AN ECONOMETRIC MODEL OF MANITOBA CROP SUPPLY RESPONSE UNDER RISK AVERSION AND PRICE UNCERTAINTY

64

BY

PAUL O. GAMBA

A Thesis Submitted To The Faculty of Graduate Studies in

Partial Fulfillment of The Requirements For the Degree of

MASTER OF SCIENCE

Department of Agricultural Economics And Farm Management

The University of Manitoba

Winnipeg, Manitoba

ISBN 0-612-13140-8

AN ECONOMETRIC MODEL OF MANITOBA CROP SUPPLY RESPONSE UNDER RISK AVERSION AND PRICE UNCERTAINTY

BY

PAUL O. GAMBA

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Restricted and unrestricted distributed lag models are used to investigate and establish probable lag structures in specific crop supply response to market and Canadian wheat board prices. The identified lag structures are in some respects consistent with other studies showing different lag structures for crop yield and acreage response and also give an indication of model sensitivity to numeraire choice in normalized quadratic functional forms.

Lag structures form the basis of expectation and variance proxies employed in risk neutral, linear mean-variance and non-linear mean-variance econometric model specification and estimation using duality. Linear SUR was used to estimate duality models in the cases of risk neutrality and linear mean-variance. Both a linear reduced form and a non-linear duality model were estimated in the case of non-linear mean-variance.

Price variances and expected prices are more significant in the risk aversion models which imply gains in model specification. Symmetry and CRTS are rejected in all models. Homogeneity conditions corresponding to risk neutrality is rejected in all models.

Constant absolute risk aversion and Constant relative risk aversion are also rejected.

DEDICATION

To Jenniffre, Victoria and Allan.

The debt I owe you can never be fully repaid.

AKNOWLEDGEMENTS

I would like to register my gratitude to IDRC for granting the Fellowship which made my studies possible.

Further gratitude is also due to Egerton University for providing the study leave which enabled me to take up the Fellowship.

Special thanks are in order for my major Advisor, Dr. Barry Coyle for guiding me through the rigours of econometric research and to members of my committee, Dr. Milton Boyd and Dr. Wayne Simpson for their valuable input.

Members of the Department of Agricultural Economics and Farm Management deserve particular mention for their support throughout the course of my studies.

I also wish to thank past and present residents of the Anexxe who provided challenging Academic and some not so Academic discussions.

All errors of omission or commission remain my sole responsibility.

CHAPTER I

INTRODUCTION

Background

Agricultural products are generally characterized by relatively long gestation periods and perishability. These attributes together with the competitive nature of the agricultural industry implies that agricultural producers have to contend with risk in their resource allocation decisions. The effects of risk and uncertainty on efficient resource use and the decision-making process by agricultural producers therefore cannot be minimized.

Consequently an illuminating resource allocation analysis should identify and include sources of risk and uncertainty in it's formulation. The major sources of risk and uncertainty in agricultural production can be categorized into production and market uncertainty respectively. Production uncertainty involves all those risks associated with variations in yield such as weather, pests and diseases. Market uncertainty may arise out of risks mainly associated with the price variability of outputs and inputs.

Manitoba agricultural producers face both production and market uncertainty and it is critical that their resource allocation behaviour be analyzed in the context of the risks they encounter. This study attempts to provide an indication of Manitoba grain producers resource allocation behaviour in the presence of market uncertainty.

Problem Statement

Previous studies on the response efficiency of Manitoba crop output supply have often assumed that risk is unimportant or that producers are risk neutral. These analyses have proceeded to elicit resource allocation behaviour under conditions of certainty contrary to the true circumstances of Manitoba producers which is inherently uncertain. In cases where risk has been incorporated, it has either been done in an ad hoc manner that is not amenable to testing on the basis of economic theory or it has employed highly aggregated measures that obscure the effects of risk on individual crop enterprises. The formulation of analytical methods that incorporate risk and uncertainty and application to Manitoba grain producers is expected to provide an improved indication of individual crop output supply response.

There are other serious problems with earlier studies of supply response in Manitoba crops that are perhaps even more basic than risk and uncertainty. Other studies have generally analyzed wheat supply response as independent of prices of other crops, and possible lags in the production decision making process have not been considered systematically. Any reasonable model of crop supply response must consider these issues in addition to and perhaps prior to, risk and uncertainty.

Objectives of the Study

The general objective of the thesis is to develop an econometric model of crop supply response in Manitoba that attempts to address the above problems in a tractable manner. This will be the first econometric study to attempt to measure the impacts of risk aversion and price uncertainty on supply of specific crops within the framework of duality theory. Given the exploratory nature of this research, it will be necessary to pay relatively little attention to dynamics, specifics of government support programs, and yield uncertainty.

A system of crop output supply equations will be estimated as conditional on (expected) prices and input prices. The model will then be extended to incorporate risk aversion and price uncertainty. It is difficult to incorporate yield uncertainty into the analysis due to the absence of farm level data on yields. Variation in yields at the provincial level greatly underestimates variation in yields at the farm level, since weather conditions are not perfectly correlated across farms.

CHAPTER II

LITERATURE ON RISK IN PRODUCTION

Mathematical Programming and Risk

Initial studies of risk in agricultural production utilized mathematical programming based methodologies. The problem was perceived from a portfolio selection perspective in a quadratic programming framework using the mean-variance (EV) approach which minimizes portfolio variance for alternative levels of expected returns. This methodology was first applied by Freund (1956) who found that the introduction of risk into the programming model reduced both the level and standard deviation of net revenue.The Freund study inspired other investigators to use the quadratic programming methodology in risk analysis.The studies that followed included Markowitz (1959), Scott and Baker(1972), Lin et al(1974),Barry and Willman(1976), Wiens(1976), Johnson(1979), Adams et al(1980) and Musser and Stamoulis(1981). The major drawback of the quadratic programming procedures was the arbitrary way in which risk aversion was specified.

Following the quadratic programming methodology was the MOTAD approach which was basically a modified linear programming model specified as a minimization of total absolute deviations , from which the acronym MOTAD is derived. The MOTAD approach has been used in such studies as Hazell(1971), Brink and McCarl(1978), Gebremeskel and Shumway(1979), Mapp et al(1979) and Persaud and Mapp(1980). Mapp and Helmers(1984) find the MOTAD approach to be inadequate, even in comparison to the quadratic programming methodology, in view of the sensitivity of it's solutions to changes in risk measures, constraints and technical coefficients.

The general criticism of mathematical programming based methodologies has been it's inability to provide for the drawing of statistical inferences which has become central to the current study of agricultural economics.The mathematical programming methodologies developed to incorporate risk in agricultural production analysis also fails on statistical inference.

Econometric Estimation and Risk

The inability to draw statistical inferences from mathematical programming methodologies , including those designed to incorporate risk, resulted in efforts to develop econometric based estimation methods. Just(1974) conducted the pioneering study that attempted to incorporate risk in estimating an econometric acreage response model. To gauge the effects of risk on California field-crop supply response, Just estimates single equation generalized adaptive expectation models by defining quadratic lag terms to capture risk effects.

Risk Attitudes and Risk Preference Structure

The next phase of risk analysis in agricultural production consisted mainly of studies on risk attitudes and preference structures of producers, both of which form the foundations of hypothesis testing in this study. For some time, there appeared to be a distinction emerging between risk attitude and risk reference structure . The former emphasized the ordering of producers by elicited attitudes toward risk which was determined through the estimation of the coefficient of absolute risk aversion. Producers are then classified risk averse, risk neutral or risk preferring depending on the estimated coefficient of absolute risk aversion. Work on risk attitudes was initiated by Dillon and Scandizzo(1978) and then followed by Binswanger(1980, 1982), Hazzel(1982), Szpiro(1982), Robison et al(1984) and Antle(1987) . The foregoing studies employed experimental methods (games), actual economic decisions or econometric estimation.

Risk preference structure studies have concentrated on identifying the specific type or nature of existing risk aversion. Risk preference structure studies are based on the acceptance of risk aversion among agricultural producers as a stylized fact.These studies have attempted to test whether producers exhibit various properties of risk aversion for instance constant, decreasing, or increasing absolute or relative risk aversion.Risk preference structure models have been formulated and estimated by Cohn et al(1975), Landskroner (1977), Lins et al(1981), Siegel and Hoban(1982), Morin and Suarez(1983), Bellante and Saba(1986), Chavas and Holt(1990) and Pope and Just(1991). To jointly determine and measure both risk attitude and preference structure Saha et al(1994) formulate and estimate an expo-power (EP) utility function using farm level wheat production data from Kansas. The superiority and flexibility of the EP utility function cannot be contested but it's application using duality approaches is yet to be accomplished. The studies on the determination and measurement of risk attitudes and preference structures do not give a reliable indication of multicrop resource allocation behaviour under risk.

Inputs and Risk

Just and Pope(1979) while analyzing effects of inputs on output production and apply a production function specifically designed to provide for the separation of the marginal contribution of inputs to the mean and variance of output. This production function has now become the basis of most risk related studies in agricultural production involving stochastic yield. Other notable studies on inputs and risk were conducted by Farnsworth and Moffit(1981), Feder(1979), Horowitz and Lichtenberg (1993, 1994).

Relevant Empirical Research

Although numerous studies have attempted to incorporate the effects of uncertainty into econometric models of production, relatively few studies have investigated the structure of risk preferences aside from testing for risk neutrality. Pope and Just (1991) estimated reduced form models of acreage demand for potatoes in Idaho using measures of the mean and variance of prices of potatoes and sugar beets and initial wealth (value of land and buildings minus associated debts). Constant absolute risk aversion (CARA)(linear mean-variance utility) was rejected, but constant relative risk aversion(CRRA) was not rejected. Saha, Shumway and Talpaz (1994) estimated jointly a Just-Pope stochastic production function and a utility for wheat in Kansas. Both CARA and CRRA were rejected (for decreasing absolute risk aversion and increasing relative risk aversion).

Chavas and Holt (1990) estimated acreage demands for corn and soybeans in the U.S. using measures of mean prices, variances and covariances of prices and yields for outputs truncated for effects of government price supports and a proxy for initial wealth (farm equity). Input prices and random variable output prices were normalized by a consumer price index. This normalization was justified by assuming expected utility maximization of household consumption together with a budget constraint equating consumption expenditure to exogenous income plus profits from corn and soybean production. However this budget constraint was seriously mis-specified (e.g. by ignoring capital investment and returns from other enterprises, and assuming an aggregate price index for household consumption). Symmetry and negativity restrictions related to compensated demands was specified by a generalized Slutsky equation. Symmetry was not rejected, whereas CARA and CRRA were rejected. Von Massow and Weeresink (1993) estimated a similar model for various crops in Ontario. Most variances were insignificant and CARA was rejected.

Coyle (1992) estimated a duality model for Manitoba agriculture assuming a linear mean-variance utility function and price uncertainty. However the model was highly aggregated to two outputs (crops and livestock), so that the model is seriously mis-specified in this respect and can have few implications for policy. In the case of a normalized quadratic functional form, inclusion of price variances in the model increased the significance of expected prices. A homogeneity condition was imposed, and symmetry and curvature properties implied by the linear mean-variance model were rejected.

Duality Models and Risk

The importance of duality theory in modelling agricultural production has been well recognized (see Pope 1982; Lopez 1982; Chambers 1981 and for a more recent review, Shumway 1994). Perhaps the most serious remaining criticism of applied duality models has been the absence of a tractable methodology for incorporating risk aversion and uncertainty (e.g. Shumway). Proceeding within the framework of expected utility maximization, Pope has argued that duality theory works poorly in modelling risk because the objective function is non-linear in parameters when either prices or yields are uncertain. Others (Epstein 1977, 1978) have reached similar negative conclusions.

Nevertheless several tractable dual models with risk and uncertainty have been developed in recent years. Coyle (1992) incorporated risk aversion and price uncertainty into a duality model of a linear mean-variance utility function. Properties of the corresponding dual indirect utility function were characterized, and application of the envelop theorem leads to output supply and input demand equations that can be estimated by linear methods. This model has subsequently been generalized to a non-linear mean-variance utility function (Coyle 1994a; Saha 1994). The one serious complication is that corresponding output supply and factor demands cannot be estimated by linear methods. A further generalization of the model permits a non-linear mean-variance utility function and yield uncertainty as well as price uncertainty (Coyle 1994b). This further complicates estimation of the (expected) output supply equations although the model remains tractable for empirical research.

Researchers have also begun to generalize the standard theory of cost minimization to stochastic outputs (Pope 1980; Pope and Just 1991b; Pope and Chavas 1994). In contrast to the above studies, these cost minimization models attempt to explain input decisions conditional on moments of output supply decisions. Thus these models are not directly applicable to empirical studies of supply response, although such dual cost functions together with a risk preference utility function can jointly specify a model of choice regarding the probability distribution of outputs.

Risk aversion and price uncertainty have also been incorporated recently into dynamic duality models. The importance of uncertainty in modelling dynamic decisions is well known, and several studies have incorporated price uncertainty into dynamic duality models of the risk neutral firm (Stefanou 1987; Chavas 1994). More recently, dynamic duality models have been specified under risk aversion and price uncertainty (Coyle 1994b; Arnade and Coyle 1995).

Theoretical Framework of the Study

The simplest assumption regarding risk preferences is a linear relation between expected profits ($E\pi$) and profit variance ($V\pi$) i.e.

(1) $$U = E\pi - \alpha/2 \, (V\pi)$$

where α is the coefficient of absolute risk aversion. A general non-linear mean-variance utility function can be formulated by allowing the coefficient of risk aversion to vary with the mean and variance of the random variable wealth, where wealth (w) is equal to initial wealth (w_0) plus profits (π). Then the firm's utility function can be expressed as:

(2) $U = w_0 + E\pi - \alpha (w_0 + E\pi, V\pi)/2 \, V\pi$

where the mean and variance of wealth are $Ew = w_0 + E\pi$, $Vw = V\pi$. Given Y and X as vectors of output and input levels and P and W as vectors of output and input prices respectively, profits are defined as follows:

(3) $\pi = PY - WX$

With the assumption that only price risk exists Y, X and W are considered non-stochastic and the expected profits and variance of profits conditional on the output and input levels becomes :

(4) $E\pi(Y,X) = P^e Y - WX$

(5) $V\pi(Y,X) = Y^T V_p Y$

where P^e and V_p represent the vector of expected output prices and covariance matrix of prices respectively.

The indirect utility function corresponding to maximization of linear mean-variance utility function (1) is

(6) $U^* (P^e, W, V_p) = \text{Max} \;\; P^e Y - WX - \alpha/2 \, (Y^T V_p Y)$

However this expression is rather restrictive in it's empirical application due to the assumption of constant absolute risk aversion (linear mean-variance risk preference). Nevertheless the linear mean-variance model continues to be used in various applied studies involving risk and uncertainty.

A more general model can be formulated in terms of a non-linear mean-variance utility function as follows

(7) $U^* (P^e, W, V_p, w_0) = \text{Max } w_0 + P^e Y - WX -$

$$\alpha(w_0 + P^e Y - WX , Y^T V_p Y)/2 \; Y^T V_p Y$$

If only one price is uncertain, then this non-linear mean-variance model is equivalent to expected utility maximization (Sinn, Meyer).

The most important properties of the dual indirect function $U^* (P^e, W, V_p)$ for the linear mean-variance model (6) can be summarized as follows (Coyle 1992): the dual is linear homogenous and convex in (P^e, W, V_p), and

(8)

$$\frac{\partial U^*(.)}{\partial P_j^e} = Y_j \qquad j=1,,M$$

$$\frac{\partial U^*(.)}{\partial W_i} = -X_i \qquad i=1,,N$$

These are analogous to properties of the dual profit function for a risk neutral competitive firm:

π (P,W)= Max PY - WX implies π (P,W) is linear homogenous

and convex in (P,W), and (Hotelling's lemma)

(9)

$$\frac{\partial U^*(.)}{\partial P_j} = Y_j \qquad j=1,,M$$

$$\frac{\partial U^*(.)}{\partial W_i} = -X_i \qquad i=1,,N$$

In addition (6) implies non-linear relations between derivatives of the dual with respect to price variances and expected prices. The coefficient of risk aversion ($\acute{\alpha}$) can be recovered from the dual, and there is a duality between the dual and technology similar to risk neutral case.

The properties of the dual indirect utility function $U^*(P^e, W, V_p, w_0)$ for the non-linear mean-variance model (7) are more complex (Coyle 1994a). The common assumption of constant relative risk aversion (CRRA) implies

(10)

$$U^*(\lambda P^e, \lambda W, \lambda^2 Vp, \lambda w_o) = \lambda U^*(P^e, W, Vp, w_o)$$

(11)

$$Y(\lambda P^e, \lambda W, \lambda^2 Vp, \lambda w_o) = \lambda Y(P^e, W, Vp, w_o)$$

$$X(\lambda P^e, \lambda W, \lambda^2 Vp, \lambda w_o) = \lambda X(P^e, W, Vp, w_o)$$

under CRRA. Note the difference from the homogeneity conditions for the linear mean-variance model: here Vp is multiplied by the λ^2 rather than by λ. The homogeneity result (11) was derived by Pope (1988). CRRA also implies the following restriction on the risk aversion function $\acute{\alpha}(Ew, Vw)$:

(12)

$$\alpha(\lambda Ew, \lambda^2 Vw) = \lambda^{-1} \alpha(Ew, Vw)$$

under CRRA. The generalized convexity relation for the dual can be stated as :

(13)

$$U^*_{vv}(v)+[\frac{\alpha(Ew^*,Vw^*)}{2}]_{vv} \quad \textit{symmetric} \quad \textit{positive} \quad \textit{definite}$$

Where V = (P^e,W,Vp,w_o).

The generalized envelope relations include

(14)

$$\frac{\dfrac{\partial U^*(.)}{\partial P_j^e}}{\dfrac{\partial U^*(.)}{\partial w_o}}=Y_j \qquad j=1,,M$$

$$\frac{\dfrac{\partial U^*(.)}{\partial W_i}}{\dfrac{\partial U^*(.)}{\partial w_o}}=Y_i \qquad i=1,,M$$

(15)

$$\frac{\partial U^*(.)}{\partial w_o}=1-\frac{\partial \alpha(.)}{\partial Ew}\frac{V\pi}{2} \qquad i=1,,M$$

The coefficient of risk aversion function $\acute{\alpha}(.)$ can be recovered locally from the dual given CRRA, and there is a duality between the dual and technology given the assumption of decreasing absolute risk aversion (a stylized fact in the theory of risk behaviour).

Allowing for linear mean-variance risk preferences as in (6) does not complicate or compromise the dual approach to production in any essential manner. In contrast, application of duality theory for the non-linear mean-variance model (7) is more complex than the risk neutral case in the following respects: a homogeneity property is not necessarily implied by the theory (risk preferences may not satisfy CRRA); and the estimating equations for output supply and factor demand (14) generally are non-linear in coefficients. Problems in non-linear estimation may be simplified to some extent by substituting (15) into (14) or by estimating (15) and (14) in an iterative manner.

CHAPTER III

ECONOMETRIC MODELS AND RESULTS

Initial Selection of Variables

The initial selection of variables for this research was based largely on results of earlier studies of Manitoba agriculture. Coyle (1993a) specified a risk-neutral model of crop acreage demands for Western Canada as follows:

(1)

$$Z_t^i = a_i + \sum_{J=1}^{4} a_{ij}\left(\frac{P^j}{W^1}\right)_t + a_{i5}\left(\frac{W^2}{W^1}\right)_t + a_{i6}K_t + a_{i7}A_t + a_{i8}A_{t-1} + e_t^i \qquad i=1,..,4$$

Here there are four crops(wheat, barley,rapeseed and other), Z^i is acres in crop i, A is total crop acreage, P^j is expected price of crop j, W^1 is price of variable inputs for crops, W^2 is wage rate for hired labour, K is the stock of machinery and equipment, and t is a time trend. Inclusion of current total crop acreage, A_t implies that livestock prices can be omitted from (1) to the extent that crops and livestock are weakly separable in production. Lagged total crop acreage A_{t-1} is also included in the model assuming that individual crop acreage demands depend on lags in adjustment of the overall crop rotation.

Expected prices for crops covered by the Canadian Wheat Board (including Wheat, barley and until recently oats) were defined as the sum of the most recently observed components of Canadian Wheat Board payments at planting time : current initial payments , plus adjustment and interim payments for crops marketed in the previous year, plus final payment for crop marketed two years previously. Expected prices for crops not covered by the Board were defined as market prices plus Government payments in the previous year. This specification of expected prices led to significant results for model (1) in contrast to specifications based on lagged market prices for Board crops or on rational expectations using forecasts from ARIMA models. This is somewhat consistent with the results of Sulewski, Spriggs and Schoney (1994), who concluded that simple models of expectation formation appeared to explain the stated expectations of Saskatchewan farmers for wheat and rapeseed prices better than do rational expectations models or futures prices.

The current study specifies output supply equations for wheat,barley,rapeseed and oats and a factor demand equation for variable crop inputs in terms of the above explanatory variables. The variance for farmers subjective probability distribution of prices is calculated as in Chavas and Holt and in Coyle (1992):

(2)

$$VAR(P_t^i) = 0.5(P_{t-1}^i - E_{t-2}(P_{t-1}^i))^2 + 0.33(P_{t-2}^i - E_{t-3}(P_{t-2}^i))^2 + 0.17(P_{t-3}^i - E_{t-4}(P_{t-3}^i))^2$$

Here current variance equals the sum of squares of prediction errors of the previous three years, with declining weights 0.50, 0.33 and 0.17. For simplicity price covariances are assumed to be zero, as in most econometric studies of risk in production.

Annual data was collected for Manitoba agriculture for 1961 - 1990. Output price data was obtained from the Canadian Wheat Board annual reports and the Canada Grain

Trade Statistics. Input price indexes were obtained for hired labour, variable inputs for crops (e.g. fertilizer) and machinery and equipment from the Farm Input Price Indexes publication of Statistics Canada. An index of the quantity of variable inputs for crops was calculated as the current value of variable expenses for crops deflated by it's price index and an index of the stock of physical capital was in the crop sector was calculated as the current value of machinery and equipment deflated by it's price index. These current values were obtained from the Farm Net Income publication of Statistics Canada. Crop acreages sown annually for harvest were obtained from the Handbook of Field Crop Statistics published by Agriculture Canada.

It is important to note the following deficiencies in selection of variables for this study: a) the influence of crop yield uncertainty on production is ignored; b) crop output supply response is not decomposed into crop acreage and crop yield responses; c) the impact of Government programs on production is not modelled. Yield uncertainty is not considered here because it cannot be measured by province level data: to the extent that weather varies by region, the contribution of yields to revenue variation or uncertainty at the farm level will be underestimated by data aggregated over producers.

There appear to be substantial advantages to decomposing econometric models of crop output supply response into crop acreage and yield response models, although this has not been done in any published studies. There may be considerably longer lags in crop yield response than in crop acreage response to prices. For example, a preliminary study of yield response to price for wheat and barley in Manitoba suggested a 3 to 4 year lag in response Coyle (1993b). This difference in lag structures implies gains in understanding and efficiency by estimating a system of crop acreage demand and yield equations. Moreover further gains in efficiency can be obtained by the adding-up restrictions in acreage demands (Coyle 1993a) and by imposing weak separability between crops in production or yield response equations.

Unfortunately this study does not decompose crop supply response into acreage demand and yield responses. The reason for this is that duality models with risk aversion have not yet been generalized to incorporate this decomposition. Indeed duality models of production under risk neutrality have only recently endogenized crop acreage demands (Chambers and Just 1989), and even these models have not yet incorporated different lags in yield and acreage response.

Initial Regressions

Distributed lag models were estimated for individual crop outputs.The general form of the equations follows:

(3)

$$Y_t^i = a_i + \sum_{S=0}^{L} b_{ij} \left(\frac{P^i}{P^{Ni}}\right)_{t-s} + e_t^i \qquad i=1,..,4$$

Where there is a distributed lag in own price deflated by a numeraire. Both unrestricted and polynomial distributed lag (PDL) models were estimated by OLS, and both market prices and CWB prices (defined as above) were considered. Representative regression results are presented in Tables A11 to A17 of Appendix I.

It is interesting to note that the distributed lags often appear in a sense to be double peaked. For example in Table A14 (A15) for an unrestricted distributed lag for wheat output, lag lengths of 1 - 2 (2) and 4 - 5 (5 - 6) but never 3 are significant. Since coefficients do not decrease uniformly or exponentially as lag length increases, these results are not consistent with geometric lag models such as the Nerlovian adaptive expectations model or Partial adjustment in supply or indeed with most models where lags are explained in terms of expectations. Instead these results can be interpreted as being broadly consistent with the crop acreage demand and yield studies referenced in the previous section: these results suggest approximately a 1 to 2 year lag in wheat acreage response and a 4 to 6 year lag in wheat yield response. Coefficient restrictions in PDL models are inappropriate for representing such discrete or double peaked lag patterns. Similar double peaked patterns are obtained for barley but a single-peaked lag pattern is obtained for canola and oats.

The smaller (one period) lags apparently can be explained to some extent by an essentially static model (eg. Coyle 1993a), but the longer (four to six period) lags presumably should be explained by an explicitly dynamic model. Given the difficulties in modelling dynamic behaviour, it was decided that the first study of Manitoba crop output response under risk should emphasize one period lags in response. Consequently this thesis will ignore the effects of longer lags in prices on crop outputs. Of course, since prices two or three years apart are highly correlated, this mis-specification of output supply models inevitably biases the interpretation of results as short-run impacts. Unfortunately this problem is common to most models of supply response. Perhaps the most appropriate method for modelling crop supply response is to decompose it into acreage and yield response models, but this is beyond the scope of this initial study.

Another matter that was considered in initial investigations was the choice of numeraire price. The standard theory of the competitive profit maximizing (and hence risk neutral) firm assumes that output supplies and factor demands are homogeneous of degree zero in output and input prices; so the choice of numeraire price is arbitrary. However, for econometric purposes the choice of numeraire price for a normalized quadratic dual profit function implies very different specifications for output supply/factor demand equations , since the equation for the numeraire commodity is quadratic in prices whereas all other equations are linear in prices. Similarly different choices of numeraire imply different restrictions on technology. In addition this risk neutral standard