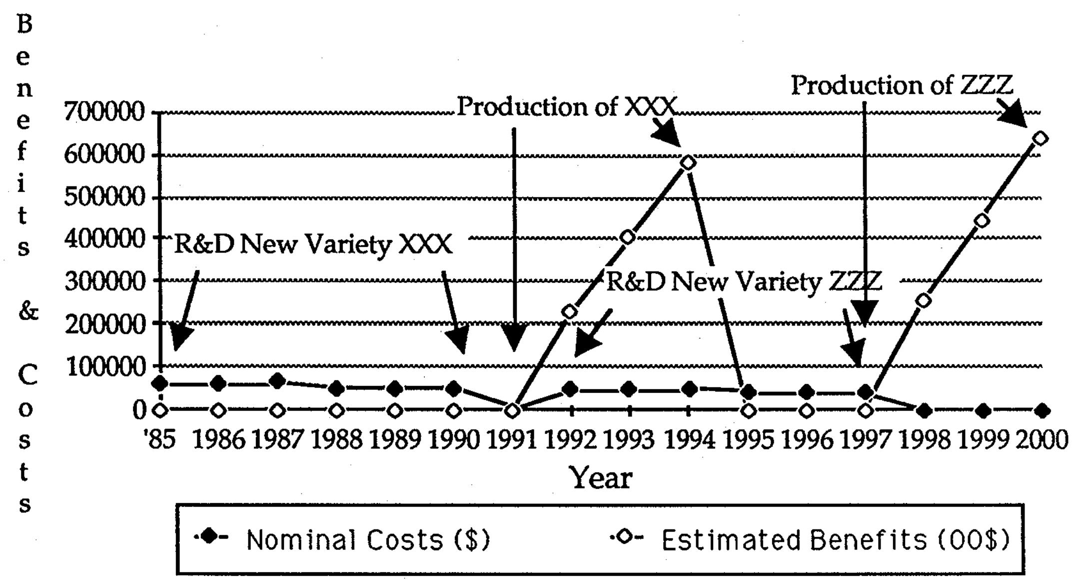
Benefits of the WGRF investment which are not easy to quantify from a producer's perspective result, in part, from the large graduate student training component. For the hybrid canola research project analyzed in this study, 5-6 M.Sc. and 2-3 Ph.D. students will have been trained in the hybrid canola breed-

Table 4.3
Costs and Returns of WGRF Investment in Canola Research: Base Case

	A	B	C	D	E	F	G
1	COSTS AND RETURNS OF WGRF INVESTMENT IN CANOLA RESEARCH: BASE CASE						
2							
3	WGRF Expenditures						
4						Discounted Producer	
5		Nominal		Deflated	Discounted	Surplus Benefit	
6	Year Ending	Costs ($)	CPI 1985=100	Costs ($)	Costs at 15% ($)	at 15% to 1985	
7	1985	59000.00	100.00	59000.00	59000.00	(See Cell E63)	
8	1986	60000.00	104.09	57642.42	50123.85		
9	1987	65000.00	108.65	59825.13	45236.39		
10	1988	50000.00		50000.00	32875.81		
11	1989	50000.00		50000.00	28587.66		
12	1990	50000.00		50000.00	24858.84		
13							
14	TOTAL ($)	334000.00			240682.55	49396551.88	
15	Benefit/Cost Ratio					205.24	
16	Benefit/Cost Ratio X .25					51.31	
17							
18							
19	Benefits Resulting from WGRF Expenditures						
20							
21	•Commercial impact begins in 1992						
22	•New variety captures 20, 35 and 50 percent of seeded acreage in 1992-94 respectively						
23	•$334 000 (nominal dollars) has been spent to obtain a yield increase of 15% over Westar						
24	•The following table is used to obtain an estimate of k, the supply curve shifter						
25	•New variety replaces the acreage planted to Westar						
26							
27		Yield Index		Year and % Canola Acreage			
28				1985	1992	1993	1994
29							
30	Westar	100		53.7	33.7	18.7	3.7
31							
32	New Variety XXX	115		0.0	20.0	35.0	50.0
33							
34	Weighted Yield Index			100.0	103.0	105.3	107.5
35							
36	•Rose's equations for a parallel supply curve shift are used to calculate total benefits, consumer and producer surplus						
37							
38	Year	1992	1993	1994			
39	K	0.03	0.05	0.08			
40	e	0.81	0.81	0.81			
41	n	1.96	1.96	1.96			
42	k	0.04	0.06	0.09			
43	P1 (1985) $	7.22	7.22	7.22			
44	Q1 (1985) 000 bu	154280.00	154280.00	154280.00			
45	P2 $	7.14	7.08	7.02			
46	Q2 000 bu	157554.97	160011.20	162467.42			
47	Y 000$	41255.61	72197.33	103139.04			
48	X 000$	437.88	1340.99	2736.72	SUM (000 $)		
49	Total Surplus 000$	41693.49	73538.32	105875.76	221107.57		
50	Consumer Surplus 000$	12191.96	21503.99	30960.06	64656.00		
51	Producer Surplus 000$	29501.53	52034.33	74915.70	156451.56		
52	%CS	29.24%	29.24%	29.24%			
53	% PS	70.76%	70.76%	70.76%			
54							
55	Gross Returns (thousands nominal $)						
56	Change in Quantity (000 bu)	3274.97	5731.20	8187.42	17193.59		
57	Price (1985) $	7.22	7.22	7.22			
58	Gross Value	23645.28	41379.23	59113.19	124137.70		
59							
60	Discounted Surplus at 15% (to 1985) (thousands $)						
61	Total Surplus	15674.13	24039.81	30096.50	69810.43		
62	Consumer Surplus	4583.41	7029.69	8800.78	20413.88		
63	Producer Surplus	11090.72	17010.12	21295.72	49396.55		

ing area and approximately 20 papers on various components of hybrid canola breeding will have been published by 1992. In addition, a considerable amount of very valuable genetic material for distribution to hybrid canola breeding programs has been and will continue to be distributed without charge. As illustrated in Figure 4.1, producer costs of the development and adoption of subsequent new varieties will be reduced because of the research capability established and the entrance of future new varieties to the market may be accelerated. In Figure 4.1, the research and development (R&D) costs of new hybrid variety ZZZ, for example, is 20 percent lower than the research and development costs of hybrid variety XXX. With the transfer of technology, variety ZZZ may also be adopted sooner, increasing market share (10 percent is illustrated in Figure 4.1) and subsequently increasing producer benefits. Therefore, producer benefits used in calculating the benefit/cost ratio in this study are significantly understated.

Figure 4.1
Schematic Representation of Benefits & Costs of
WGRF-Funded Canola Research



4.3 ESTIMATION OF HYBRID CANOLA RESEARCH COSTS

The costs associated with hybrid canola research at the University of Manitoba are broken down into two components. Similar to benefits of the research, there are quantified and unquantified costs.

4.3.1 Quantified Costs

According to Dr. McVetty, the WGRF allocated $59,000 to hybrid canola research at the University of Manitoba in 1985. In 1986 and 1987, $60,000 and $65,000, respectively, were allocated. This was to be followed by $50,000 per year from 1988 to 1990. In total, $334,000 (nominal dollars) was invested in hybrid canola research by the WGRF. (See Table 4.3 cells B7 to B14.)

4.3.2 Unquantified Costs

There are three requirements for successful canola breeding.[14] Firstly, heterosis must be greater than 15 percent. That is, the yield increase obtained by crossing two parent seeds must be at least 15 percent greater than the yield of any one parent. Secondly, research must be conducted on a pollination control mechanism to ensure the production of seed when the new variety is grown. Thirdly, commercial seed production must be possible. Previous research efforts at the University of Manitoba found sufficient heterosis in hybrid canola. The WGRF investment of funds from 1985 to 1987 led to the discovery of a pollination control mechanism. The committment of funds, from 1988 to 1990 facilitated the search for a seed production mechanism permitting commercial production of seed. Thus, the WGRF contributed to fulfilling the second and third requirements of successful canola breeding while the first requirement was fulfilled by sources of funding which were not solely the WGRF. In addition, the university component has not been accounted for. The provision and maintenance of laboratories and equipment available at the Univeristy of Manitoba is a cost to the university but difficult to quantify in terms of the hybrid canola research project. In total, the canola breeding program at the University of Manitoba directs approximately $250 thousand annually toward labor, operation and maintenance costs with approximately $150 thousand allocated to labor only.[15] Therefore, the cost of finding a commercially viable hy-

14. Personal communication with Dr. P.B.E. McVetty, Department of Plant Science, University of Manitoba.

15. Personal communication with Dr. P.B.E. McVetty and Dr. I. Morrison, Department of Plant Science, University of Manitoba.

brid canola variety is not limited to the funds committed by the WGRF.

One further consideration is market development and extension costs which can be considered as investments complementary to the WGRF investment in canola research. For example, annual sums of $200,000 have been directed by the Canola Council of Canada into market development efforts, as well as extension funds to the "Grow with Canola" program (Canola Council annual reports). According to Dr. B.R. Stefansson (personal communication), the initial work on rapeseed breeding was an attempt to develop a Canadian oilseed to compete with soybean oil in the Japanese market. Although it may be argued that market development and extension costs are external to the present WGRF decision framework, they must be recognized as the success of such efforts impacts on the success of any new variety entering the market.

4.4 BENEFIT/COST RATIO FOR HYBRID CANOLA RESEARCH

Benefits and costs of the WGRF investment in canola research are summarized in the spreadsheet given in Table 4.3. Before discounting, total producer benefits of canola research from 1992 to 1994 are estimated to be $156.45 million (cell E51). Total costs from 1985 to 1990 are $334,000 (cell B14). A 15 percent discount rate is used which is assumed to represent a 6 percent inflation rate and a 9 percent real rate of interest. Since the WGRF hybrid canola research is only one of several similar hybrid canola research projects under way and it is likely that marketing and distribution sectors will receive a share of the calculated producer benefits, the producer benefit is reduced to 25 percent of the benefit calculated from the model. The result is a benefit/cost ratio of 51.31:1

(cell F16) meaning that for every dollar invested by the WGRF on behalf of producers, approximately $51 in benefits can be expected.

4.5 SENSITIVITY OF RESULTS

It is common in benefit/cost analysis to provide decision-makers a range of results. The following sections will examine best and worst case scenarios and the sensitivity of results to the economic and technical factors outlined in equation (3.13).

4.5.1 Best and Worst Case Scenarios

The worst case scenario is failure to breed a variety with a yield significantly higher than Westar. With no yield benefits resulting from research efforts, the benefit/cost ratio would depend on other unquantified benefits. Considering quantified benefits only, the benefit/cost ratio would be 0 and the net present value would be negative in the amount invested in research. In this case, the net present value would be negative $240,683.

An optimistic or best case scenario includes a 20 percent increase in values for the following variables: canola prices, acreage planted to the new variety, yield and market penetration. An optimistic scenario would also include a lower discount rate. In Table 4.4, a discount rate of 10 percent results in a benefit/cost ratio of 134.37:1 (cell F16).

Table 4.4
Costs and Returns of WGRF Investment in Canola Research: Optimistic Case

	A	B	C	D	E	F	G
1	COSTS AND RETURNS OF WGRF INVESTMENT IN CANOLA RESEARCH: OPTIMISTIC CASE						
2							
3	**WGRF Expenditures**						
4						Discounted Producer	
5		Nominal		Deflated	Discounted	Surplus Benefit	
6	Year Ending	Costs ($)	CPI 1985=10	Costs ($)	Costs at 10% ($	at 10% to 1985	
7	1985	59000.00	100	59000.00	59000.00	(See Cell E63)	
8	1986	60000.00	104.09	57642.42	52402.20		
9	1987	65000.00	108.65	59825.13	49442.25		
10	1988	50000.00		50000.00	37565.74		
11	1989	50000.00		50000.00	34150.67		
12	1990	50000.00		50000.00	31046.07		
13							
14	TOTAL	334000.00			263606.94	118067157.98	
15	Benefit/Cost Ratio					447.89	
16	Benefit/Cost Ratio X .30					134.37	
17							
18							
19	**Benefits Resulting from WGRF Expenditures**						
20							
21	•Commercial impact begins in 1992						
22	•New variety captures 20, 35 and 50 percent of seeded acreage in 1992-94 respectively						
23	•$334 000 (nominal dollars) has been spent to obtain a yield increase of 15% over Westar						
24	•The following table is used to obtain an estimate of k, the supply curve shifter						
25	•New variety replaces the acreage planted to Westar						
26							
27		Yield Index		Year and % Canola Acreage			
28				1985	1992	1993	1994
29							
30	Westar	100		53.7	29.7	11.7	0.0
31							
32	New Variety XXX	118		0.0	24.0	42.0	53.7
33							
34	Weighted Yield Index			100.0	104.3	107.6	109.7
35							
36	•Rose's equations for a parallel supply curve shift are used to calculate total benefits, consumer and producer surplus						
37							
38	Year	1992	1993	1994			
39	K	0.0432	0.0756	0.09666			
40	e	0.81	0.81	0.81			
41	n	1.96	1.96	1.96			
42	k	0.053333	0.0933333	0.119333			
43	P1 (1985) $ with 20% increase	8.66	8.66	8.66			
44	Q1 (1985) 000 bu	154280	154280	154280			
45	P2 $	8.53	8.43	8.36			
46	Q2 000 bu	158995.96	162532.92	164831.95			
47	Y 000$	71289.70	124756.98	159510.71			
48	X 000$	1089.57	3336.82	5454.85	**SUM (000 $)**		
49	**Total Surplus 000$**	72379.28	128093.80	164965.56	365438.64		
50	**Consumer Surplus 000$**	21165.06	37457.03	48239.03	106861.12		
51	**Producer Surplus 000$**	51214.22	90636.77	116726.53	258577.52		
52	%CS	29.24%	29.24%	29.24%			
53	% PS	70.76%	70.76%	70.76%			
54							
55	**Gross Returns (thousands nominal $)**						
56	Change in Quantity (000 bu)	4715.96	8252.92	10551.95	23520.83		
57	Price (1985) $ with 20% increase	8.66	8.66	8.66			
58	Gross Value	40859.04	71503.31	91422.09	203784.45		
59							
60	**Discounted Surplus at 10% (to 1985) (thousands $)**						
61	Total Surplus	37142.01	59756.70	69961.50	166860.22		
62	Consumer Surplus	10861.02	17473.98	20458.06	48793.06		
63	Producer Surplus	26280.99	42282.72	49503.45	118067.16		

4.5.2 The Sensitivity of Results to Risk and Uncertainty

In some cases, the risk and uncertainty associated with a future cash flow is accomodated in a larger-valued discount rate. For example, in evaluating risky projects, rather than use the discount rate of 15 percent which is applied to certain business projects, a risk-adjusted discount rate of 18 percent may be used. Lusztig and Schwab (1983) criticized the risk-adjusted discount rate approach to capital expenditure analysis and suggested the certainty equivalent approach as a more appropriate alternative in dealing with risk. The problem with the adjusted discount rate is that the effects of risk and the time value of money were not being evaluated separately and "by linking together the time value of money and risk, we assume that the uncertainty of a projects's cash flows increases over time in a narrowly specified manner."[16] As illustrated in Figure 4.2, the risk-adjusted discount rate is a short-cut that may introduce undesirable biases into the evaluation. To avoid this problem, Lusztig and Schwab suggest the use of a risk-free discount factor in addition to certainty equivalent values between 0 and 1 (where 1 would reflect no risk) which is multiplied by each annual cash flow in the discounting formula. The certainty equivalent would be set subjectively and as decision makers saw future cash flows being more uncertain, the certainty equivalent value used in the formula would approach zero.

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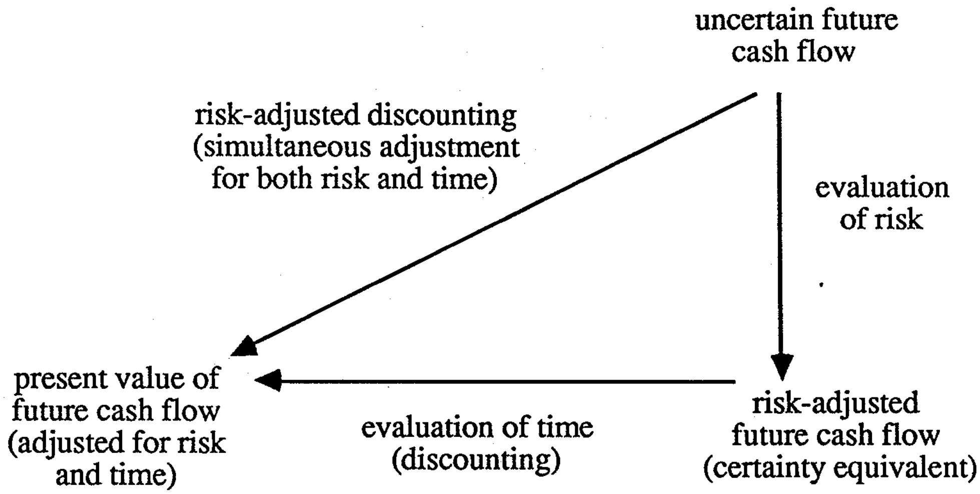
16. P. Lusztig and B. Schwab. Managerial Finance in a Canadian Setting. (Toronto: Butterworth & Co. Ltd.), 1983, p.231.

Figure 4.2
Evaluation of Risk and Time in Investment Decisions



Source: Lusztig and Schwab (1983)

In this study, future benefits are expected to occur from 1992 to 1994. Table 4.5 summarizes the results obtained by applying a number of certainty equivalents to the producer benefits in the base case scenario. Under considerable risk and uncertainty, represented by a certainty coefficient of 0.3 in the final year benefits are expected, the benefit/cost ratio is 27.61. Less uncertainty, represented by certainty coefficients of 0.5 to 0.8 in the final year benefits are expected, results in benefit/cost ratios ranging up to 45.12. Nevertheless, recognizing some degree of risk and uncertainty in future benefits and applying the certainty equivalent approach causes the benefit/cost ratios to decrease in comparision to the base case where uncertainty is ignored. However, a favorable benefit/cost ratio is still suggested for the WGRF-funded hybrid canola research.

Table 4.5
Sensitivity of Benefit/Cost Results to Uncertainty

Certainty Equivalent in 1992	1993	1994	Benefit/Cost Ratio Base Case
1.0	0.9	0.8	45.12
0.9	0.8	0.7	39.99
0.9	0.7	0.5	33.80
0.9	0.6	0.3	27.61

4.5.3 Sensitivity of Results to Economic and Technical Factors

As given in equation (3.13), a number of economic and technical factors are expected to effect benefit/cost results. A summary of these effects under low, medium and high risk assumptions is given in Table 4.6 and discussed below. A certainty equivalent of one was applied to each annual cash flow under low risk assumptions. For the years benefits are expected, 1992, 1993 and 1994, certainty equivalents of 0.9, 0.8 and 0.7 under medium risk and 0.9, 0.6 and 0.3 under high risk assumptions are used, respectively. Assumptions for the base case are described in sections 4.2.1 and 4.3.1.

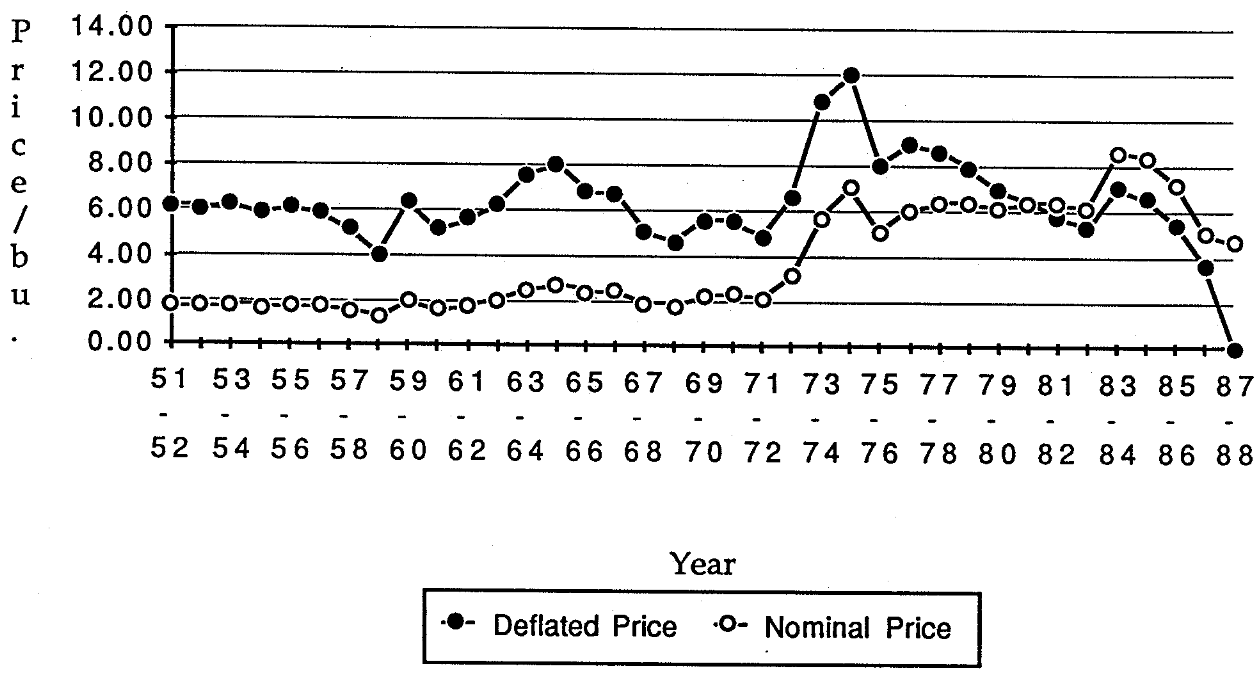
Table 4.6
Sensitivity of Results to Economic and Technical Factors

Factor Changed	Risk and Uncertainty*	Benefit/Cost Ratio
Base Case**	Low	51.31
	Medium	39.99
	High	27.61
20% Yield Increase	Low	68.86
	Medium	53.66
	High	37.02
n = 5	Low	62.67
	Medium	48.84
	High	33.70
n = 0.5	Low	27.42
	Medium	21.38
	High	14.77
e = 5	Low	3.27
	Medium	2.55
	High	1.76
e = 0.5	Low	93.83
	Medium	73.12
	High	50.46
P1 = 8.65	Low	61.47
	Medium	47.91
	High	33.07
P1 = 4.68	Low	33.26
	Medium	25.92
	High	17.89
r = 10%	Low	67.51
	Medium	52.43
	High	35.77
r = 18%	Low	43.68
	Medium	34.11
	High	23.71
Benefits in 1991-93	Low	59.01
	Medium	45.99
	High	31.75
Benefits in 1996-98	Low	29.34
	Medium	22.86
	High	15.78
30% Market Share	Low	61.57
	Medium	47.98
	High	33.13

*Certainty equivalents for low, medium and high risk: 1.0, 1.0, 1.0; 0.9, 0.8, 0.7 and 0.9, 0.6, 0.3 in 1992, 1993 and 1994 respectively
**Base Case: P1 = $7.22, r = 15%, e = 0.81, n = 1.96, 25% market share, 15% yield increase in 1992-94

In general, favorable results were obtained under the most conservative assumptions. A 20 percent yield increase over Westar, rather than the 15 percent used in the base case, results in a benefit/cost ratio of 53.66 under medium risk assumptions. This represents an increase in benefits of more than $13 for every dollar invested, compared to the base case. An increase in price from $7.22 (base case) to $8.65 had roughly the same effect. From examining the price cycle of canola as illustrated in Figure 4.3, it is apparent that future canola prices will likely exhibit similar troughs and peaks experienced in the past. In order to understand the effect of such price fluctuations on the WGRF investment, high and low prices, $8.65 and $4.68 per bushel respectively were included in the sensitivity analysis. Under medium risk assumptions, benefit/cost ratios of 47.91 and 25.92 were obtained for the high and low prices, respectively. Under high risk, the low price still maintained a respectable ratio of 17.89. Discount rates of 10 and 18 percent were examined. Under medium risk, results were ratios of 52.43 and 34.11 for the low and substantially high discount factors. When variety adoption was accelerated by one year in order that benefits accrue from 1991 to 1993, the ratio improved moderately to 45.99 from 39.99 (base case) under medium risk. However, if benefits were to accrue later, from 1996 to 1998, rather than from 1992 to 1994, the ratio drops by almost half to 22.86. An increase in market share for producers from 25 to 30 percent contributes $8 more to benefits for every dollar in costs, in comparision with the base case. Clearly, benefits decrease with high risk assumptions, however, given further conservative assumptions such as low prices or a high discount rate, re-

Figure 4.3
Canola Price Cycle



spectable benefit/cost ratios are obtained. Compared with other factors, the results are most sensitive to changes in elasticity of supply. Low benefit/cost ratios, in the vicinity of 3, were obtained when e equals 5.

4.5.4 Farm Financial Perspective

The factors affecting producer benefits given in equation (3.13) include product and input prices. Assuming all else is held constant, higher product prices increase producer benefits by increasing total revenue. However, if input levels also increase, then production costs increase and producers may gain little if any at all. In this respect, the concept of producer surplus is weak because it considers only changes in total revenue. In this study, the time period producer benefits are expected to occur in is 1992-94 which makes prediction of changes in product and input prices difficult. The sensitivity of benefit/cost results to changes in product prices is covered in section 4.5.3. However, to understand the effect of input prices on producer returns, a financial analysis which considers both revenue and costs to producers is necessary. Whereas a producer surplus analysis only considers total revenue, a financial analysis captures effects of input costs, government subsidies and market imperfections on producer returns. A useful exercise would be to locate high and low cost producers in western Canada, through a financial analysis and determine the effect of a new higher-yielding Brassica napus variety of spring canola, such as the one developed at the University of Manitoba, on these producers. The Canola Council of Canada database of canola producers was studied for this purpose.

The Canola Council of Canada administers a program for canola producers called the "Grow With Canola" Program. This program is designed to help producers lower their per bushel cost of canola by maximizing their yield. In addition, producers have the opportunity to provide the Canola Council with information on their production practices on an Attentive Crop Management (ACM) Field Sheet. This information is recorded in a computer database by the Canola Council and developed into an Attentive Crop Management (ACM) Report. The report, distributed to producers providing production information, gives producers insight on how they compare with other producers in their area.

For the 1987 crop year, 868 ACM field sheets were entered into the Canola Council's database. Excluding producers who did not grow canola in 1987 or were not located in Canada, 836 records were used in this study. All data on varieties grown, yield and variable costs is available in Appendix III, in addition to a description of variable cost calculations. The following is a summary.

In Table 4.7, canola variety and average yield data are summarized for all records and by province. Westar was most common for all records with 56 per cent. In Alberta, the Brassica campestris variety, Tobin, was most common. Brassica campetris varieties require a shorter growing period and yield lower than any Brassica napus variety such as Westar. Westar dominated Saskatchewan and Manitoba. Excluding Ontario where winter canola is grown, average yield by province ranged from 21 to 27 bushels per acre. Twenty-seven crop districts divided the prairie provinces. As illustrated in

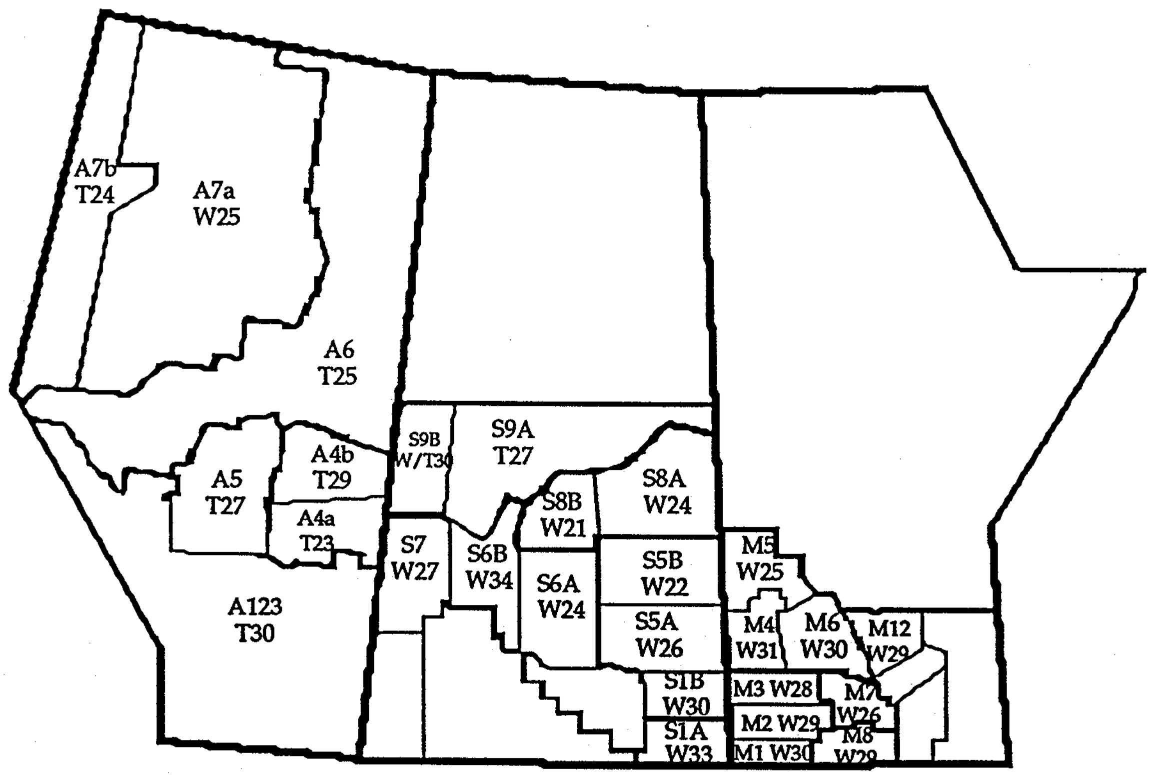
Figure 4.4, 19 of 27 crop districts reported Westar as the most common variety grown. Seven crop districts, mostly in Alberta, reported Tobin as the most common variety. Average yield by crop district ranged from 21 to 33 bushels per acre.

Table 4.7
Canola Council Database Records: Yield, Variety and
Gross Margin Per Acre by Province

Province (# records)	Average Yield (bu)	Common Variety	% Growing Common Variety	Gross Margin
Total (836)	27	Westar	56	$70.98
BC (5)	21	Tobin	100	$48.66
Alberta (199)	27	Tobin	72	$67.15
Saskatchewan (368)	26	Westar	65	$68.31
Manitoba (238)	29	Westar	79	$77.42
Ontario (26)	31	Global	50	$83.31

Gross margin is defined as revenue less variable costs or the income above variable costs which may be contributed toward fixed costs (Kay, 1981). Variable costs are costs related to the inputs used. In studying the Canola Council database, the variable cost components were fertilizer cost, herbicide cost, seed and treatment costs and fieldwork cost. Labour is not included as a variable cost. Notes explaining the approach in calculating these costs are given in Appendix III. As given in Table 4.7, the average gross margin for all records in the database is $70.98 per acre which means approximately $71 per

Figure 4.4
Common Variety and Average Yield of ACM Producers by Crop District



T24 represents Tobin with average yield of 24 bu. per acre
W27 representsWestar with average yield of 27 bu. per acre

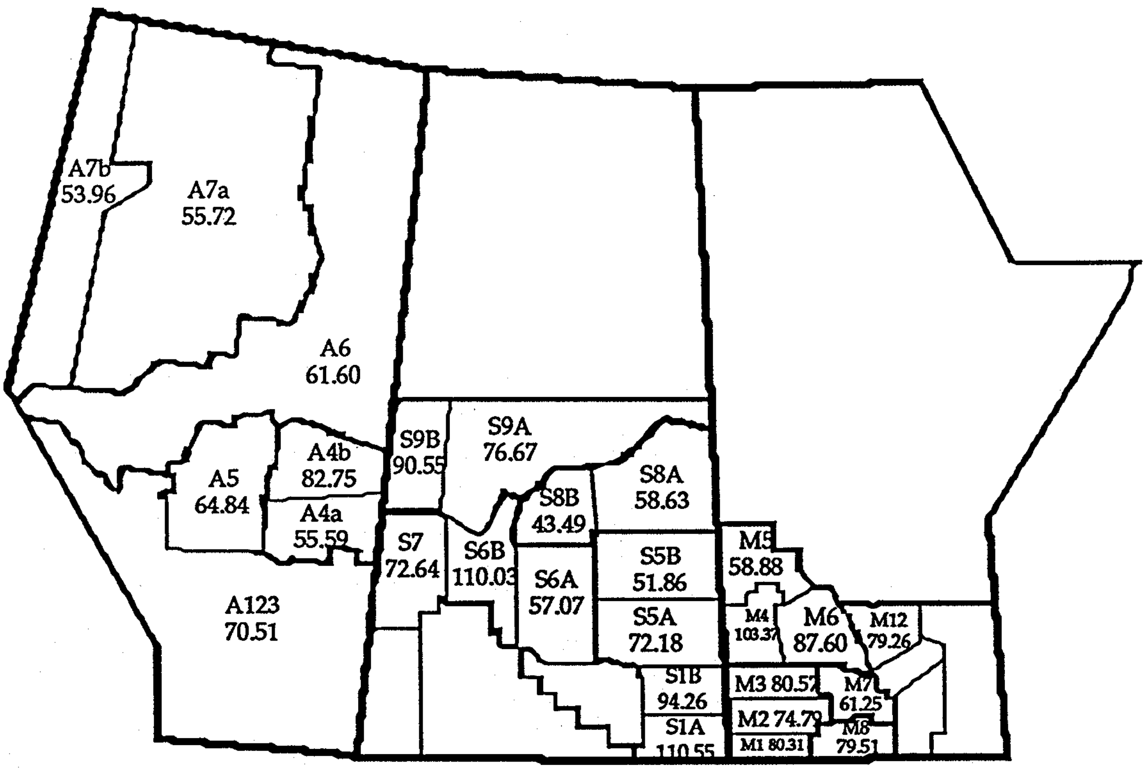
acre is available to pay the fixed costs associated with growing canola. An estimate for fixed costs of growing canola in 1987 by Manitoba Agriculture was $69.45 per acre[17] which means that, on average, records from producers participating in the ACM program indicate that fixed costs could be covered in 1987. From another perspective, with an average return of $1.53 ($70.98 - $69.45) per acre and 6.6 million acres[18] of canola grown in Canada in 1987, approximately $10.1 million accrued to canola producers.[19] The average gross margin by province indicates Manitoba producers were the only prairie province producers able to meet fixed cost commitments. Figure 4.5 presents a summary of gross margin per acre by crop district. Sixteen of the 27 prairie province crop districts, mostly in Manitoba and Saskatchewan, reported gross margins above the estimated level required to meet fixed costs. Considering only the crop districts growing spring canola, the crop district reporting the highest gross margin was S1A in the southeast corner of Saskatchewan where Westar was produced by 94 per cent of the producers. Table 4.8 presents the top and bottom 4 prairie crop districts ranked by gross margin. The 4 crop districts with the highest gross margin reported Westar as the most common variety being grown by 73 to 94 per cent of producers. Two of the 4 crop districts with the lowest gross margin reported Westar as most common but with only 50 to 68 per cent of producers growing this variety. Tobin was the second most com-

17. Manitoba Agriculture Farm Management. Farm Business Management Information Update. January, 1987, p. 4.

18. Source: Statistics Canada, Cereals and Oilseeds Review (22-007).

19. The fixed costs per acre estimated by Manitoba Agriculture were land investment costs ($29.00), machinery depreciation ($12.00), machinery investment ($9.60), storage costs ($2.85) and labour and management costs ($16.00) for a total of $69.45 per acre. The income remaining from the gross margin after these fixed costs are subtracted is a net return.

Figure 4.5
Average Gross Margin ($/acre) of ACM Producers by Crop District



mon variety in these districts. In the remaining 2 crop districts, Tobin was grown most frequently, 64 to 95 per cent of the time.

Table 4.8
Top and Bottom Prairie Crop Districts by Gross Margin

Top Four			
Crop District	Gross Margin	Common Variety	Percentage Grown
S1A	$110.55	Westar	94
S6B	$110.03	Westar	79
M4	$103.37	Westar	75
S1B	$94.26	Westar	73
Bottom Four			
Crop District	Gross Margin	Common Variety	Percentage Grown
S8B	$43.49	Westar	50
S5B	$51.86	Westar	68
A7b	$53.96	Tobin	95
A4a	$55.59	Tobin	64

4.6 DISCUSSION OF RESULTS

The results of the benefit/cost model for WGRF-funded hybrid canola research exhibit considerable potential gains for prairie producers. The conservative but likely set of assumptions used in the base case results in approximately $51 worth of benefits for every dollar invested by the WGRF. In other words, there is potential for over $49 million (1985 dollars) in benefits to accrue to prairie producers between 1992 and 1994 if research efforts are successful and a higher-yielding Brassica napus canola variety replaces Westar. The project gains favor considering the potential loss of approximately $241 thousand under the worst case scenario of research failure and no yield benefits. It should be noted that the benefit/cost ratios reported in this study are very conservative. Benefits of the new variety are only calculated for 3 years; whereas, varieties have often been prominent much longer. Westar, for example, has been popular on the prairies since 1984. Further, the benefit/cost ratios only include the revenue-enhancing benefits of the 15 percent yield advantage that the new variety is expected to have over Westar. The substanial benefits resulting from the public information of hybrid canola breeding techniques, graduate student training and genetic material availability have not been included in monetary terms. As given in Table 4.9, even replacing WGRF expenditures on canola research at the University of Manitoba by the University's total budget for the canola breeding program results in a respectable benefit/cost ratio of 17.17:1.

As expected, the sensitivity of results to all economic and technical factors was greatest under high risk assumptions. However, even extremely conservative assumptions about the price (P1 = $4.68) and the discount rate (r = 18%) resulted in reasonable benefit/cost ratios of 17.89 and 23.71, respectively, under high risk. If the time period in which benefits are expected is delayed to 1996, the benefit/cost ratio would remain a respectable 15.78 under high risk assumptions. From a less conservative perspective, for every dollar invested by

Table 4.9
Costs and Returns of WGRF Investment in Canola Research: Base Case with All Breeding Program Costs

	A	B	C	D	E	F	G
1	COSTS AND RETURNS OF WGRF INVESTMENT IN CANOLA RESEARCH: BASE CASE WITH ALL BREEDING PROGRAM COSTS						
2							
3	**WGRF Expenditures**						
4						Discounted Producer	
5		Nominal		Deflated	Discounted	Surplus Benefit	
6	Year Ending	Costs ($)	CPI 1985=100	Costs ($)	Costs at 15% ($)	at 15% to 1985	
7	1985	250000.00	100.00	250000.00	250000.00	(See Cell E63)	
8	1986	250000.00	104.09	240176.77	208849.37		
9	1987	250000.00	108.65	230096.64	173986.12		
10	1988	250000.00		50000.00	32875.81		
11	1989	250000.00		50000.00	28587.66		
12	1990	250000.00		50000.00	24858.84		
13							
14	TOTAL ($)	1500000.00			719157.79	49396551.88	
15	Benefit/Cost Ratio					68.69	
16	Benefit/Cost Ratio X .25					17.17	
17							
18							
19	**Benefits Resulting from WGRF Expenditures**						
20							
21	•Commercial impact begins in 1992						
22	•New variety captures 20, 35 and 50 percent of seeded acreage in 1992-94 respectively						
23	•$334 000 (nominal dollars) has been spent to obtain a yield increase of 15% over Westar						
24	•The following table is used to obtain an estimate of k, the supply curve shifter						
25	•New variety replaces the acreage planted to Westar						
26							
27		Yield Index		Year and % Canola Acreage			
28				1985	1992	1993	1994
29							
30	Westar	100		53.7	33.7	18.7	3.7
31							
32	New Variety XXX	115		0.0	20.0	35.0	50.0
33							
34	Weighted Yield Index			100.0	103.0	105.3	107.5
35							
36	•Rose's equations for a parallel supply curve shift are used to calculate total benefits, consumer and producer surplus						
37							
38	Year	1992	1993	1994			
39	K	0.03	0.05	0.08			
40	e	0.81	0.81	0.81			
41	n	1.96	1.96	1.96			
42	k	0.04	0.06	0.09			
43	P1 (1985) $	7.22	7.22	7.22			
44	Q1 (1985) 000 bu	154280.00	154280.00	154280.00			
45	P2 $	7.14	7.08	7.02			
46	Q2 000 bu	157554.97	160011.20	162467.42			
47	Y 000$	41255.61	72197.33	103139.04			
48	X 000$	437.88	1340.99	2736.72	**SUM (000 $)**		
49	**Total Surplus 000$**	41693.49	73538.32	105875.76	221107.57		
50	**Consumer Surplus 000$**	12191.96	21503.99	30960.06	64656.00		
51	**Producer Surplus 000$**	29501.53	52034.33	74915.70	156451.56		
52	%CS	29.24%	29.24%	29.24%			
53	% PS	70.76%	70.76%	70.76%			
54							
55	**Gross Returns (thousands nominal $)**						
56	Change in Quantity (000 bu)	3274.97	5731.20	8187.42	17193.59		
57	Price (1985) $	7.22	7.22	7.22			
58	Gross Value	23645.28	41379.23	59113.19	124137.70		
59							
60	**Discounted Surplus at 15% (to 1985) (thousands $)**						
61	Total Surplus	15674.13	24039.81	30096.50	69810.43		
62	Consumer Surplus	4583.41	7029.69	8800.78	20413.88		
63	Producer Surplus	11090.72	17010.12	21295.72	49396.55		

the WGRF, $61.47 in benefits can be expected with high prices (P1 = $8.65) and low risk. Similarly, with a 20 percent yield advantage over Westar, instead of 15, $68.86 in benefits results.

The effect of input costs on results could not be determined from a producer surplus analysis. In a financial analysis of the Canola Council of Canada 1987 database of canola producers, it was found that many low-cost western canola producers participating in the Canola Council's Attentive Crop Management Program grew Westar, a high-yielding brassica napus variety. (See Table 4.7.) The new variety developed at the University of Manitoba is intended to replace Westar and likely assist these low-cost producers. Further, it was found that many high-cost producers were growing Tobin, a lower-yielding Brassica campestris variety grown where the growing season is not long enough for Westar. It is not likely the new variety will affect these high-cost producers as long as its growing period is similar to Westar's.

The canola acreage reported in the database represents 2.8 percent of the total Canadian canola acreage for 1987. Continued study and statistical analysis of the Canola Council database for subsequent years would provide further information on the above observations.

Chapter V

FRAMEWORK FOR ASSESSING WGRF EXPENDITURES

The WGRF fund has been made available to support research for the explicit benefit of prairie producers. Accordingly, consumer benefits and other indirect benefits which are often considered as benefits to agricultural research are a secondary consideration in research project selection.

With the use of the model developed in chapter three, annual WGRF research funds can be allocated to selected projects with the highest benefit/cost ratio resulting from a likely set of assumptions. The assumptions would be based on the following technical and economic factors:

1. yield increase per acre;
2. commodity price;
3. acreage benefiting from the increased yield;
4. factors affecting demand such as demand elasticity estimates;
5. factors affecting supply such as supply elasticity estimates;
6. other factors including the probability of research success and rate of adoption and
7. project cost.

The sum of individual project benefits and costs can be discounted to the date of project application. Projects can be ranked according to their benefit/cost ratio and high-ranking projects can be selected until annual funds are exhausted. In a funds constrained situation where annual disbursements are equal to the budget available, this is a rational economic decision rule. A similar approach is commonly used to allocate a fixed corporate capital budget to individual projects (Lusztig and Schwab, 1983). The ranking of project net present values and selecting high-ranking projects until annual funds are exhausted provides the same allocation of funds and maximizes the net present value for the annual WGRF budget. Further, it would be rational to fund projects with benefit/cost ratios greater than one and with positive net present values. The residual budget could be invested at the market interest rate.

Risk can be incorporated into the decision-making process in a number of ways. Anderson, Dillon and Hardaker (1977), in their book on agricultural decision analysis, present a comprehensive review of investment under conditions of certainty and uncertainty. A discussion of the literature in this area as it applies to the WGRF investment is given in a paper by Kolody (1988).

Applying a sensitivity analysis to relevant factors provides a range of results for decision-makers' consideration and is considered to be one method of dealing with risk (Gittinger, 1982). Sensitivity analysis is useful in deciding the favorability of one project. When one or more projects must be selected from a group of projects, a simple application of decision analysis described by Anderson et al. (1977) may be used. Assigning a probability to the net present value from the best, worst and most likely scenarios of each project, multiplying the probability by the net present value and adding the products for each project, provides an alternative measure by which projects may be ranked and selected. Projects with the highest adjusted net present value would be selected until the annual WGRF funds are exhausted. To illustrate the application of probabilities, the net present values of the hybrid canola research project are used. From chapter four:

$$NPV_{\text{Worst Case}} = -\$240{,}700$$

$$NPV_{\text{Optimistic Case}} = \$35{,}156{,}538$$[20]

$$NPV_{\text{Base Case}} = \$12{,}108{,}455$$[21].

Assuming each case has equal probability of occurring, each net present value is multiplied by .33 and added together to give an adjusted net present value of $15,518,016. The assignment of probabilities is arbitrary and can be adjusted to incorporate the intuition and experience of decision-makers.

Information obtained from examination of the database of canola producers may also be used in assessing WGRF expenditures. By analysing the production practices of the canola producers, it was found that the new variety developed at the University of Manitoba will likely benefit low cost producers growing the high yielding, long growing period, Brassica napus variety, Westar. Higher cost producers growing the lower yielding, shorter growing period, Brassica campestris variety, Tobin, will likely not be affected if the new variety possesses the same growing season attributes as Westar. Such information may be used by decision-makers based on their objectives and mandate in providing funds for research.

20. Obtained by multiplying cell F14 (benefits) from Table 4.4 by .30 for market share and subtracting cell E14 (costs).

21. Obtained by multiplying cell F14 (benefits) from Table 4.3 by .25 for market share and subtracting cell E14 (costs).

Chapter VI

LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

This study is limited in that it specifically addresses the type of research project that has an established market on the prairies for the crop being researched. The model developed to determine research benefits is based on the assumption that supply and demand for the crop exist. Research resulting in the introduction of a crop unfamiliar to the prairies would require a different model. However, the framework used in evaluating the benefits and costs of hybrid canola research can be applied to other varietal development research proposals.

As emphasized by Rose (1980) the results of an economic surplus model are crude but useful information. The information is crude because the supply curve shift is assumed to be parallel since the best information available is a single point estimate on the supply curve. In reality, the supply curve shift could be divergent or convergent but evidence of the nature of the shift is not available. The information is useful because more accurate information is not yet possible.

The uncertainty of future benefits is a major limiting factor in this study. As given in equation (3.13), the factors affecting producer benefits include: productivity improvement, supply and demand factors, the rate of interest and inflation, product and input prices, marketing and other factors. While some factors are associated with some degree of certainty, others must be treated arbitrarily such as interest and inflation rates. The estimate of productivity improvement is based on the varietal breeding work of Dr. McVetty and therefore is associated with a significant degree of certainty. Acceptance of the new hybrid variety by producers is less certain as is the degree of market penetration. From the perspective of the producer, the advantages of hybrid seed include: higher yields, predictable growth patterns and the availability of seed from a vendor. This will be considered by producers in addition to hybrid seed disadvantages: annual seed purchases, higher seed costs and the vulnerability of the crop to specific diseases and pests (Holman, 1988). Whether advantages outweigh disadvantages is left to the discretion of producers. Further, the release of new canola varieties by private firms such as Allelix and Conti-Seeds will serve as competition for market share against the hybrid canola seed developed with WGRF funds.

With respect to supply and demand factors, regression analysis was used in this study to obtain recent estimates of supply and demand price elasticity. Simple double log functions were estimated individually for demand and supply. According to Varian (1984), the double log or Cobb-Douglas form imposes serious restrictions on the estimation. In order to improve the sophistication of the price elasticities, alternate forms could be evaluated. Alternatives presented by Varian (1984) include the constant elasticity of substitution (CES), generalized Leontief and translog functional forms for estimating production. On the demand side, a recent model for demand developed by Deaton and Muellbauer (1980), called the Almost Ideal Demand System (AIDS) could be attempted. With respect to the supply equation, alternate substitutes of the crop may be attempted. Flax price was not a significant variable; however, attempts with other oilseeds may be productive. According to theory, another possibility for improving elasticity estimates is to model canola demand and supply as a system of equations rather than as independent equations. In reality, buyers and sellers do not act in isolation and the observed price of a commodity depends on both supply and demand. Successful application of two or three stage least squares regression to a system of equations will result in more sophisticated elasticity estimates than those obtained using ordinary least squares. In this study, sensitivity analysis of supply and demand elasticities presented a possible range of results which could be considered rather than relying on one estimate.

Examination of the production practices of a number of canola producers located high and low cost producers and determined the likely location that the impact of the new variety could be expected. Producers were classified as high or low cost on the basis of their gross margin. The gross margin is defined as revenue less variable costs or the income remaining to cover fixed costs. As fixed costs likely differ from producer to producer and from region to region a more accurate classification of producers would be on the basis of net returns. This means the fixed costs of each producer would have to be determined and subtracted from the gross margin. This would give an accurate account of producers who are or who are not realizing a profit from their production of canola. This information would indicate which varieties need to be developed to assist the producers requiring additional productivity to be profitable. Continued study of the Canola Council's Attentive Crop Management database of canola producers would provide further insight into the accuracy of observations made in this study as well as insight into the effect of low prices and unfavorable weather conditions.

The sensitivity of results to market margins for commercial seed, chemicals and other factors were considered to be beyond the scope of this study. Further research is necessary to determine the impact of such factors on producer benefits.

Lastly, market development and extension costs which can be considered as investments complementary to the WGRF investment require analysis. As canola research was initiated to develop an oilseed which could compete for the Japanese market, a more complete analysis of returns to producer research investments would include complementary extension and market development benefits and costs.

Chapter VII

SUMMARY AND CONCLUSIONS

Accomodating the needs of decision-makers representing the interests of producers requires significant modification to conventional evaluation procedures applied to investments in agricultural research. From the social benefit/cost framework used in the evaluation of WGRF-funded hybrid canola research, a social rate of return was obtained from a producer perspective. A benefit/cost ratio of 51.31:1 suggests the project is a favorable investment.

6.1 PROBLEM DISCUSSION AND ANALYTICAL FRAMEWORK

The WGRF is a private organization with a mandate to serve the agricultural producers of Western Canada. The purpose of the WGRF is to provide funds to research and extension projects that will improve the productivity and profitability of grain and oilseed production. In 1988, this study was funded to provide an estimate of benefits and costs to producers associated with the hybrid canola research conducted by Dr. P.B.E. McVetty at the University of Manitoba and to recommend a framework for assessing benefits and costs associated with subsequent project proposals.

The factors affecting producer benefits from varietal improvement research include: productivity improvement, supply and demand factors, the rate of interest and inflation, product and input prices, marketing and other factors. The model developed to estimate benefits of research was an economic surplus model adapted from Ulrich et al. (1984). In this model, the supply curve for canola was shifted forward to represent the acceptance of a new higher-yielding brassica napus spring canola variety. Ex ante benefits were calculated from the area between the post- and pre-innovation supply curves under the demand curve.

The supply curve was shifted forward annually from 1992 to 1994 using an index number. With the assumption that the new variety would replace Westar, the current high-yielding Brassica napus variety, the index number accounted for the yield difference between Westar and the new variety and the acreage seeded to both varieties. The equations of Rose (1980) for a parallel supply curve shift were then used to estimate annual benefits accruing to producers.

Annual benefits and costs of the hybrid canola project were discounted to 1985, the year the decision to fund the project was considered.

6.2 RESULTS AND CONCLUSIONS

In order to use the equations of Rose, a number of assumptions were made and classified as the likely set of assumptions:

1. The new variety's yield increase over Westar was 15 per cent.
2. The acreage of the new variety was 20, 35 and 50 percent of total acreage replacing the acreage seeded to Westar.

Further assumptions necessary in obtaining a benefit/cost ratio were:

3. Producers would capture 25 percent of the potential producer benefits due to the possibility of the new variety capturing less than 100 percent the market and marketing agents receiving a share of benefits.
4. Costs of research were limited to the funds provided by the WGRF.

5. A 15 percent discount rate (6 percent inflation, 9 percent real interest) was used.

In the base case, the sum of annual discounted benefits over the sum of annual discounted costs resulted in a benefit/cost ratio of 51.31:1. In order to determine the sensitivity of this result to the factors affecting producer benefits, an optimistic or best case was also evaluated. Increasing canola prices, acreage planted to the new variety, yield and market penetration by 20 percent resulted in a benefit/cost ratio of 134.37:1 with a 10 percent discount rate. The worst case scenario or research failure resulted in a benefit/cost ratio of zero and negative net present value of $240.7 thousand.

Sensitivity analysis produced a range of benefit/cost ratios by varying economic and technical factors. The analysis illustrated the increase in producer benefits as values for demand elasticity increased and values for supply elasticity decreased. That is, the more elastic the demand for canola, the more producer benefits. Conversely, the more inelastic the supply of canola, the more producer benefits. Low prices, low yields, high discount rates, set-backs in introducting research results to the market, loss of market share to varieties developed by other researchers, marketing agents and accomodating risk and uncertainty each had a negative impact on producer benefits.

Examination of the Canola Council of Canada database of canola producers participating in the Attentive Crop Management program revealed that low-cost producers, growing the high-yielding, <u>Brassica napus</u> variety, Westar, will likely benefit from the development of a higher-yielding <u>Brassica napus</u> variety. High-cost producers, growing the lower-yielding Brassica compestris variety, Tobin, will likely not be affected.

Based on the results indicating benefit/cost ratios greater than one and as high as 93.83 for the WGRF-funded hybrid canola research project, it is concluded that, in this case, research funded by producers is beneficial to producers. This conclusion is reinforced considering that the benefit/cost estimates are understated because no monetary value was assigned to benefits such as graduate student training and genetic material and information availability. Even with the inclusion of all canola breeding costs at the University of Manitoba, a positive benefit/cost ratio of 17.17 was obtained. The framework for assessing benefits and costs of subsequent research proposals, in chapter five, will provide a means of determining how other research projects compare to hybrid canola research from an producer investment perspective. Additional research is required to obtain more sophisticated elasticity estimates used in the equations for estimating producer benefits. Further, insight on the impact of new canola varieties, low prices and unfavorable weather would be obtained by continued study of the Canola Council of Canada database of producers participating in the Attentive Crop Management program. A thorough evaluation of WGRF research investment would include an analysis of market development and extension costs.

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Appendix I

PARALLEL SUPPLY CURVE SHIFT MODEL

From a parallel supply curve shift model, Pinstrup-Andersen and Tweeten (1971) derived the equation for P2, post-innovation price. Using the model of Pinstrup-Andersen and Tweeten, Rose derived the following equations for post-innovation price and quantity:

$$P2 = P1 * [1 - (k * e) / (e + n)]$$

$$Q2 = Q1 * [1 + (k * e * n) / (e + n)]$$

where

P1 = pre-innovation price

Q1 = pre-innovation quantity

k = cost decrease as a proportion of P1

e = elasticity of supply

n = elasticity of demand.

Rose's general formula for total surplus is composed of X and Y:

$$Y = .5 * Q1 * (k * P1 + A1 - A2)$$

where A1 and A2 are intercept terms which simplifies to

$Y = k * P1 * Q1$ for a parallel supply curve shift and

$X = .5 * k * P1 * (Q2 - Q1)$.

Rose notes that the formula for total surplus is strictly correct for a parallel shift because Q2 in the equation for X is derived from Pinstrup-Andersen and Tweeten's parallel supply curve shift model.

APPENDIX II

Table A2.1
Data for Estimating Canola Supply Equation

	A	B	C	D	E	F
1	Year	Production	Price	Flax Price	Wheat Stocks	Research
2		000 bu	$/bu	$/bu	000 bu	Contributions $000
3						
4	1950-51					4.00
5	51-52					4.30
6	52-53					4.50
7	53-54					4.50
8	54-55					13.70
9	55-56					14.40
10	56-57					15.10
11	57-58					16.80
12	58-59					21.60
13	59-60					34.40
14	60-61	11120	1.63	2.75	599589.180	35.40
15	61-62	11220	1.80	3.32	608042.464	36.80
16	62-63	5860	2.04	3.06	391210.086	41.10
17	63-64	8360	2.52	2.91	487247.241	48.80
18	64-65	13230	2.74	2.94	459440.128	96.60
19	65-66	22600	2.41	2.71	513024.073	158.40
20	66-67	25800	2.47	2.72	420119.462	201.90
21	67-68	24700	1.92	3.08	576754.871	227.40
22	68-69	19400	1.83	2.88	665489.216	253.80
23	69-70	33400	2.29	2.57	851812.969	403.80
24	70-71	72200	2.33	2.21	1008668.840	430.10
25	71-72	95000	2.16	2.20	734198.626	485.40
26	72-73	57300	3.16	4.02	583772.784	521.10
27	73-74	53200	5.72	9.31	365409.135	558.50
28	74-75	51300	7.06	4.77	370663.384	699.20
29	75-76	77100	5.08	2.32	295340.234	
30	76-77	36900	6.08	7.01	257.606	
31	77-78	87000	6.38	5.74	210.903	
32	78-79	154200	6.36	7.71	283.468	
33	79-80	150400	6.15	8.36	307.016	
34	80-81	109500	6.38	9.60	352.562	
35	81-82	81000	6.35	8.94	328.641	
36	82-83	99100	6.18	7.47	274.378	
37	83-84	114320	8.65	9.25	339.850	
38	84-85	150420	8.38	8.93	327.988	
39	85-86	154280	7.22	7.41	272.334	
40	86-87	166940	5.04	5.33	195.839	
41						
42						
43	Sources:	Statistics Canada, Ulrich et al. (1984)				
44						
45	Columns B-E:	Cereals and Oilseeds Review (22-007)				
46		Field Crop Reporting Series (22-002)				
47		Grain Trade of Canada (22-201)				
48		Handbook of Agricultural Statistics (21-516)				
49						
50	Column F:	Ulrich et al. (1984), p. 34.				

Table A2.2
Data for Estimating Canola Demand Equation

	A	B	C	D	E	F	G	H	I
1	Year	Price	Canola	Canola	Total Demand	Soybean Oil	Soybean Meal	Can $/Yen	Japan GDP/capita
2		$/bu	Dom.Dem. bu	Exports bu	bu	US $/mt	US $/mt		Can $
3									
4	1961-62	1.80	2600000		2600000	287	97	0.002971	492.75
5	62-63	2.04	3000000		3000000	228	89	0.002996	766.34
6	63-64	2.52	3000000		3000000	224	91	0.002996	894.56
7	64-65	2.74	4000000		4000000	205	89	0.002995	974.97
8	65-66	2.41	7137076	13632267	20769343	270	97	0.002975	1102.84
9	66-67	2.47	9308000	13817739	23125739	262	107	0.002979	1302.09
10	67-68	1.92	8660000	12308677	20968677	217	99	0.002989	1534.72
11	68-69	1.83	9509000	14311194	23820194	178	98	0.003005	1776.27
12	69-70	2.29	12773000	22212620	34985620	228	95	0.002916	2006.54
13	70-71	2.33	18043000	46811000	64854000	307	104	0.002912	2208.32
14	71-72	2.16	20287000	42603000	62890000	323	105	0.003270	2760.76
15	72-73	3.16	25702000	54059000	79761000	270	129	0.003696	3445.38
16	73-74	5.72	22308000	39183000	61491000	465	302	0.003354	4084.99
17	74-75	7.06	19907000	26145000	46052000	795	184	0.003430	4550.92
18	75-76	5.08	22279000	30116	22309116	619	155	0.003327	4893.05
19	76-77	6.08			50794854	438	198	0.003980	6447.84
20	77-78	6.38	36753424	44707260	81460684	576	230	0.005480	9664.55
21	78-79	6.36	45544970	75848027	121392997	607	213	0.005375	10141.20
22	79-80	6.15	55531355	76831234	132362589	662	243	0.005183	10427.69
23	80-81	6.38	55562218	60495889	116058107	598	262	0.005450	11922.04
24	81-82	6.35	49596841	59931537	109528378	507	253	0.004966	11304.16
25	82-83	6.18	51236989	56051617	107288606	447	219	0.005190	12196.33
26	83-84	8.65	65442787	66029184	131471971	527	238	0.005457	13546.93
27	84-85	8.38	71774111	64195040	135969151	736	203	0.005767	15097.60
28	85-86	7.22	70006102	64195040	134201142	710	220	0.008296	22542.05
29									
30									
31									
32	Columns B-I:	Cereals and Oilseeds Review (22-007)							
33		Grain Trade of Canada (22-201)							
34		World Bank, *Commodity Trade and Price Trends,*							
35		Journal of International Financial Statistics							
36		Bank of Canada Review			1985				

APPENDIX III

Table A3.1

	A	B	C	D	E	F	G
1	CANOLA COUNCIL DATABASE SUMMARY OF VARIETIES GROWN AND YIELD						
2							
3				*Provinces*			
4		ALL	BC	AB	SK	MB	ON
5	Number of Records	836	5	199	368	238	26
6							
7	Variety						
8							
9	Tobin	33.01%	100.00%	71.86%	30.71%	6.30%	0.00%
10	Torch	0.12%	0.00%	0.50%	0.00%	0.00%	0.00%
11	Westar	56.10%	0.00%	22.11%	64.67%	78.99%	0.00%
12	Tower	0.24%	0.00%	1.01%	0.00%	0.00%	0.00%
13	Tribute	1.56%	0.00%	0.00%	1.36%	3.36%	0.00%
14	Triton	3.59%	0.00%	0.00%	1.63%	8.40%	15.38%
15	Regent	0.12%	0.00%	0.00%	0.27%	0.00%	0.00%
16	Pivot	0.72%	0.00%	3.02%	0.00%	0.00%	0.00%
17	Stellar	0.12%	0.00%	0.00%	0.00%	0.42%	0.00%
18	Global	2.15%	0.00%	1.01%	0.00%	1.26%	50.00%
19	Hanna	0.12%	0.00%	0.00%	0.00%	0.00%	3.85%
20	Crystal	0.12%	0.00%	0.00%	0.00%	0.00%	3.85%
21	Tandem	0.48%	0.00%	0.00%	0.00%	0.00%	15.38%
22	Other	1.08%	0.00%	0.50%	1.36%	0.84%	3.85%
23	No Response	0.36%	0.00%	0.00%	0.00%	0.42%	7.69%
24	Total %	99.88%	100.00%	100.00%	100.00%	100.00%	100.00%
25							
26	Yield						
27							
28	0 - 10 bu	10.29%	20.00%	12.06%	12.23%	4.62%	19.23%
29	11 - 15 bu	2.99%	20.00%	5.03%	2.45%	1.26%	7.69%
30	16 - 20 bu	8.61%	0.00%	8.04%	10.05%	7.56%	3.85%
31	21 - 30 bu	41.51%	40.00%	34.67%	42.66%	48.32%	15.38%
32	31 - 40 bu	29.55%	20.00%	27.64%	27.99%	34.87%	19.23%
33	41+ bu	7.06%	0.00%	12.56%	4.62%	3.36%	34.62%
34	Total %	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table A3.1

	H	I	J	K	L	M	N	O
1								
2								
3					*Crop Districts*			
4	M1	M2	M3	M4	M5	M6	M7	M8
5	39	24	30	12	15	18	33	50
6								
7								
8								
9	2.56%	0.00%	23.33%	16.67%	26.67%	0.00%	0.00%	0.00%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11	84.62%	87.50%	66.67%	75.00%	53.33%	88.89%	84.85%	76.00%
12	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
13	2.56%	8.33%	3.33%	0.00%	13.33%	0.00%	3.03%	2.00%
14	7.69%	4.17%	3.33%	0.00%	6.67%	11.11%	12.12%	14.00%
15	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
16	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
17	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.00%
18	0.00%	0.00%	3.33%	0.00%	0.00%	0.00%	0.00%	4.00%
19	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
21	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
22	2.56%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.00%
23	0.00%	0.00%	0.00%	8.33%	0.00%	0.00%	0.00%	0.00%
24	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
25								
26								
27								
28	2.56%	0.00%	6.67%	0.00%	6.67%	0.00%	9.09%	8.00%
29	2.56%	0.00%	0.00%	0.00%	0.00%	0.00%	3.03%	2.00%
30	0.00%	16.67%	6.67%	0.00%	6.67%	5.56%	12.12%	4.00%
31	53.85%	54.17%	50.00%	58.33%	66.67%	50.00%	48.48%	38.00%
32	41.03%	29.17%	36.67%	33.33%	20.00%	38.89%	21.21%	40.00%
33	0.00%	0.00%	0.00%	8.33%	0.00%	5.56%	6.06%	8.00%
34	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table A3.1

	P	Q	R	S	T	U	V	W
1								
2								
3					*Crop Districts*			
4	M121	O1	O8	S1A	S1B	S5A	S5B	S6A
5	16	13	13	16	15	49	65	24
6								
7								
8								
9	6.25%	0.00%	0.00%	6.25%	13.33%	16.33%	26.15%	8.33%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11	87.50%	0.00%	0.00%	93.75%	73.33%	81.63%	67.69%	91.67%
12	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
13	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.62%	0.00%
14	6.25%	0.00%	30.77%	0.00%	0.00%	0.00%	1.54%	0.00%
15	0.00%	0.00%	0.00%	0.00%	0.00%	2.04%	0.00%	0.00%
16	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
17	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
18	0.00%	61.54%	38.46%	0.00%	0.00%	0.00%	0.00%	0.00%
19	0.00%	0.00%	7.69%	0.00%	0.00%	0.00%	0.00%	0.00%
20	0.00%	0.00%	7.69%	0.00%	0.00%	0.00%	0.00%	0.00%
21	0.00%	30.77%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
22	0.00%	0.00%	7.69%	0.00%	13.33%	0.00%	0.00%	0.00%
23	0.00%	7.69%	7.69%	0.00%	0.00%	0.00%	0.00%	0.00%
24	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
25								
26								
27								
28	0.00%	7.69%	30.77%	0.00%	0.00%	8.16%	18.46%	20.83%
29	0.00%	0.00%	15.38%	0.00%	0.00%	2.04%	3.08%	0.00%
30	25.00%	0.00%	7.69%	12.50%	0.00%	8.16%	12.31%	4.17%
31	31.25%	23.08%	7.69%	37.50%	60.00%	44.90%	43.08%	41.67%
32	43.75%	7.69%	30.77%	37.50%	40.00%	36.73%	21.54%	33.33%
33	0.00%	61.54%	7.69%	12.50%	0.00%	0.00%	1.54%	0.00%
34	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table A3.1

	X	Y	Z	AA	AB	AC	AD	AE
1								
2								
3					*Crop Districts*			
4	S6B	S7	S8A	S8B	S9A	S9B	A4a	A4b
5	14	12	52	44	46	33	22	42
6								
7								
8								
9	21.43%	33.33%	28.85%	40.91%	60.87%	48.48%	63.64%	80.95%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11	78.57%	66.67%	61.54%	50.00%	39.13%	48.48%	36.36%	19.05%
12	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
13	0.00%	0.00%	0.00%	2.27%	0.00%	3.03%	0.00%	0.00%
14	0.00%	0.00%	5.77%	4.55%	0.00%	0.00%	0.00%	0.00%
15	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
16	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
17	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
18	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
19	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
21	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
22	0.00%	0.00%	3.85%	2.27%	0.00%	0.00%	0.00%	0.00%
23	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
24	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
25								
26								
27								
28	7.14%	16.67%	11.54%	20.45%	6.52%	9.09%	18.18%	4.76%
29	7.14%	0.00%	3.85%	6.82%	0.00%	0.00%	9.09%	4.76%
30	0.00%	8.33%	15.38%	11.36%	13.04%	6.06%	9.09%	2.38%
31	14.29%	25.00%	50.00%	45.45%	45.65%	33.33%	40.91%	42.86%
32	42.86%	41.67%	17.31%	13.64%	32.61%	33.33%	4.55%	38.10%
33	28.57%	8.33%	1.92%	2.27%	2.17%	18.18%	18.18%	7.14%
34	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table A3.1

	AF	AG	AH	AI	AJ
1					
2					
3			*Crop Districts*		
4	A5	A6	A7a	A7b	A123
5	47	22	12	21	37
6					
7					
8					
9	80.85%	90.91%	33.33%	95.24%	45.95%
10	0.00%	0.00%	0.00%	4.76%	0.00%
11	17.02%	4.55%	66.67%	0.00%	29.73%
12	0.00%	4.55%	0.00%	0.00%	2.70%
13	0.00%	0.00%	0.00%	0.00%	0.00%
14	0.00%	0.00%	0.00%	0.00%	0.00%
15	0.00%	0.00%	0.00%	0.00%	0.00%
16	0.00%	0.00%	0.00%	0.00%	16.22%
17	0.00%	0.00%	0.00%	0.00%	0.00%
18	0.00%	0.00%	0.00%	0.00%	5.41%
19	0.00%	0.00%	0.00%	0.00%	0.00%
20	0.00%	0.00%	0.00%	0.00%	0.00%
21	0.00%	0.00%	0.00%	0.00%	0.00%
22	2.13%	0.00%	0.00%	0.00%	0.00%
23	0.00%	0.00%	0.00%	0.00%	0.00%
24	100.00%	100.00%	100.00%	100.00%	100.00%
25					
26					
27					
28	8.51%	9.09%	16.67%	9.52%	24.32%
29	4.26%	13.64%	0.00%	4.76%	2.70%
30	12.77%	4.55%	8.33%	19.05%	2.70%
31	29.79%	45.45%	33.33%	47.62%	13.51%
32	34.04%	22.73%	41.67%	14.29%	27.03%
33	10.64%	4.55%	0.00%	4.76%	29.73%
34	100.00%	100.00%	100.00%	100.00%	100.00%

Table A3.2

	A	B	C	D	E	F	G
1	CANOLA COUNCIL DATABASE SUMMARY OF COSTS						
2				*Provinces*			
3		ALL	BC	AB	SK	MB	ON
4	Number of Records	836	5	199	368	238	26
5							
6							
7	per acre						
8	Fertilizer Cost	9.94	8.26	9.57	7.6	12.26	25.15
9							
10	Herbicide Cost	7.3	2.96	10.35	7.01	5.89	1.98
11							
12	Seed & Treatment Cost	5.04	5.85	4.87	5.12	5.01	5.29
13							
14	Fieldwork Cost	42.36	42.12	44.35	41.01	43.17	38.96
15							
16	Variable Cost	64.64	59.2	69.13	60.73	66.33	71.38
17							
18	Revenue	135.62	107.86	136.28	129.04	143.75	154.69
19							
20	Gross Margin	70.98	48.66	67.15	68.31	77.42	83.31
21							
22							
23	COSTS BY DISTRICT ASSORTED IN ASCENDING AND DESCENDING ORDER						
24							
25							
26	Fertilizer Cost	5.27	5.83	5.95	5.97	7.31	7.47
27		S6B	A7a	S1B	S5A	S1A	S5B
28							
29	Herbicide Cost	0.88	2.15	3.08	3.82	4.22	4.27
30		O8	S1A	O1	M121	S8A	S9A
31							
32	Seed & Treatment Cost	3.95	4.06	4.15	4.42	4.54	4.64
33		M4	A5	S7	S9A	A4a	A4b
34							
35	Fieldwork Cost	37.04	37.46	38.09	38.12	38.63	38.65
36		S1B	O1	M4	A123	S7	S6A
37							
38	Variable Cost	54.97	56.4	57.95	59.53	59.73	59.88
39		M4	S1A	S1B	S6B	S9A	M3
40							
41	Revenue	198.5	169.56	166.95	158.34	152.42	152.21
42		O1	S6B	S1A	M4	S9B	S1B
43							
44	Gross Margin	122.86	110.55	110.03	103.37	94.26	90.55
45		O1	S1A	S6B	M4	S1B	S9B
46							
47							
48	COSTS BY PROVINCE ASSORTED IN ASCENDING AND DESCENDING ORDER						
49							
50							
51	Fertilizer Cost	7.6	8.26	9.57	12.26	25.15	
52		SK	BC	AB	MB	ON	
53							
54	Herbicide Cost	1.98	2.96	5.89	7.01	10.35	
55		ON	BC	MB	SK	AB	
56							
57	Seed & Treatment Cost	4.87	5.01	5.12	5.29	5.85	
58		AB	MB	SK	ON	BC	
59							
60	Fieldwork Cost	38.96	41.01	42.12	43.17	44.35	
61		ON	SK	BC	MB	AB	
62							
63	Variable Cost	59.2	60.73	66.33	69.13	71.38	
64		BC	SK	MB	AB	ON	
65							
66	Revenue	154.69	143.75	136.28	129.04	107.86	
67		ON	MB	AB	SK	BC	
68							
69	Gross Margin	83.31	77.42	68.31	67.15	48.66	
70		ON	MB	SK	AB	BC	

Table A3.2

	H	I	J	K	L	M	N	O
1								
2					*Crop Districts*			
3	M1	M2	M3	M4	M5	M6	M7	M8
4	39	24	30	12	15	18	33	50
5								
6								
7								
8	11.99	12.51	10.28	8.38	11.23	11.66	15.48	12.44
9								
10	6.62	6.58	4.62	4.56	5.79	6.96	6.63	6.15
11								
12	4.74	5.32	4.94	3.95	5.68	5.43	5.47	4.7
13								
14	45.48	45.06	40.05	38.09	44.75	40.12	42.36	43.76
15								
16	68.83	69.48	59.88	54.97	67.45	64.16	69.94	67.05
17								
18	149.13	144.27	140.45	158.34	126.34	151.76	131.19	146.56
19								
20	80.31	74.79	80.57	103.37	58.88	87.6	61.25	79.51
21								
22								
23								
24								
25								
26	7.47	7.62	7.69	7.87	8.33	8.38	8.51	8.57
27	S7	S8B	A4b	S9B	S6A	M4	A4a	A6
28								
29	4.56	4.62	4.93	5.23	5.5	5.55	5.79	6.15
30	M4	M3	A4a	A7b	S9B	A6	M5	M8
31								
32	4.7	4.72	4.72	4.72	4.74	4.83	4.94	4.97
33	M8	O1	S6B	A6	M1	S9B	M3	A123
34								
35	38.92	39.61	40.05	40.12	40.47	40.9	41.27	41.62
36	S5A	S6B	M3	M6	O8	S8B	S1A	S5B
37								
38	60.49	60.56	61.02	61.37	61.54	61.87	62.42	63.02
39	S5B	A4a	S5A	S8A	S8B	S9B	S6A	S7
40								
41	151.76	149.57	149.13	147.36	147.11	146.56	144.27	140.45
42	M6	A123	M1	A4b	M121	M8	M2	M3
43								
44	87.6	82.75	80.57	80.31	79.51	79.26	76.67	74.79
45	M6	A4b	M3	M1	M8	M121	S9A	M2
46								
47								
48								
49								
50								
51								
52								
53								
54								
55								
56								
57								
58								
59								
60								
61								
62								
63								
64								
65								
66								
67								
68								
69								
70								

Table A3.2

	P	Q	R	S	T	U	V	W
1								
2								
3	M121	O1	O8	S1A	S1B	S5A	S5B	S6A
4	16	13	13	16	15	49	65	24
5								
6								
7								
8	13.03	30.37	19.92	7.31	5.95	5.97	7.47	8.33
9								
10	3.82	3.08	0.88	2.15	8.77	10.78	6.3	9.75
11								
12	4.99	4.72	5.85	5.68	6.18	5.35	5.1	5.69
13								
14	46	37.46	40.47	41.27	37.04	38.92	41.62	38.65
15								
16	67.85	75.63	67.12	56.4	57.95	61.02	60.49	62.42
17								
18	147.11	198.5	110.88	166.95	152.21	133.2	112.35	119.49
19								
20	79.26	122.86	43.76	110.55	94.26	72.18	51.86	57.07
21								
22								
23								
24								
25								
26	8.72	9.22	10	10.16	10.28	11.23	11.66	11.99
27	S8A	S9A	A7b	A123	M3	M5	M6	M1
28								
29	6.3	6.58	6.62	6.63	6.96	7.06	7.47	7.84
30	S5B	M2	M1	M7	M6	A4b	A5	S8B
31								
32	4.99	5.1	5.18	5.25	5.32	5.35	5.43	5.47
33	M121	S5B	S8B	S8A	M2	S5A	M6	M7
34								
35	41.83	42.36	42.57	43.17	43.66	43.75	43.76	44.22
36	S9A	M7	A4a	S8A	S9B	A7b	M8	A7a
37								
38	64.16	64.4	64.61	65.56	67.05	67.12	67.45	67.76
39	M6	A6	A4b	A7b	M8	O8	M5	A7a
40								
41	137.58	136.41	135.66	133.2	131.19	126.34	126	123.48
42	A5	S9A	S7	S5A	M7	M5	A6	A7a
43								
44	72.64	72.18	70.51	64.84	61.6	61.25	58.88	58.63
45	S7	S5A	A123	A5	A6	M7	M5	S8A
46								
47								
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Table A3.2

	X	Y	Z	AA	AB	AC	AD	AE
1								
2		*Crop Districts*						
3	S6B	S7	S8A	S8B	S9A	S9B	A4a	A4b
4	14	12	52	44	46	33	22	42
5								
6								
7								
8	5.27	7.47	8.72	7.62	9.22	7.87	8.51	7.69
9								
10	9.92	12.77	4.22	7.84	4.27	5.5	4.93	7.06
11								
12	4.72	4.15	5.25	5.18	4.42	4.83	4.54	4.64
13								
14	39.61	38.63	43.17	40.9	41.83	43.66	42.57	45.22
15								
16	59.53	63.02	61.37	61.54	59.73	61.87	60.56	64.61
17								
18	169.56	135.66	119.99	105.04	136.41	152.42	116.15	147.36
19								
20	110.03	72.64	58.63	43.49	76.67	90.55	55.59	82.75
21								
22								
23								
24								
25								
26	12.44	12.46	12.51	13.03	15.48	19.92	30.37	
27	M8	A5	M2	M121	M7	O8	O1	
28								
29	8.77	9.75	9.92	10.78	10.99	12.77	25.81	
30	S1B	S6A	S6B	S5A	A7a	S7	A123	
31								
32	5.68	5.68	5.69	5.85	6.18	6.59	6.72	
33	M5	S1A	S6A	O8	S1B	A7b	A7a	
34								
35	44.75	45.06	45.22	45.48	45.56	46	48.74	
36	M5	M2	A4b	M1	A6	M121	A5	
37								
38	67.85	68.83	69.48	69.94	72.74	75.63	79.06	
39	M121	M1	M2	M7	A5	O1	A123	
40								
41	119.99	119.52	119.49	116.15	112.35	110.88	105.04	
42	S8A	A7b	S6A	A4a	S5B	O8	S8B	
43								
44	57.07	55.72	55.59	53.96	51.86	43.76	43.49	
45	S6A	A7a	A4a	A7b	S5B	O8	S8B	
46								
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Table A3.2

	AF	AG	AH	AI	AJ
1					
2	*Crop Districts*				
3	A5	A6	A7a	A7b	A123
4	47	22	12	21	37
5					
6					
7					
8	12.46	8.57	5.83	10	10.16
9					
10	7.47	5.55	10.99	5.23	25.81
11					
12	4.06	4.72	6.72	6.59	4.97
13					
14	48.74	45.56	44.22	43.75	38.12
15					
16	72.74	64.4	67.76	65.56	79.06
17					
18	137.58	126	123.48	119.52	149.57
19					
20	64.84	61.6	55.72	53.96	70.51
21					
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NOTES TO CANOLA COUNCIL DATABASE SUMMARY OF COSTS

The following lists the prices assumptions used in calculating variable costs for each record in the Canola Council database.

Fertilizer Cost

- lbs of nutrient applied X average 1987 cost per lb of nutrient (average of Pioneer, Paterson and Pool prices)
- S (0-0-0-90) ... $0.16/lb
- K (0-0-62) ... $0.06/lb
- P (11-52-0) ... $0.15/lb
- N (average price of 34-0-0, 46-0-0 and 82-0-0) ... $0.11/lb

Herbicide Cost

- level of herbicide applied X average 1987 cost per litre or kilogram (average of Pioneer, UGG, Pool, Paterson and Coop)
- Treflan at ≤ 5 was considered liquid ... $7.78/l
- Treflan at > 5 was considered granualar ... $1.14/kg
- Rival at ≤ 3 was considered liquid ... $9.30/l
- Rival at > 3 was considered granualar ... $2.25/kg
- Triflurex ... no price available (23 records used this product/not included)
- Fortress ... price of $57.90 found without units (3 records used this product/not included)
- Excel ... no price available (0 records used this product)

- Poast ... \$18.78/l
- Longtrel ... \$57.00/l
- Hoegrass ... \$10.25/l
- Fusilade ... \$39.30/l
- Avadex at ≤ 6 was considered liquid ... \$7.88/l
- Avadex at > 6 was considered granualar ... \$2.30/l

Seed and Treatment Cost

- evaluated by variety and presence of seed treated
- seeding rate X average 1987 cost of seed per pound (average of Pioneer, Pool and UGG)
- *Type of Seed* — *Price if Untreated* — *Price if Treated*

Type of Seed	Price if Untreated	Price if Treated
Tobin	\$0.36/lb	\$0.86/lb
Westar	\$0.36/lb	\$0.87/lb
Triton	\$0.38/lb	\$0.91/lb
Tribute	\$0.43/lb	\$0.95/lb
Global	\$0.85/lb	\$1.23/lb
Other (averaged from above varieties)	\$0.48/lb	\$0.96/lb

Fieldwork Cost

- # of times over a field X average 1987 cost of implement use (Source: Farm Machinery Costs, Alberta Agriculture, AGDEX No. 825-4)

- *Fall Tillage:*

Harrow ... $2.75/acre

Vibrashank ... $4.92/acre (no cost available/used average cost of fall machinery use)

Deep Tillage ... $4.50/acre

Double Disc ... $7.50/acre

Other ... $4.92/acre (used average cost of fall machinery use)

- *Spring Tillage:*

Harrow ... $2.75/acre

Vibrashank ... $3.84/acre (no cost available/used average cost of spring machinery use)

Deep Tillage ... $4.50/acre

Double Disc ... $7.50/acre

Packers ... $2.75/acre

Harrow/Packers ... $3.00/acre

Rodweeder ... $2.55/acre

Other ... $3.84/acre (used average cost of spring machinery use)

- in addition, $23.50/acre was added to fieldwork costs for seeding, swathing and combining (i.e. seeding-$6.00/acre, swathing-$4.50/acre, combining-$13.00/acre)

Variable Cost

- equals Fertilizer Cost + Herbicide Cost + Seed and Treatment Cost + Fieldwork Cost

Revenue

- bushels per acre X 1987 price of canola per bushel, $5.04

Gross Margin

- equals Revenue - Variable Cost