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UNIVERSITY OF ALBERTA

Economic Structural Analysis of the Alberta and Canadian Agricultural Sectors

by

GURMIT SINGH SANDHU

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

IN

AGRICULTURAL ECONOMICS

DEPARTMENT OF RURAL ECONOMY

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for the acceptance, a thesis entitled ECONOMIC STRUCTURAL ANALYSIS OF THE ALBERTA AND CANADIAN AGRICULTURAL SECTORS submitted by GURMIT SINGH SANDHU in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in AGRICULTURAL ECONOMICS.

William E. Phillips

Dr. W. E. Phillips (Supervisor)

T. S. Veeman

Dr. T. Veeman (Committee Chairman)

W. Adamowicz

Dr. W. Adamowicz (Committee Member)

Michael Percy

Dr. M. Percy (Committee Member)

Melville McMillan

Dr. M. McMillan (Committee Member)

A. Weersink

Dr. A. Weersink (External Examiner)

Date: Sept. 6, 1991

DEDICATION

To my parents for their support and encouragement to seek higher education.

ABSTRACT

The purpose of this study is to analyze the Alberta and Canadian agricultural production sectors over the period 1926 to 1988. Economic analysis is focused on the estimation of certain parameters including elasticities of substitution between the factors of production, own-price elasticities, scale effects of production and biases in technical change. Aggregate agricultural output is a function of labor, capital, intermediate goods, and land and building structures. The application of duality theory allows for the use of aggregate cost functions for both sectors.

Unlike earlier studies, dynamic models of a system of share equations are fitted to the data for both sectors. Selection of the models is based on tests of adequacy (statistical diagnostic tests) and of restrictions from underlying economic theory. Potential models representing both sectors include a static model (long-run equilibrium model), a partial adjustment model and an autoregressive process of order one for disturbances model, all of which are rejected. However, a system of share equations of a multivariate autoregressive process of order one of the translog functional form fits the data for both sectors satisfactorily.

One feature of the dynamic models utilized in this study is the ready availability of estimates of the long-run parameters. One significant difference between this study and earlier studies is the calculating of standard errors of estimates of elasticities, which are obtained using a statistical simulation procedure. Confidence intervals for the estimates of elasticities are constructed using the simulated

results. Most earlier studies either did not estimate standard errors or approximated them with standard error estimates of the coefficients, which are also used to calculate the elasticities; an approach which is faulty.

The results of this study show that the long-run production structure for both the Alberta and Canadian agricultural sectors are non-homothetic. Scale of production is intermediate goods using and labor saving for both the sectors. Technical change for Canada is intermediate goods using and land saving. Whereas, the technical change for Alberta is factor neutral.

Labor and land and building structures, and intermediate goods and land and building structures are substitutes for Canada. For the Alberta agricultural sector capital and labor are substitutes, while capital and land and building structures are complements.

All factors except land and building structures are inelastic to their own prices. Land and building structures appears to be elastic to its own price for Canada but inelastic for Alberta.

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Chapter 1
INTRODUCTION

The purpose of this study is to develop a model to analyze changes in the Canadian and Alberta agricultural sectors over time. Agricultural sectors are integral parts of the Alberta and Canadian economies. Therefore, from a policy and continuing research point of view, it is important to recognize the long term behavior in these sectors over time.

The Alberta and Canadian agricultural industries have visibly changed in this century. The development of these sectors can be credited to the invention and adoption of new technology for the sectors, in particular: farm mechanization, the adoption and development of improved varieties of crops and livestock, the greater use of fertilizers for increased yield and the use of chemicals for weed and pest control etc. [Manning (1985, 1986a), Furniss (1964,1970)]. Farm management skills have improved as well. Opportunity costs for farm and off-farm labor have increased due to the commercialization of agriculture and the industrialization of Canada.

Furniss (1964, 1970) studied the productivity of Canadian agriculture from 1935-60 and 1950-69 respectively. Statistics on the distribution of the changing input mix were provided in these studies. Capital (machinery and equipment) was substituted for labor over both of these time periods. The share of labor in the total input mix declined from 63% in the 1935-39 period to 53% in the 1945-49 period and further to 24% in the 1965-69 period. On the other hand, the proportion of machinery and equipment in the total input mix increased from 8.5% for 1935-39, to 19% for 1950-54 and to 22% for 1965-69.

Purnell and Heighton (1970) credited the substitution of capital for labor in agriculture as a result of economic development in Canada. Furniss (1964), credited the substitution of capital for labor also as a result of farm mechanization. Farm mechanization can be characterized as the shift from the use of farm produced power (horses and mules) and human labor to the use of purchased mechanical power and energy. On average in Canada there were 20 tractors for every hundred farms and almost 4 horses per farm in 1941, while in 1946 there were 29 tractors per hundred farms and 3.2 horses per farm. By 1960, there was on the average more than one tractor per farm and only one horse per farm. As farms shifted toward the use of mechanical power, productivity increased with greater output becoming available in markets. In the process, non-equine livestock populations increased partly because of greater feed availability from the decline of the equine population, but also because of higher feed production and improved feed conversion technology. "*For example in poultry meat production, the rate of feed conversion per pound of gain had dropped from 6 pounds prewar to 2.5 pounds or less today.*"(Furniss, 1964) Present day conversions are even lower and are approaching one pound of feed per pound of gain. Since the end of World War II, the use of purchased inputs, such as feed, seed, fertilizers and pesticides increased significantly. Using Laspeyres's index numbers Furniss (1964), concluded that "*the volume of feed and seed purchased increased by 312 per cent from 1935-39 to 1946 but not significantly after---. The quantity of commercial fertilizer* *used on farms was fourfold greater in 1960 than in 1935-39. The use of pesticides in significant quantities has been a post World War II development. In 1960, the quantities of all pesticides used were 132 per cent greater than in 1947 and the increase in use of these inputs is continuing."* The proportion of real estate in the total input mix was approximately 21% in 1935-39 and grew slightly to 24% in 1969 (Furniss, 1964, 1970). Real estate had been refer to both owned and rented real estate and include interest on investment in land and buildings, depreciation and repairs on buildings, property taxes and fencing maintenance. Every thing was valued at 1949 prices.

Shute (1975) analyzed the Canadian agriculture sector for the period 1961 to 1973. She concluded that the proportionate share of real estate, labor, machinery and capital (livestock, feed seed, fertilizers etc.) were 27.7%, 34.6%, 20.2% and 17.5% respectively in 1961 and 28.4%, 20.5%, 25% and 26.1% in 1973.

In 1961, there were 480,900 census farms of all types in Canada with an average size of 369 acres (Shute 1975). The total acreage of farm land did not change significantly from 1951 to 1971 (Census of Agriculture. Statistics Canada). The number of census farms declined from 480,900 in 1961 to 366,000 in 1971 (Shute 1975). However, the average number of acres per farm increased from 359 acres in 1961 to 464 acres in 1971 (Shute 1975). From the evidence presented by these researchers it can be concluded that technology adopted by Canadian farms was labor saving , land and capital using during the period from 1931 to 1971. Shute (1975) included interest on investment, depreciation and repairs on buildings, and property taxes for both owned and rented real estate.

Manning (1985, 1986a, 1986b) studied in detail the productivity in the Alberta and Canadian agricultural sectors. Manning (1985) found that the share of labor in the input mix for Canada declined from 36.6% in 1951 to 16.7% in 1981. Whereas, the proportionate shares of energy inputs (petroleum products and electricity) and fertilizer and lime increased from 4.6% and 1.3% in 1951 to 5.2% and 4.6% in 1981 respectively. These figures suggest that the trend of substitution of capital for labor continued into the 1980's. Further, he concluded that there had been continuous growth in agricultural productivity since 1946 in Alberta and Canada. In particular, during the period from 1946 to 1984 the productivity indexes for Alberta and Canada increased at a compound annual rate of 1.4% and 1.9% respectively.

The studies, discussed above, analyzed Canadian agriculture using estimates of the proportionate shares of inputs and of productivity measures by employing various methods of index number calculations. With the increased availability of advanced computers and sofiware, and the development of duality theory, the use of more sophisticated econometric techniques to analyze the agricultural sectors has become possible. Estimates of parameters such as elasticities of substitution, factor price elasticities, biases in technical change and scale effects describe the changing structure of the agricultural sector more explicitly. In this study, these parameters will be estimated through the estimation of cost functions in order to analyze changes in the Alberta and Canadian agricultural sectors.

Several studies have been undertaken to analyze the U.S and the

Canadian agricultural sectors. The majority of these studies focused on the estimation of parameters such as elasticities of substitution among inputs. Most of these studies also contained estimates of aggregated (static[1]) cost, production or profit functions. Only those studies that put no a-priori restrictions on estimators of elasticities of substitution are reviewed below (i.e., studies with flexible cost, production or profit functions). The studies which imposed economic restrictions without testing have been omitted because of statistical objections which will be discussed below.

1.1 RECENT STUDIES ON THE CANADIAN AGRICULTURAL SECTOR

Islam and Veeman (1980), Lopez (1980) and Adamowicz (1986) analyzed the Canadian agricultural sector. Islam and Veeman (1980) analyzed changing input use and productivity in the Canadian agriculture sector for the period 1961 to 1978. Cost share equations corresponding to a homothetic translog cost function (static) were estimated. Symmetry conditions were imposed without testing their prior validity. Lopez (1980) analyzed the Canadian agriculture sector for the period 1946 to 1977. Derived demand equations corresponding to the Generalized Leontief (GL) cost function (static) were estimated. This study tested for symmetry and integrability conditions and concluded that these conditions hold. This is the only published Canadian study that tested restrictions consistent with economic theory. Adamowicz (1986) analyzed the Canadian agricultural sector for the period of

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[1] Static models are models which do not have lagged dependent and independent variables as explanatory variables.

1940 to 1981. Adamowicz (1986) tested the effects of aggregation of inputs on the estimation of parameters defining the structure of the agriculture sector. In this study, the aggregate translog cost function (static model) was estimated simultaneously with the cost share equations. Symmetry conditions were imposed without being tested.

Rahuma (1989) analyzed the Alberta agricultural grain sector. A translog cost function (aggregated static model) along with share equations were estimated for the Alberta grain sector. However, symmetric conditions were imposed without testing first. Manning (1986a) used total factor productivity measures to study the Alberta agricultural sector. In addition, Manning (1985) analyzed the effects of rising energy prices on grain production in Canada. This study also used total factor productivity as a measure of the growth of productivity.

1.2 STUDIES ON THE UNITED STATES AGRICULTURAL SECTOR

There have been several studies [Binswanger (1974a, 1974b), Brown and Christensen (1979), Ray (1982), Antle (1984, 1986)] which analyzed United States agricultural time series data. Each of these studies, except for Antle (1986), estimated either a static production, cost or profit function. The estimated models were used to analyze changes in the agricultural sector. Antle (1986) used a dynamic production process in analyzing the agricultural sector. The dynamic production process is defined as a production process in which the production function is a function of current and past inputs and past outputs. Antle (1986) argued that sufficient identifying restrictions had to be imposed on econometric models using aggregate data in order to measure and explain technological change. Antle (1986) stated that:

"The question of identifying restrictions has not been addressed in the studies by Binswanger, Antle and others. Thus it can be questioned whether these studies have obtained valid measures of technological change and whether or not their evidence can be interpreted as supporting the induced innovation explanation of the technological change."

By extension, the results of the studies on the Canadian agricultural sector undertaken by Islam and Veeman (1980), Lopez (1980) and Adamowicz (1986) and on the United States agriculture sector by Ray (1982) while making very significant contributions to the understanding of agricultural sectors could also be questioned for not imposing sufficient identifying restrictions on their econometric models.

The restrictions used by Antle (1986) were that the short adjustment lags between prices and productivity are due to firms' expectations, and that the large lags are evidence of induced innovation.

Antle (1986) estimated marginal rate of technical substitution equations. In his study, the estimated equations consisted of relative input prices as dependent variables, while current and past input prices, output, and time were explanatory variables. Because of the large number of explanatory variables, a degrees of freedom problem arose when a flexible functional form was specified. Therefore, Antle (1986) arbitrarily specified a log linear functional form for the estimating equations to overcome this problem.

A study by Anderson and Blundell (1982) is worth noting, though it was not applied to any agricultural sector. This study developed an estimation and hypothesis testing procedure for a dynamic singular equation system. A singular system of equations is defined as a system of linearly dependent equations. The system of demand equations and the share equations are singular because of the additivity condition from economic theory. Anderson and Blundell (1982) discussed the concern regarding rejection of the restrictions, which corresponds to consistency with economic theory in empirical studies. They pointed out that one of the reasons for the rejection of economic restrictions may be the misspecification or exclusion of the dynamic parts of the econometric models used in empirical studies. As stated earlier in this section, most of the studies of the Canadian and the United States agricultural sectors impose economic restrictions on the econometric models rather than testing them first. Therefore, there is no way of knowing whether or not these econometric models would have satisfied economic restrictions. Lopez (1980) tested these restrictions.

Anderson and Blundell (1982) contended that if an estimated function does not satisfy economic restrictions, then it should not be used for further economic analysis. They further suggested that tests of economic restrictions could be used as tests for the correct specification of the econometric models.

One assumption that is commonly maintained in estimating econometric models using time series data is that the structure of technology (structure of production or cost functions) does not change over time. Antle (1984) tested for structural change in the United States agriculture. He rejected the null hypothesis of no structural change over the period 1910-78 against the alternative hypothesis that there is a change of structure of technology between the prewar and the postwar periods.

1.3 PROBLEM ANALYSIS

Following Antle (1986), one can conclude that the previous studies on the Canadian and the United States agricultural sectors referred to in this paper, except Antle (1986), may not have valid estimates of technological change. This conclusion is based on the fact that these earlier studies do not differentiate between long-/and short-run responses to changes in relative factor prices. The root cause of this problem is the application of static models to the study of agricultural sectors over time. Static models assume that agricultural production sectors are always in equilibrium and that they adjust instantaneously to the changes in relative factor prices.

The assumption that both the Alberta and Canadian agricultural sectors are always in equilibrium and adjust instantaneously to the changes in the relative prices is not realistic. There is an abundance of literature [e.g., Antle (1986), Berndt and Field (1981)] which questions this assumption in almost all applications in different branches of the economy. One of the main reasons which undermines this assumption is that there is a lag between changes in relative prices and adjustments made by firms in agricultural and other sectors. Adjustments to most changes in relative factor prices and technology cannot be made immediately presumably because of adjustment and information costs [Anderson and Blundell (1982)]. The existence of lags introduces a dynamic aspect to the analysis of agricultural production sectors. Therefore, the application of a static model to analyze data, which were generated by a dynamic process may lead to incorrect and misleading results or conclusions. Anderson and Blundell (1982) stated in their study:

"*The literature on the systems of demand equations abounds with examples of empirical studies in which restrictions from the economic theory, such as homogeneity and symmetry, are rejected. This is of concern to economic theorists, who see fundamental economic hypotheses being challenged, and has called into question the appropriateness of the empirical modelling used. (See*[2] *[2, p. 37; 7, p. 77].) We believe that the root cause of the problem is the econometric approach taken in examining the implications of the economic theory ; in particular little attention has been paid to the dynamic structure of the models used.*"

Antle (1986) estimated a dynamic model to study technological change and to test the induced innovation hypothesis (Binswanger (1974)) for the United States agricultural sector. There are a few problems with this study. First, most studies (e.g. Lopez (1980)) assume that input prices are determined in non-agricultural sectors of the economy. However, Antle (1986) used relative prices (marginal rates of technical substitution) as response variables. Therefore the results

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[2] Barten, A. P. (1977) and Deaton, A. S. (1977) are the papers referred here.

obtained from this study can be challenged on the basis that an exogenous variable cannot be used as a response variable. A second difficulty is that, Antle (1986) arbitrarily selected a log linear functional form for the estimating equations without a set of across-equation restriction that would had been implied by specifying a functional form of the aggregate production function. It was argued that a specific functional form for the estimating equation could be derived with a set of across-equation restrictions implied by the production function. Therefore, each equation was estimated separately since each equation had identical explanatory variables. These estimates are the same as seemingly unrelated regression estimators. In other words, there was no *ex ante* (Lau, 1985) choice of functional form and theoretical economic consistency was not tested. Therefore, it could be argued that the estimation procedure used by Antle (1986) is not a significant improvement on the earlier static model procedures since the functional form was not derived using across-equations restrictions based on the economic behavior of a production process. This model may not adequately represent the production process under consideration.

To summarize, there are problems with static models used in earlier studies and with the model used by Antle (1986). The static models do not represent the dynamic structure of agriculture sectors, while the Antle (1986) estimating equations do not correspond to a theoretically consistent production function.

This study proposes a dynamic cost function approach to analyze the Alberta and Canadian agriculture sectors. The approach will be similar to that used by Anderson and Blundell (1982).

1.4 THESIS OBJECTIVE AND OUTLINE

The objective of this thesis is to perform economic analysis of the changes in the structure of the Alberta and Canadian agricultural sectors over time. Based on earlier studies, a model of a system of share equations will be estimated for each of the agricultural sectors under consideration. One of the criteria for selection of a functional form of the model will be to test the results with regard to restrictions which are derived from underling economic theory. Most of the earlier studies imposed these restrictions without testing them in their models. If a tentative model does not reject the restrictions, then the model with restrictions will be selected. The selected models will have to pass statistical diagnostic tests as well. Economic analysis will be based on the estimates of the following economic parameters: elasticities of substitutions between the factors of production and of own-price, scale effects of production and biases of technical change. Significance levels or confidence intervals of the estimates of the parameters should be obtained in order to reac[illegible] lid statistical inferences. Most of the studies discussed earlier either did not estimate standard errors or utilized poor estimators of standard errors of elasticities. This problem arose because the statistical distributions of the elasticities estimators are not well behaved. In this study standard errors of elasticities estimates will be obtained by utilizing statistical simulation procedures. Asymptotic confidence intervals will be constructed from these simulated results.

Chapter 2 contains a detailed discussion of the methodology, and economic and statistical theories used in this thesis. A brief description of the data and their transformations are also given in chapter 2. Chapters 3 and 4 contain empirical results and economic analysis of the models of Canadian and Alberta agricultural sectors. Chapter 5 is on the assessment and comparison of empirical results of this study to the earlier studies. Chapter 6 includes summary and conclusions.

Chapter 2
METHODOLOGY

Since the 1970's, the application of a cost function in the study of technological change and the substitution behavior of inputs of the production process has gained popularity. The increase in the popularity of the cost function in empirical work can be attributed to the development of duality theory. According to duality theory (Diewart, 1971, 1981), the cost function can completely describe a production function under certain regularity conditions; the cost function is non-negative, linearly homogeneous in prices for any fixed level of output, non-decreasing in prices and output, concave and continuous in prices, and continuous from below in output. Diewart (1981, p.533) states that "*there is duality between cost and production functions in the sense that either of these functions can describe the technology of the firm equally well in certain circumstances*". Technology determines how different factor inputs can be used to produce output. In this study, the following parameters defining the technology in agricultural production for Alberta and Canada will be estimated:

Elasticity of substitution between factors of production;

Own-price elasticities;

Scale effects of production; and

Bias of technological change.

There are several advantages in using a cost function rather than a production function in estimating production parameters. The following brief list of advantages of using cost function instead of production function is taken from Binswanger (1974b) and McFadden (1978).

Principal practical advantage is the partial derivative of the cost function with respect to prices yield cost minimizing input demand functions. (McFadden 1978)

For the cost function approach, prices are independent variables in the estimating equations as compared to production function, which have factor quantities as independent variables, which are not exogenous variable.(Binswanger 1974)

For the estimation of the elasticity of substitution and factor demand in many-factor case, matrix of the estimated coefficient have to be inverted if a production function is used. This could exaggerate estimating errors. No inversion is required if cost function is used (Binswanger 1974)

High multicollinearity among factor quantities could cause problem if production function is used.

Therefore, in this study cost function approach will be utilized for the analyses of the Alberta and Canadian agriculture sectors. Furthermore, since the study of the behavior of substitution of factor inputs is an objective, a flexible form cost function will be used. Based on earlier studies, there are two flexible functional forms of interest: a transcendental logarithmic functional form (translog), and a generalized Leontief functional form. The generalized Leontief form creates a degree of freedom problem for multivariate autoregressive process of order one for a four input case. Therefore, the translog functional form for the cost function is selected for the purpose of this study.

Some of earlier studies have estimated cost function along with the system of share equations [Ray (1982), Adamowicz (1986)]. It was argued that estimation of the full dual system (cost function and share equations) results in more efficient estimation. However, for the case of multivariate autoregressive process model (which is used in this study) that would lead to the problem of degree of freedom and further derivation of the corresponding dynamic model is very complicated. Therefore, in this study, system of share equations alone will be estimated. Note that all of the parameters of interest for this study are available from the estimated share equations.

2.1 STATIC MODEL

The objective of this study is to estimate the parameters of agricultural production for Alberta and Canada based on long-run aggregate (static) cost functions. A long-run cost function is defined as the solution to the problem of minimizing the cost of producing at least output of level q given a fixed price vector of $p^T = (p_1, p_2, \dots, p_n)$ and given a production function f(w). That is

$$C(q,p) = \min_{w} \{ p^T w : f(w) \geq q \} \tag{1}$$

where f(w) is a n-input production function and $w^T=(w_1, w_2, \dots, w_n)$ is a vector of n-inputs and q is output. In obtaining the optimal solution to the above minimization problem, the assumption is made that the optimal value w^0 adjusts to changes in the price p (between periods) instantaneously. An aggregate (static) translog cost function corresponding to (1) can be written as

$$\ln C^{O}(t) = \alpha_{0}+ \sum_{i=1}^{n} \alpha_{i} \ln p_{i}(t) + \frac{1}{2} \sum_{i=1}^{n} \beta_{ij}(\ln p_{i}(t)(\ln p_{j}(t) + \gamma \ln q + \frac{1}{2} \gamma_{q}(\ln q)^{2}+ \sum_{i=1}^{n} \gamma_{ip}(\ln q)(\ln p_{i}(t)) + \theta \tau+ \frac{1}{2} \theta_{\tau}\tau^{2} + \sum_{i=1}^{n} \theta_{i\tau}\tau (\ln p_{i}(\tau)) \qquad (2)$$

where τ is a time trend variable used as a proxy for the state of technology and τ in the subscript of the parameter θ is used for notation only and is not a variable.

The above cost function is static because it depends on prices and output indexes for the current period only and assumes that if there are changes in any of the explanatory variables, there is an instantaneous adjustment to these changes. Furthermore, (2) is a deterministic form of the cost function, whereas in reality, realized values of $w^{O}(t)$ are stochastic due to the existence of unsystematic factors, which cannot be controlled by producers. The stochastic form of the cost function (2) can be obtained by adding a random error term u(t). It corresponds to an unsystematic random error, which cannot be controlled by producers. Thus

$$\ln C (t) = \alpha_{0}+ \sum_{i=1}^{n} \alpha_{i} \ln p_{i}(t) + \frac{1}{2} \sum_{i=1}^{n} \beta_{ij}(\ln p_{i}(t)(\ln p_{j}(t) + \gamma \ln q + \frac{1}{2} \gamma_{q}(\ln q)^{2}+ \sum_{i=1}^{n} \gamma_{ip}(\ln q)(\ln p_{i}(t)) + \theta \tau+ \frac{1}{2} \theta_{t}\tau^{2} + \sum_{i=1}^{n} \theta_{it}\tau (\ln p_{i}(t)) + u(t) \qquad (3)$$

Since

$$\frac{\partial \ln C^{0}(t)}{\partial \ln p_{i}(t)} = \frac{P_{i}(t)}{C^{0}(t)} \frac{\partial C^{0}(t)}{\partial p_{i}(t)}$$

by Shepard's Lemma

$$\frac{\partial C^{0}(t)}{\partial p(t_{i})} = w_{i}^{0}(t) \qquad (4)$$

where $w_{i}^{0}(t)$ is the optimum derived demand for the i^{th} factor. Equation (3) can be rewritten as,

$$\frac{\partial \ln C^{0}(t)}{\partial \ln p_{i}(t)} = \frac{P_{i}(t)\, w_{i}^{0}(t)}{C(t)} = S_{i}^{0}(t) \qquad (5)$$

where $S_{i}^{0}(t)$ is the optimum cost share for the i^{th} factor of production. From eq.(2) and eq.(5), the cost share equations can be written as

$$S_{i}^{0}(t) = \alpha_{i} + \sum_{j=1}^{n} \beta_{ij} \ln p_{j} + \gamma_{iq} \ln q + \theta_{i\tau}\tau \qquad (6)$$

where $i = 1,2,\ldots,n$.

The system of share equations for (6) is deterministic. However, realized data from the production process are always stochastic. Therefore, the stochastic form of the model (6) can be written as

$$S_{i}(t) = \alpha_{i} + \sum_{j=1}^{n} \beta_{ij} \ln p_{j} + \gamma_{iq} \ln q + \theta_{i\tau}\tau + v_{i}(t)$$

where $i = 1,2,\cdots,n$ and $v_{i}(t)$ is the random error term. The above system of share equations can be rewritten as

$$S(t) = \alpha + \Pi X(t) + \theta\tau + v(t) \qquad (7)$$

where

$$S(t) = \begin{bmatrix} S_1(t) \\ S_2(t) \\ \vdots \\ S_n(t) \end{bmatrix}, \quad X(t) = \begin{bmatrix} \ln p_1(t) \\ \ln p_2(t) \\ \vdots \\ \ln p_n(t) \\ \ln q(t) \end{bmatrix}, \quad v(t) = \begin{bmatrix} v_1(t) \\ v_2(t) \\ \vdots \\ v_n(t) \end{bmatrix} \text{ and}$$

$$\alpha = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \cdot \\ \alpha_n \end{bmatrix}, \quad \Pi = \begin{bmatrix} \beta_{11} & \cdots & \beta_{1n} & \gamma_{1q} \\ \beta_{21} & \cdots & \beta_{2n} & \gamma_{2q} \\ \cdot & \cdots & \cdot & \cdot \\ \beta_{n1} & \cdots & \beta_{nn} & \gamma_{nq} \end{bmatrix}, \quad \theta = \begin{bmatrix} \theta_{1\tau} \\ \theta_{2\tau} \\ \cdot \\ \theta_{n\tau} \end{bmatrix}$$

If $\sum_{i=1}^{n} S_i(t) = 1$, then the property of additivity of factor shares exists. The additivity property imposes the following restriction on the parameters and error terms for the system of share equations in (7), that is

$$\sum_{i=1}^{n} \alpha_i = 1, \quad \sum_{i=1}^{n} \beta_{ij} = 0, \quad \sum_{i=1}^{n} \gamma_{iq} = 0, \quad \sum_{i=1}^{n} \theta_{i\tau} = 0$$

$$\text{and} \quad \sum_{i=1}^{n} v_i(t) = 0 \tag{8}$$

The parameters of interest in equation (3) can be estimated by estimation of the system of equations in (7). From duality theory, the following restrictions have to be satisfied by the estimated parameters to insure that the estimated cost function describes the same technology as the production function which, in turn, generates the data for the production sectors in question:

1. C(t) is linear homogeneous in prices;
2. C(t) is non-decreasing in prices; and
3. C(t) is concave in prices which implies symmetry of the β_{ij}

parameters i. e., $\beta_{ij} = \beta_{ji}$ for i,j = 1,2,...,N and the Hessian matrix is negative semi-definite.

Most earlier studies imposed these restrictions on the system of share equations without testing the validity of such actions. Therefore, there is no way of knowing whether the restrictions imposed on their models, if tested, would have been rejected. From duality theory a cost function describes the technology of the production function of the data generating process, if the integrability restrictions are not rejected by the cost function. To determine whether the cost function is correctly specified, these restrictions should be tested. If the restrictions are rejected by a cost function then the cost function is likely misspecified. In this case, the inferences made on the data generating process of the producing sector may be incorrect based on an estimated model with restrictions imposed that would otherwise be rejected, if tested.

Misspecification of a system of share equations may result due to (a) an incorrect specification of the functional form of the share equations (e.g., using a generalized Leontief form, when technology of the generating process is translog form or vice versa), and/or to (b) a correctly specified functional form but with some of the relevant explanatory variables omitted (e.g., lagged dependent and independent variables). The type (b) misspecification is discussed below in detail.

It is possible that the integrability conditions can be rejected even though the long-run system of share equations is correctly specified. This situation may occur when the observed share values do not correspond to long-run optimum values. The assumption that agricultural production sectors are operating at a long-run equilibrium state cannot be easily supported. The data are more likely being generated from a dynamic production process. The presence of dynamics in the production process may result from the inability of producers to adjust instantaneously to changes in the economy. Adjustment lags occur because of the existence of costs of adjustment and costs of obtaining information (Anderson and Blundell 1982). Furthermore, outputs are not realized instantly at the time of input decisions. Therefore, producers tend to forecast output and prices on the basis of past experiences.

Based on the above discussion, dynamics enter the production process in two ways (Antle 1986): output may be a function of current and past inputs because of costs of adjustment (Lucas (1967) or time taken to build (Kydland and Prescott (1982)); and output may depend on past output produced because of the models of learning-by-doing (Arrow (1962) and multi-stage production (Long and Plosser (1983), Antle (1983)).

Integrability conditions can be rejected as discovered in this study (Chapter 3 and Chapter 4) in circumstances when a static system of share equations are estimated when in fact the data seem to have been generated by a dynamic production process. Therefore, a model based on a dynamic system of share equations like those used in the studies by Anderson and Blundell (1982) and Nakamura (1985) are considered for this study. One of the interesting properties of this model is in fact that a static model is nested within it and thus restricted model suitability can be tested. Further long-run (static) parameters are also readily available from the estimated parameters of the dynamic model.

2.2 SYSTEM OF DYNAMIC SHARE EQUATIONS

When a static model is fitted, it is assumed that the data is generated from a production process operating at a long-run optimum (equilibrium) state. Therefore, in the estimation of the system of equations (7), it assumed that

$$E_s[\ S(t)|\ X(t)\ ] = S^0 \qquad (10)$$

where the subscript s indicates that the expectation is taken for the static model (7). However, based on the discussion above, the data may have been generated by a dynamic process. Thus, if a static model is estimated, some of the explanatory variables (lagged input price and output quantity indexes) may have been omitted and assumption (7) may not hold.

Based on Nakamura (1985), assumption (10) is replaced by[3]

$$E_d[\ S(t)|\ X(s) = X^*,\ \tau = \tau^*,\ s \le t\ ] = S^0 \qquad (11)$$

where d denotes that expectation taken under a dynamic model. Assumption (11) means that if prices, state of technology and output for periods preceding the current one are constant, then the expected share values of a dynamic model are long-run optimum values. This assumption also implies that

$$E_d[\ S(t)|\ X(s) = X^*,\ \tau = \tau^*,\ s \le t] = E_s[\ S(t)|\ X(t) = X^*] \qquad (12)$$

This follows from the fact that if the exogenous variables are constant

[3] Nakamura (1985) did not have time trend variable τ as an explanatory variable in his model. However, he stated that inclusion of the time trend variable in the assumption (equation (11)) is consistent with the assumption without the time trend variable.

for all preceding periods and the present period, then the production process is in fact static.

There is a group of models, known as stationary multivariate autoregressive models, ARX(r,r) of order r which satisfy assumption (11). These models were first considered by Anderson and Blundell (1982) for the estimation of a singular system of share equations. One of the interesting properties of these models is that estimates of the long-run parameters are readily available from the estimated parameters. A general form of system of equations based on ARX(r,r) is given by

$$S(t) = \gamma + \Phi_1 S(t-1) + \ldots + \Phi_r S(t-r) + \Gamma_1 X(t) + \Gamma_2 X(t-1) + \ldots + T_r X(t-r) + \delta\tau + \varepsilon(t) \quad (13)$$

To fit an ARX model of order $r \geq 2$, a very large data set is required. For a time series data set it is usually not possible. For this study, with four aggregated factor categories, only $r = 1$ is considered because of data limitations. A system of share equations based on ARX(1,1) is given by

$$S(t) = \gamma + \Phi_1 S(t-1) + \Gamma_0 X(t) + \Gamma_1 X(t-1) + \delta\tau + \varepsilon(t) \quad (14)$$

where γ, Φ_1, Γ_0, Γ_1, δ are matrices of unknown constants of order $n \times 1$, $n \times n$, $n \times (n+1)$, $n \times (n+1)$ and $n \times 1$ respectively. $\varepsilon(t)$ is a $n \times 1$ [n is equal to four for this study] vector of random errors of $N(0,\Omega)$, where Ω is a variance-covariance matrix.

Additivity of share equations

$$i^T S(t) = 1$$

implies the following restrictions on the parameters (unknown constants) of equation (14) where i is a sum vector of order $n \times 1$.

$$i^T\gamma = 1 - k$$

$$i^T\Phi_1 = ki^T$$

These specifications imply that every column of Φ_1 sums up to the constant k which is unknown.

$$i^T\Gamma_0 = i^T\Gamma_1 = 0i^T = (0,0,\dots,0)$$

$$i^T\varepsilon(t) = 0$$

This specification and the assumption that $\varepsilon(t)$ follows $N(0,\Omega)$ implies that

$$i^T\Omega i = 0$$

In other words, the variance-covariance matrix, Ω, is singular. Therefore, the system of equations represented by model (14) is singular. To estimate the parameters of model (14) , a transformation of the parameters must be made so that the transformed system is non-singular. This issue is considered below. A relationship between the parameters of the system of equations specified by (7) and (14) exists because of assumption (12). Assumption (12) is required to estimate the parameters of (7) from the estimated model (14). If $X(s) = X^*$ and $\tau = \tau^*$ for all $s \leq t$, then from (14) one has

$$E[S(t)|\ X(s) = X^*,\ \tau = \tau^*,\ s \leq t] = E[S(t-1)|\ X(s) = X^*,\ \tau = \tau^*,\ s \leq t]$$

and

$$E[S(t)|\ X(s) = X^*,\ \tau = \tau^*, s \leq t] = \lambda + \Gamma_0 X^* + T_1 X^*$$
$$+ \Phi_1 E[S(t-1)|\ X(s) = X^*,\ \tau = \tau^*, s \leq t] + \delta\ \tau^*$$

Assuming $(I-\Phi_1)$ is non-singular, where I is an identity matrix of order n, the above can be written as

$$E[S(t)|\ X(s) = X^*,\ \tau = \tau^*,\ s\leq t] = (I-\Phi_1)^{-1}\lambda$$
$$+ (I-\Phi_1)^{-1}(\Gamma_0 + \Gamma_1)X^* + (I-\Phi_1)^{-1}\delta\tau^* \qquad (15)$$

From (7) one has

$$E[S^{*}(t)|X(t)=X^{*}]= \alpha + \Pi X^{*} + \theta \tau^{*} \tag{16}$$

Under assumption (12), equations (15) and (16) imply that

$$\alpha = (I-\Phi_1)^{-1}\lambda,\ \Pi = (I-\Phi_1)^{-1}(\Gamma_0+ \Gamma_1),\ \text{and}\ \theta = (I-\Phi_1)^{-1}\delta \tag{17}$$

Substituting the conditions of (17) into model (14), one obtains

$$S(t) = (I-\Phi_1)\alpha + \Gamma_0 X(t) +\Phi_1 S(t-1) + ((I-\Phi\ )\Pi - \Gamma_0)X(t-1) + (I-\Phi_1)\theta\tau + \varepsilon(t) \tag{18}$$

or

$$S(t) = (I-\Phi_1)\alpha + \Phi_1 S(t-1) + +\Gamma_0 \Delta X(t) + (I-\Phi\ )\Pi\ X(t-1) +(I-\Phi_1)\theta\tau + \varepsilon(t) \tag{19}$$

where $\Delta X(t) = X(t) - X(t-1)$ represents the first difference of $X(t)$. The parameters of model (19) follow the additivity restrictions described for models (7) and (14). Consequently, the system of equations specified by model (19) is singular.

Model (19) has several interesting properties. The estimation of long-run parameters, α, Π and τ, is readily available. Further, several well known models used in some previous studies of this kind are nested within model (19) [Anderson and Blundell (1982), Nakamura (1986)].

2.3 MODELS NESTED WITHIN THE DYNAMIC MODEL

Three models nested within the dynamic models are discussed below.

2.3.1 PARTIAL ADJUSTMENT MODEL

The dynamic system of equations (19) reduces to a system of share equations corresponding to the partial adjustment model, if $\Gamma_0= (I-\Phi_1)\Pi$ and is given by

$$S(t) = (I-\Phi_1)\alpha + \Phi_1 S(t-1) + (I-\Phi_1)\Pi X(t) + (I-\Phi_1)\theta\tau + \varepsilon(t) \qquad (20)$$

The more popular form of this partial adjustment model used in the literature is

$$(I-\Phi_1) = \Phi.$$

2.3.2 AUTOREGRESSIVE PROCESS FOR THE DISTURBANCES

If $\Gamma_0 = \Pi$, the dynamic model (19) reduces to a system of share equations with errors following an autoregressive process of order one. AR(1) is given by

$$S(t) = (I-\Phi_1)\alpha + \Phi_1 S(t-1) + \Pi X(t) - \Phi_1 \Pi X(t-1) + (I-\Phi_1)\theta\tau + \varepsilon(t) \qquad (21)$$

This is the model developed by Berndt and Savin (1975) with notation difference that Φ_1 in (21) is equal to R.

2.3.4 STATIC MODEL

If $\Gamma_0 = \Pi$ and $\Phi_1 = 0$, then dynamic model (19) reduces to static model (7).

2.4 ESTIMATION

An objective of this study is to estimate a model following the parsimony principle. In other words, the estimated model should be the one which fits the data adequately, but involves the least number of parameters. The competing models are (19) through (21). All of the models are singular because of additivity. Further, the maximum likelihood estimation procedure is used to estimate these models because of non-linearity of the parameters. Models (19) through (21) can be made non-singular by dropping one of the equations. However, whether the estimates of parameters are invariant to the equation dropped and whether the estimates of the parameters of the dropped equation are identifiable from the estimates of parameters of the remaining n-1 equations are two questions to be considered. The answers are discussed in Barten (1969), Berndt and Savin (1975), Anderson and Blundell (1982) and Nakamura (1985). The next two subsections briefly discuss their conclusions.

2.4.1 INVARIANCE

Vector $\varepsilon(t)$ of model (19) follows a normal distribution with mean zero and variance-covariance matrix Ω. The density of vector $\varepsilon(t)$ is given by

$$f(\varepsilon(t)) = (2\pi)^{-\frac{1}{2}n} \quad |\Omega|^{-\frac{1}{2}} \exp\left\{ - \frac{1}{2}\, \varepsilon'(t)\ \Omega^{-1}\varepsilon(t) \right\} \tag{22}$$

However, the above density does not exist because Ω is singular (Anderson (1974) p25). If all of shares are non-zero, the system of equations can be made non-singular by dropping one of the equations (say the n^{th}). Let the superscript, n, in the following equations denote the vectors and matrices of the system of share equations with the n^{th} equation dropped and the resulting variance-covariance matrix of error vector be denoted by Ω_n. The density of vector $\varepsilon^n(t)$ can be written as

$$f(\varepsilon^n(t)) = (2\pi)^{-\frac{1}{2}(n-1)} \quad |\Omega_n|^{-\frac{1}{2}} \exp\left\{ - \frac{1}{2}\, \varepsilon^n(t)'\ \Omega_n^{-1}\varepsilon^n(t) \right\}$$

The log likelihood function of $\varepsilon^n(t)$ ($t = 1,2,\cdots,T$) is given by

$$L(\varepsilon^n(t)) = (2\pi)^{-\frac{1}{2}T(n-1)} \left|\Omega_n\right|^{-T\frac{1}{2}} \exp\left\{ -\frac{1}{2}\sum_{t=1}^{T} \varepsilon^n(t)' \, \Omega_n^{-1}\varepsilon^n(t) \right\} \qquad (23)$$

The objective here is to show that maximum likelihood estimates based on the above likelihood does not depend on which equation is dropped. Let E_n be an n × n matrix defined as

$$E_n = \begin{bmatrix} I & -i \\ -i' & -1 \end{bmatrix}$$

where I is an n-1 × n-1 identity matrix and $i' = (1,1,\cdots 1)$ is an 1xn-1 sum vector. E_n is a symmetric non-singular matrix and the determinant is -n. Let ε_i and σ_{ij} denote the i^{th} and $(i,j)^{th}$ elements of $\varepsilon(t)$ and Ω, respectively.

Therefore, additivity implies that

$$\sigma_{in} = -\sum_{j=1}^{n-1} \sigma_{ij}$$

Further, it follows that

$$E_n \begin{bmatrix} \Omega_n & 0 \\ 0 & \frac{1}{n} \end{bmatrix} E_n = \Omega + \frac{1}{n}\, ii'$$

where the right-hand side matrix is non-singular (see Barten (1969) p.25). Also, note that

$$\left|\Omega + \frac{1}{n}\, i\, i'\right| = \left|E_n\right|^2 \left|\Omega_n\right| \frac{1}{n}$$
$$= n\left|\Omega_n\right| \qquad (24)$$

and that

$$\varepsilon^n(t)' \, \Omega_n^{-1} \, \varepsilon^n(t) = [\ \varepsilon^n(t)' \ \ 0\ ] \begin{bmatrix} \Omega_n & 0 \\ 0 & \frac{1}{n} \end{bmatrix}^{-1} \begin{bmatrix} \varepsilon^n(t) \\ 0 \end{bmatrix}$$

$$= [\ \varepsilon^n(t)'\ 0\ ]\ E_n(\ \Omega + \frac{1}{n}\ ii')^{-1}E_n \begin{bmatrix} \varepsilon^n(t) \\ 0 \end{bmatrix}$$

$$= \varepsilon(t)'\ (\ \Omega + \frac{1}{n}\ ii')^{-1}\varepsilon(t) \qquad (25)$$

By substituting (24) and (25) into (23) one has

$$L(\varepsilon^n(t)) = n^{\frac{T}{2}}(2\pi)^{-\frac{1}{2}T(n-1)} |\Omega + ii'|^{-T\frac{1}{2}} \exp\left\{-\frac{1}{2}\sum_{t=1}^{T} \varepsilon(t)'(\Omega + \frac{1}{n}ii')^{-1}\varepsilon(t)\right\} \qquad (26)$$

From (25), it becomes apparent that any equation can be brought to the n^{th} position and dropped and its likelihood would be equivalent to the right hand side of (26). In other words, likelihood does not depend on which equation is dropped. This leads to the conclusion that maximum likelihood estimates are invariant to the equation dropped in order to make the system of share equations non-singular.

2.4.2 IDENTIFICATION

The identification of a model determines whether the estimates of the parameters of the complete system of equations are uniquely identified from the estimates of the non-singular system of equations, as a result of dropping one of the equations. Let G be an $n\times(n-1)$ matrix obtained from E_n by deleting its last column and e be an nx1 unit vector with unity as the n^{th} element (Nakamura (1985). The following conditions hold for model (15) because of additivity

$$S(t) = e + G\ S^n(t)\ ,\ \alpha = e + G\ \alpha^n,\ \Pi = G\ \Pi^n,\ \Gamma_0 = G\ \Gamma_0^n,$$
$$\text{and } \varepsilon(t) = G\ \varepsilon^n(t)$$

Substituting the above into (15) and simplifying

$$GS(t) = (I-\Phi_1)G\ \alpha^n + \Phi_1 G\ S^n(t-1) + G\ \Gamma_0^n\ \Delta X(t)$$
$$+ (I-\Phi_1)\ G\Pi^n X(t-1) + (I-\Phi_1)\ G\theta^n\tau + G\ \varepsilon^n(t)$$

This system consists of n equations, one of which is redundant because of additivity (singularity). By dropping the n^{th} equation, the above system of equation reduces to

$$S^n(t) = (I-D)\,\alpha^n + D\,S^n(t-1) + \Gamma_0^n\,\Delta X(t)$$
$$+ (I-D)\,\Pi^n X(t-1) + (I-D)\,\theta^n \tau + \varepsilon^n(t) \qquad (27)$$

D is an n-1 × n-1 matrix obtained from $\Phi_1 G$ by dropping its last row and is given by

$$D = \begin{bmatrix} \Phi_{11} - \Phi_{1n} & \Phi_{12} - \Phi_{1n} & \cdots & \Phi_{1n-1} - \Phi_{1n} \\ \Phi_{21} - \Phi_{2n} & \Phi_{22} - \Phi_{2n} & \cdots & \Phi_{2n-1} - \Phi_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \Phi_{(n-1)1} - \Phi_{(n-1)n} & \Phi_{(n-1)2} - \Phi_{(n-1)n} & \cdots & \Phi_{(n-1)(n-1)} - \Phi_{(n-1)n} \end{bmatrix}$$

The system of equations (27) is the non-singular transformation of model (19). Model (27) and its subsets are estimated by using the maximum likelihood estimation procedure. However, there is the question of whether the estimates of the model corresponding to (19) can be identified from the estimates of (27). The answer is no because the estimates of Φ cannot be identified from the estimates of D (Berndt and Savin (1975), Anderson and Blundell (1982) and Nakamura (1985)). The estimates of remaining parameters can uniquely be obtained from the estimated parameters of model (27). The objective of this study is to obtain estimates of the long-run parameters, the non-identification of Φ has no serious effect on such estimation.

2.5 MODEL SPECIFICATION, ESTIMATION AND DIAGNOSTIC TESTING

A correct theoretical model can be specified only if the physical and economic nature of the agricultural sector to be analyzed is completely understood. This, in reality, is not practical to achieve. A purely empirical model is one which is selected entirely on the basis of statistical procedures applied to data available for the Alberta and Canadian agricultural sectors. However, a purely empirical model will not be of much use for economic analysis of the sectors. A model building technique that lies between an exact theoretical model and exclusively empirical model; an iterative model building technique based on work by Box and Jenkins (1976) will be used here.

The iterative model building technique to be used involves the following stages:

(a) Postulation of a class of models based on information of the economic and physical nature of the agricultural sector;

(b) Tentative selection of a model from the postulated class of models with the objective of selecting the simplest and most satisfactory model possible following the parsimony principle;

(c) Estimation of the tentative model; and

(d) Model diagnostic checking.

Various tests of statistical assumptions and economic restrictions of the model are made in this stage. Tests to check whether any improvement is made in estimating the model in question over the nested models if there exists any, will be performed. The motive for this test is to check whether significant improvement is being made in selecting a model over nested models. The nested models may already be rejected because of rejection of economic and statistical restrictions. Therefore, if a model is to be selected over nested models then nested models should be rejected with respect to the model. Likelihood ratio test statistics will be used to test for the nested models.

If the model passes the tests in the diagnostic checking stage, then it will be selected for economic structural analysis. If the tentative model is found to be inadequate, the iterative cycle of tentative identification, estimation and diagnostic checking is repeated until a suitable model is selected from the class of postulated models.

2.6 STAGES OF THE ITERATIVE MODEL BUILDING TECHNIQUE

Each of the stages of the iterative model building technique are described in more detail below.

2.6.1 POSTULATION OF A CLASS OF MODELS

Based on the methodology of this study, a class of postulated models consists of the following models which are defined in this chapter:

a system of static translog share equations;

a system of partial adjustment translog share equations;

a system of share equations with autoregressive errors; and

a system of mutivariate autoregressive translog share equations, ARX(1,1).

2.6.2 IDENTIFICATION OF A TENTATIVE MODEL

The simplest model from the class of postulated models is selected as a tentative model. The relative simplicity of a model is defined here as one involving the least number of parameters to be estimated and ease of estimation. The models listed above are ordered by increasing complexity with exception that partial adjustment and autoregressive errors models are of equal complexity as both involve the same number of parameters. Further, none of these two model is not nested in other. At stage 1 of iteration 1, a system of static translog share equations is selected as a tentative first model for estimation because of its relative simplicity.

2.6.3 ESTIMATION OF THE TENTATIVE MODEL

The parameters of the tentative model are estimated using the maximum likelihood estimation procedure. At each iteration three forms of the tentative model are estimated; an unrestricted form, a homogeneous form, and a homogeneous and symmetric form. One of the share equations is dropped for each form of the model to take care of the singularity of the system of equations caused by their additivity.

2.6.4 DIAGNOSTIC CHECKING

The objective is to select and estimate the model which satisfies the statistical assumptions and the regularity conditions defined earlier in this chapter. A further objective of this study is to undertake economic analysis based on the estimated model. Therefore, a model which satisfies all the desirable statistical properties but fails to satisfies economic restrictions will still be rejected. Economic restrictions, therefore, will be tested first. If the restrictions are not rejected by the model then the statistical diagnostic tests will be performed on the model.

Diagnostic tests for a statistically good fit are however discussed first. To test whether errors for each equation are white noise, residual autocorrelation and partial autocorrelation plots are used. Other tests that could have been used were the multivariate portmanteau tests by Hosking (1980) and Li and McLeod (1981) which are developed to check for adequacy of fitted multivariate autoregressive moving average models. However, these tests are not utilized in this study. Normal probability plots are used to test for normality of the error terms. These tests are performed only on the homogeneous, symmetric model because it is this model that is of most interest.

An homogeneous model is nested in the most unrestricted model and a symmetric model is nested in the homogeneous model. Homogeneity is automatically imposed due to additivity when symmetry is imposed on the model. The objective is to check whether homogeneity and symmetry restrictions are satisfied by the model in question. Therefore, first a test of homogeneity and symmetry (imposed simultaneously on the unrestricted model) is performed. If the test results in rejection then homogeneity and symmetry are tested separately to see whether one or both of these restriction are rejected. The likelihood ratio tests are used since the restricted models are nested in the model without the restrictions in question. The following hypotheses are defined to test for these regularity conditions:

H_0: The model satisfies the homogeneity and symmetry restrictions;

against

H_A: The model does not satisfies the homogeneity and symmetry restrictions.

The hypothesis to test for the regularity restrictions separately are:

H_{01}: The model is homogeneous; against

H_{A1}: The model is not homogeneous; and

H_{02}: The homogeneous model is symmetric; against

H_{A2}: The homogeneous model is not symmetric.

Let Θ denote the parametric set of the model. Then Max loglik $\{\Theta_{01}\}$ denotes the maximum likilihood of the model under H_{01}. Let

$$\log \lambda = \text{Max loglik } \{\Theta_{0}\} - \text{Max loglik } \{\Theta_{A}\}$$

$$\log \lambda_1 = \text{Max loglik } \{\Theta_{01}\} - \text{Max loglik } \{\Theta_{A1}\}$$

$$\log \lambda_2 = \text{Max loglik } \{\Theta_{02}\} - \text{Max loglik } \{\Theta_{01}\}$$

Further $-2 \log \lambda$, $-2 \log \lambda_1$ and $-2 \log \lambda_2$ are likelihood ratio test statistics for tests of the hypotheses stated above respectively. They follow χ^2 distributions with q, q_1 and q_2 degrees of freedom respectively. Here, q is the number of restrictions applied to the unrestricted model to obtain an homogeneous and symmetric model, q_1 is the number of restrictions applied to the unrestricted model to obtain the homogeneous model and q_2 is the number of independent restrictions imposed on the homogeneous model to obtain the homogeneous and symmetric model.

If the model passes all of the above tests, it is selected for further economic analysis. Otherwise, some other model from the class of postulated models is selected as a new tentative model (stage 2.6.2). Stages 2.6.3 and 2.6.4 are repeated until a satisfactory model is determined. If there is no satisfactory model, a new class of postulated models is specified and the iterative model building technique is performed again.

2.6.5 GOODNESS OF FIT TESTS FOR THE NESTED MODELS

Once a model is selected which satisfies the economic restrictions and diagnostic checks, it can be taken as the maintained hypothesis model to further check whether this model fits the data significantly better than the nested model (with economic restrictions). The objective of this test is to evaluate the model and decide whether the maintained hypothesis model is just a marginally better or a significantly better fit than the nested models. The likelihood test ratio test will be used to test the goodness of fit of the maintained hypothesis model as compared to the nested models. Akaike Information Criterion (AIC) will also be used to perform the goodness of fit test. The AIC can be used for testing nested as well as non-nested models. AIC will be useful if partial adjustment or autoregressive error for disturbances models are selected since theses models are not nested in each other. AIC is defined as (Harvey 1981)

$$AIC = -2 \log lik \{\hat{\Theta}\} + 2K$$

where K is the total number of parameters estimated and log lik $\{\hat{\Theta}\}$ is the maximum log likelihood estimate. The decision rule is to accept the model with the minimum AIC. This test makes appropriate allowance for parsimony of the model since it involves both max likelihood estimate as well as the number of parameters estimated (Harvey 1981).

However, it should be noted that some of the nested models considered are obtained by putting restrictions on D (e.g., a static model is obtained from the ARX(1,1) model if D = 0 and $\Gamma_0 = \Pi$). As noted earlier Φ is not identifiable (Nakamura 1985, Berndt and Saving 1975). Following Nakamura (1985) and Berndt and Saving (1975) , restrictions on D are only necessary and are not sufficient. For example $\Phi = 0$ implies that D = 0 and the converse is not true since D = 0 implies that elements of Φ in each row are equal for the n-1 rows (i.e.,without the dropped nth row, i.e, for n-1 rows only).

2.7 ECONOMIC STRUCTURAL ANALYSIS

In this section parameters of the structure of technology are discussed. The parameters under investigation are technological change, homotheticity, and substitution and own-price elasticities.

2.7.1 TECHNOLOGICAL CHANGE

Measurement of the rate of technological change is important for the economic analysis of sectors over time. Different measures of technological change have been defined in past. Different techniques in estimating those measures have also been developed. However, before deciding how to measure technological change, it is necessary to define technological change. Thirtle and Ruttan (1987) defined technical progress as an increase in output from the same quantity of inputs or equivalently, a decrease in inputs required to produce a given level of output. Thirtle and Ruttan (1987) discussed the advantages and disadvantages of this definition of technological change. One of the disadvantages pointed out was that technological change does not always affect every input factor equally, giving rise to the issue of technological bias. This has led various economists to seek to define technical change differently.

Hicks defined technological change in the case of two factor inputs as labor saving, neutral or using if the proportional change in the capital-labor ratio is increasing, constant, or decreasing respectively at constant factor prices. Binswanger (1974) defined bias in technological change in terms of changes in share equations for the case of more than two inputs. Binswanger defined technical change as i^{th} factor using, neutral or saving, if $B_i > 0$, $B_i = 0$ or $B_i < 0$ respectively, where B_i is defined as

$$B_i = \frac{dS_i}{dt} \frac{1}{S_i}$$

where S_i is the i^{th} factor share and for this share change, relative factor prices are held constant. Moroney and Trapani (1981) used this definition of technological change for the case of a translog form cost model to infer bias of technological change in natural resource intensive industries. Adamowicz (1985) and Lopez (1980) also used the above definition to estimate technological change in the Canadian agricultural sector.

The procedure used in this study to estimate technological bias in the Alberta and Canadian agricultural sectors is based on Binswanger's definition supported by the above studies. The time trend variable τ is tested for significance in the system of long-run share equations. If the estimate of long-run coefficient θ is not significant, it can be concluded that bias of technological change is neutral. Otherwise, biases of technological change will depend on the sign of the estimated coefficients of the time index in their respective share equations. The assumption that bias of technological change is constant over the time period of the study is a disadvantage of this technique.

2.7.2 HOMOTHETICITY

Shephard (1953, 1970) generalized the concept of linear homogeneity of a production function to the homotheticity of a production function. A production function f(.) [Shephard (1970), Fuss and McFadden (1978)] is homothetic if f(w) is of the form

$$q = f = f(g(w))$$

where g(w) is positive homogeneous of degree one in w (vector of factors of production) in addition to regular properties of the production function and f(.) is a monotonic increasing function. Following Shephard (1953, 1970), homothetic production functions are useful for the study of returns to scale. A homogeneous production function is a special case of a homothetic production function. A homothetic production function has a special property in which the expansion path is a ray from origin (Shephard (1970), proposition 8, page 34). Therefore, marginal rates of technical substitution for a homothetic production structure do not depend on the scale of production.

Shephard (1953, 1970) proved that a cost function for a homothetic production structure can be written as

$$C(q,p) = c(q).P(p)$$

where P(p) is homogeneous of degree one in the price vector p [for the properties of c(q) and P(p) see Shephard (1970) pages 92-94]. This form of the cost function implies certain economic properties: the ratio of

any two factor demand equations are independent of the output level (this can easily be seen by applying Shephard's Lemma) and the elasticity of the total cost function is independent of factor prices. Therefore, a cost function corresponding to a homothetic production structure is restrictive. It is desirable to test the hypothesis of homotheticity rather than to take it as a maintained hypothesis as even Shephard summarized that "*Perhaps one should seek tests for homotheticity in econometrics.*" [Shephard 1970 pg. 36].

Most of the studies mentioned above did test for homotheticity. For the case of a translog cost function, homotheticity of the long-run production structure implies that $\gamma_{iq} = 0$, for i = 1,2,•••,n. Therefore, in order to test the hypothesis, one first estimates the system of share equations corresponding to a non-homothetic production structure, then estimates of the system of share equations with restrictions γ_{iq} = 0, for i = 1,2,•••n, and then uses the likelihood ratio test statistic. The dynamic system of share equations with the restrictions is a dynamic system of share equations corresponding to a long-run homothetic production structure. The system of share equations corresponding to the homothetic production structure is nested within the non-homothetic system of share equations. Most earlier studies have rejected homotheticity.

An hypothesis of constant returns to scale is automatically rejected when the hypothesis of homotheticity is rejected. This follows from the fact that returns to scale is defined in terms of degree of homogeneity of the production function. In addition, an homogeneous production function of any degree is homothetic (Chambers 1988), however, the opposite is not true. Therefore, rejection of homotheticity implies rejection of constant returns to scale.

The non-homothetic production structure does not provide a measure of returns to scale since the level of scale of production depends on the relative proportions of the input factors used. Nevertheless, inferences regarding the relationships between scale of production and particular factor inputs can be drawn.

2.7.3 ELASTICITIES

Estimates of own-price elasticities and elasticities of substitution between factor inputs of an industry are important to structural and policy analyses.

In economic analysis, it is useful to have a measure of how "substitutable" one factor input is for another. The most frequently used measure of substitutability is elasticity of substitution. Arrow et.al (1981, Vol. II) defined elasticity of substitution between two factor inputs x_1 and x_2, when all other inputs are held constant as the elasticity of the ratio of the factors with respect to the marginal rate of technical substitution. Varian (1984) and Arrow et al. pointed out that this definition is problematic in cases of a three or more factor production process, and in such cases only the concept of partial elasticity of substitution among the inputs can be defined. Arrow et al. have stated that the two best known measures are *the direct elasticity of substitution* and *the Allen partial elasticity of substitution.* The Allen partial elasticity of substitution estimators have been used in various studies: Binswanger (1974), Islam and Veeman

(1980), Lopez (1980), Morney and Trapani (1981), Adamowicz (1985). For factor i and j the elasticity of substitution is defined as

$$\sigma_{ij} = \frac{C\,C_{ij}}{C_i C_j}$$

where $C_i = \frac{\partial C}{\partial p_i}$ and $C_{ij} = \frac{\partial C_i}{\partial p_j}$ and for the long-run translog cost function, it can be easily written as

$$\sigma_{ij} = 1 + \frac{\Pi_{ij}}{S_i S_j}$$

where S_i is the i^{th} share and Π_{ij} is the i,j^{th} element of the matrix Π of the long-run parameters of the share equations. The σ_{ij} is the estimator of the long-run elasticities of substitution between factors i and j ($i < j$ and $= 1,2,3,4$).

From Moroney and Trapani(1981) and the various other studies mentioned above, own-price elasticities can be written as

$$\eta_{ii} = S_i + \frac{\Pi_{ii}}{S_i} - 1$$

Moroney and Trapani (1981), pointed out that estimates of own-price elasticities are important from a policy point of view, since they are a measure of the proportionate reduction of a factor input in response to a given proportionate increase in the factor price. The more substitutable a factor is with other factors, the greater the opportunity to conserve it, especially in the case of the increase in scarcity of that factor.

The above definitions do not incur any difficulty provided that a static system of share equations fits the data in question. However, if a static model does not fit the data well enough and one of the other models (ARX(1,1), partial adjustment model or the autoregressive error) is selected, a question arises whether it is valid to use the observed values of S(t) or estimated values of shares from the model fitted. The answer is "no". As discussed in previous sections of this chapter, the observed share values may not correspond to the optimum long-run share values of the production process. Recall the objective of this study is to analyze the long term economic structure of the Alberta and Canadian agricultural sectors. To estimate long-run elasticities, the long-run values of the shares have to be used. However, the long-run values of the shares cannot be observed and have to be estimated. The long-run values of shares are obtained as

$$\hat{S}(t) = \hat{\alpha} + \hat{\Pi} X(t) + \hat{\theta} \tau \qquad (28)$$

Here, $\hat{\alpha}$, $\hat{\Pi}$ and $\hat{\theta}$ are maximum likelihood estimates of their respective parameters. In other words, estimates of long-run cost minimizing values of shares are obtained by using estimates of long-run parameters from the fitted model. Elasticities are calculated at mean expected values of shares $\hat{S}(t)$ for four sub-sample groups: 1959-68; 1969-78; 1979-88 for Canada (1979-87 for Alberta); and 1926-88 for Canada (1926-87 for Alberta). Mean expected values of long-run shares are given by

$$\bar{\hat{S}}(r) = \sum_{t=t_r}^{t_R} \hat{S}(t)/(t_R - t_r) \qquad (29)$$

where r stands for the sub-sample (r=1,2,3 and 4), t_r and t_R denotes respective lower and higher index year for the range. Estimates of elasticities of substitution and own-price are obtained by

$$\hat{\sigma}_{ij}(r) = 1 + \frac{\hat{\Pi}_{ij}}{\bar{\hat{S}}_i(r)\,\bar{\hat{S}}_j(r)} \tag{30}$$

and

$$\hat{\eta}_{ii}(r) = \bar{\hat{S}}_i(r) + \frac{\hat{\Pi}_{ii}}{\bar{\hat{S}}_i(r)} - 1 \tag{31}$$

To make statistical tests and inferences regarding the elasticities, the distributions and/or standard errors of the estimators of the elasticities are required. Making statistical decisions on the basis of point estimates (MLE estimates) alone could be misleading. For example, suppose the estimated elasticity of substitution between any two arbitrary inputs is a large positive value indicating that the two inputs are good substitutes. If the hypothesis of zero substitution is not statistically rejected because of a large estimated standard error, the above conclusion will be wrong.

In general, the distribution of the above estimators of elasticities is not a well behaved one. The estimators are the ratios of the normal variable ($\hat{\Pi}_{ij}$) and the product of two normal variables ($\hat{S}_i$ and $\hat{S}_j$). Under certain conditions, the distribution of the product of two normal variables is normal (see Anderson and Thurnsby (1986)). Further, the ratio of two independent normal variables follows the Cauchy distribution (Hogg and Craig (1978), p. 142), however, the mean and higher moments of the Cauchy density do not exist (Mood, Graybill and Boes (1974) p.117). Therefore, the estimators of elasticities do not have nice small sample properties. Therefore, some procedure other than a parametric method have to be used to obtain standard errors of estimates of elasticities since their analytic expressions are not available. In the past an asymptotic (Taylor's series) approximation has been used, however, Green and Hahn (1987) argued against this method. They used a non-parametric Effron's bootstrap method (Effron and Gong (1983)) to derive the standard errors of estimates of elasticities for a linear expenditure system. However, the bootstrap procedure is not suitable to obtain estimates of standard errors of elasticities for the system of share equations of ARX(1,1) and other dynamic models of translog functional form used in this study due to the complexity of the models. Therefore, a statistical simulation procedure will be used to obtain the standard errors of elasticities. A similar procedure had been utilized by Adamowicz et. al. (1989a, 1989b) to obtain variance of consumer's surplus for several functional forms of demand relations.

Let θ denote a vector of the parameters α and Π with $V(\theta)$ as the associated variance-covariance matrix. Further, let $\hat{\theta}$ and $V(\hat{\theta})$ denote the maximum likelihood estimators of θ and $V(\theta)$. Under certain regularity conditions $\sqrt{T}(\hat{\theta}-\theta)$ is asymptotic normal with mean zero and has a asymptotic variance covariance matrix $I^{-1}(\theta)$ (see Judge et. al (1984) p.178 and Cox and Hinkley (1974) Ch.9.2). This result is used to generate samples corresponding to the parameter $\hat{\theta}$ and the variance-covariance matrix $V(\hat{\theta})$. Specifically, 1000 samples from a multivariate normal distribution with mean $\hat{\theta}$ and variance-covariance matrix $V(\hat{\theta})$ are generated. Expected share values corresponding to each sample are obtained using equation (28). One thousand sets of elasticities are calculated using these expected shares and equations (29) and (30). Standard errors of estimates of elasticities are approximated to the standard deviations of the 1000 simulated elasticities.

The well known Central limit theorem (Hogg and Craig (1974)) states that "*if $X_1, X_2, \cdots X_n$ denote a random sample of size n from any distribution having positive variance σ^2 (and hence finite mean μ), then the random variable $\sqrt{n}\,(\bar{x}-\mu)/\sigma$ has a limiting normal distribution with mean 0 and unit variance.*" Therefore, large sample confidence intervals for estimates of elasticities can be constructed using the (1-α) percentile from a normal distribution. Hence, the (1-α)% confidence intervals for the estimated elasticities are given by

$$\bar{\sigma}_{ij} \pm Z_{\alpha}.\mathrm{S.E.}(\sigma_{ij})$$

$$\bar{\eta}_{ii} \pm Z_{\alpha}.\mathrm{S.E.}(\bar{\eta}_{ii})$$

Where $\bar{\sigma}_{ij}$ and $\bar{\eta}_{ii}$ are the average elasticities (for all i,j) and S.E($\bar{\sigma}_{ij}$) and S.E.($\bar{\eta}_{ii}$) are their respective standard errors generated from the simulated set of one thousand values of elasticities. If zero lies in the confidence interval, then the hypothesis of zero elasticity is not reject at (1-α)% level of significance.

The methods detailed here dictate the data requirements necessary to achieve the estimation of parameters for both the Canadian and Alberta agricultural production sectors. The following section describes the data acquired and their transformations for use in methods application.

2.8 DATA DESCRIPTION

This study utilizes secondary data which were originally assembled by T. W. Manning for his work [Manning (1985, 1986a, 1986b)] on the Alberta and Canadian agricultural sectors. Most of the data were obtained from various Statistics Canada publications but augmented by unpublished data from Alberta Agriculture and Statistics Canada. The original data sets covered the period 1926 to 1984. For the purposes of this study, the Alberta data are updated to 1987 and Canadian data set to 1988. A detailed description of the data on Alberta agriculture is given in Manning (1986a, 1986b). A complete list of input and output commodities and their sources is given in Appendix 1. Notes on procedures to estimate missing data for some commodities are also provided in Appendix 1.

Data on prices and quantities of outputs produced and inputs used in the agricultural production sectors of Alberta and Canada are required. Actual production data for most of crops (see Appendix 1) were available until 1984. Average farm prices of major crops after 1984 for Alberta are obtained from Alberta Agriculture. Prices for Canada are estimated using weighted average processes on the information available in Statistics Canada publication 22-200 (Appendix 1). Data on the values of most inputs are available from Statistics Canada publications. If average prices are not available then price indexes from various Statistics Canada publications are used. Data on quantities of inputs are obtained by dividing values by prices. Annual values of unpaid labor and owned land are estimated from the residual values reflecting the differences between total output values and total values of of remaining inputs [for details see Appendix 1].

Estimation of a system of share equations of a translog cost function is undertaken in this study. Therefore, data on output indexes, as well as share and input price indexes of selected aggregated input categories are required. The four input categories are capital, intermediate goods, labor, and land and building structures.

Capital input is the aggregate of depreciation, repairs on machinery and 15% of the beginning inventories of livestock. Labor is the aggregate of hired and unpaid (including family) labor. Land and building structures is the aggregate of land owned and rented, and depreciation and repairs of building structures on farms. All other inputs such as feed, seed, fuel, fertilizers,chemicals, electricity, financial expenses etc., are aggregated into the intermediate goods categories. Complexity, especially with regard to a model of system of share equations of a multivariate autoregressive process of order one creates a degrees of freedom problem if more than four input aggregates are used.

The Tornqvist indexing procedure, which is an approximation of the Divisia continuous procedure [Christensen (1975), Diewert (1978), Isalam and Veeman (1980), Manning (1985, 1986b)], is used to obtain the four aggregated input price and share values, along with output quantity indexes. The Tornqvist price index is defined as

$$\log\ (\ p(t)/p(t-1)) = \sum_i \bar{S}_i(t).\log\ (p_i(t)/p_i(t-1))$$

where

$$S_i(t) = \{\ p_i(t)w_i(t)\ \} \ /\ \{\ \sum_j p_j(t)w_j(t)\ \}$$

and

$$\bar{S}_i(t) = \{ S_i(t) + S_i(t-1)\} / 2$$

$p_i(t)$ and $w_i(t)$ are the price and quantities of i^{th} input.

The resultant transformed data sets for the Alberta and Canadian agricultural sectors are used to obtain parameter estimates described above. The next two chapters present the estimated model and results for the Canadian and Alberta agricultural sectors, respectively.

Chapter 3

A MODEL FOR THE CANADIAN AGRICULTURAL SECTOR

In this chapter, a model of the Canadian agricultural production sector is developed. Selection of a model is based on the parsimony principle. The iterative model building technique, described in Chapter 2, based on the Box and Jenkins (1976) procedure, is utilized. A system of share equations corresponding to a translog cost function is estimated. The share equation for land and building structures is arbitrarily dropped because of additivity. The order of model selection progresses from the simplest to the more complex model from the class of competitive models outlined in the methodology chapter (Chapter 2).

Anderson and Blundell (1982) and Nakamura (1985) tested homotheticity and symmetry simultaneously only. However, homogeneity and symmetry restrictions are tested simultaneously as well as separately herein. Testing these restrictions separately is necessary because rejection of any one of the two restrictions could result in the rejection of the simultaneous hypothesis. If homotheticity and symmetry restrictions are rejected when tested simultaneously, then these restrictions will be tested separately to decide whether one or the other or both of the restrictions are to be rejected. Homogeneity will be tested first, since it is imposed automatically due to additivity when symmetry restrictions are applied.

Maximum log-likelihood estimates for the models under consideration and likelihood ratio test statistics for various tests are presented in Table 3.1a. Hypotheses of homotheticity and neutral technical change are presented in section 3.2. Estimates of Allen partial elasticities of substitution and own-price elasticities along with their confidence intervals are presented in section 3.3.

3.1 MODEL SELECTION

Data on the prices of factor inputs are aggregated into four categories and output quantities are aggregated into one quantity index using the Tornqvist indexing procedure, which is an approximation of the Divisia continuous index described in Chapter 2. The four input categories are capital, intermediate goods, labor , and land and building structures. The following notations will be used;

$p_1(t)$ = aggregate price of capital at time t;

$p_2(t)$ = aggregate price of intermediate goods at time t;

$p_3(t)$ = aggregate price of labor at time t;

$p_4(t)$ = aggregate price of land and building structures at time t:

$q(t)$ = aggregate quantity index at time t ;

τ = time trend index.

3.1.1 STATIC MODEL

First, the most unrestricted static model corresponding to equation (7) is estimated using maximum likelihood estimation procedures[4]. From (7) the system of share equations can be written as

$$S(t) = \alpha + \Pi\, X(t) + \theta\, \tau + v(t)$$

where n = 4 is the number of equations and t = 1, 2, ···,63 (years 1926

[4] Computer software package Shazam is used to estimate all the models.

to 1988). Equation four (for land and building structures) is arbitrarily dropped to correct for singularity caused by additivity of the shares. The above can be rewritten as

$$S^4(t) = \alpha^4 + \Pi^4 X(t) + \theta^4 \tau + v^4(t)$$

The superscript 4 indicates that the system of equations is obtained by dropping the fourth equation. The parameters of the dropped equation can be obtained by the following restrictions of additivity

$$\alpha_4 = 1 - \alpha_1 - \alpha_2 - \alpha_3,$$

$$\beta_{4j} = - \beta_{1j} - \beta_{2j} - \beta_{3j}, \text{ and } j = 1,2,3,4$$

and

$$\theta_{4\tau} = - \theta_{1\tau} - \theta_{2\tau} - \theta_{3\tau}$$

The homogeneous model is obtained from the above unrestricted static model by imposing the following restriction due homogeneity.

$$\beta_{i4} = - \beta_{i1} - \beta_{i2} - \beta_{i3}, \text{ i=1,2,3,4.}$$

The symmetry model is obtained by imposing the following restriction on the homogeneous model

$$\beta_{ij} = \beta_{ji} \text{ where i,j = 1,2,3,4.}$$

The homogeneous model is nested within the unrestricted static model and the symmetric model is nested within the homogeneous model. The likelihood ratio test is applied to test the following hypotheses.

The null hypothesis for the simultaneous test of homogeneity and symmetry is:

H_{0s}:The static model is linear homogeneous[5] in prices and satisfies the symmetry restrictions.

The alternative hypothesis is:

H_{As}: The static model does not satisfy the homogeneity and symmetry restrictions.

The hypotheses for the separate tests are:

H_{01}: The static model is homogeneous of degree one in prices; and

H_{02}: The homogeneous static model satisfies the symmetric restriction.

The above null hypotheses are tested against their respective alternative hypotheses:

H_{A1}: The static model is not homogeneous of degree one in prices; and

H_{A2}: The homogeneous model does not satisfies symmetric restrictions.

The estimates of maximum log-likelihood for the models and the likelihood ratio test statistics ($-2\log\lambda$) are give in Table 3.1a.

Homogeneity and symmetry are rejected when tested simultaneously, since the test statistic, 77.75, is highly significant. The likelihood ratio statistic ($-2\ \log\lambda$) to test H_{01} is 24.59, which is highly statistically significant at 1% level of significance ($\chi^2_3(.01)=11.3$). Therefore, the hypothesis that the static model is homogeneous of degree one in prices is rejected. Although the homogeneous model itself is rejected, the symmetry restrictions are still tested for the sake of completeness. From Table 3.1a, symmetry restrictions are also rejected ($-2\log\ \lambda_3= 53.17$). Therefore, the static model is rejected from further

[5] By linear homogeneity of the model it is meant (in this study) that the system of share equations are from the cost function which is linear homogeneous in factor prices.

economic analysis.

Table 3.1a: Maximum Likelihood Estimates and Likelihood Ratio Statistic for Canadian Agricultural Sector.

Model		Estimated Max. Log-Likelihood	Likelihood Ratio $-2\log\lambda_3$	Statistics $-2\log\lambda_6$
STATIC	UNRESTRICTED	717.19		
	HOMOGENEOUS	704.90	24.59	77.75
	SYMMETRIC	678.32	53.17	
PARTIAL ADJUSTMENT	UNRESTRICTED	738.09		
	HOMOGENEOUS	733.70	8.79	23.40
	SYMMETRIC	726.39	14.62	
AR(1) ERROR	UNRESTRICTED	806.65		
	HOMOGENEOUS	800.44	12.42	20.31
	SYMMETRIC	796.50	7.89	
ARX(1,1)	UNRESTRICTED	835.50		
	HOMOGENEOUS	829.09	12.76	15.95
	SYMMETRIC	827.50	3.18	

$\chi^2_3(.05) = 7.815$, $\chi^2_3(.01) = 11.345$, $\chi^2_6(.05) = 12.592$ and $\chi^2_6(.01) = 16.812$

The above tests indicate that the hypotheses of homogeneity and symmetry are rejected by the static model. However, the validity of the tests depends whether the model fits the data adequately in a statistical sense. Adequacy of the model is determined by checking whether the assumptions on the error terms are supported by the tested model (e.g., errors from each equation are white noise and follow normal distributions etc.). If the model does not fit the data adequately then estimates of the maximum likelihoods may not be correct and the economic tests may not be valid. Therefore it is important to test whether the model fits the data adequately.

The plots of estimated residuals, residual autocorrelation and partial autocorrelation, and normal probability (Figures 1, 2 and 3 respectively) are contained in Appendix 2. Plots of the estimated residuals obtained from the three share equations indicate systematic behavior. Residuals from the capital share equation are negative for years 1937 to 1956, are positive for 1957 to 1982, and are again negative from 1983 onward. The pattern followed by the residuals indicates non-random behavior of the residuals. A similar pattern, but not to the same extent, is indicated by the estimated residuals for the other two share equations. From Fig. 2, Appendix 2, residual autocorrelation for the capital share equation is significant for the first few lags but dampens out instead of truncating. This suggests that the residuals from the capital share equation follow an autoregressive process instead of a white noise pattern. The residual partial autocorrelation function truncates after the first lag, suggesting the case of an autoregressive process of order one. A similar conclusion can be drawn from the residual autocorrelation and partial autocorrelation plots for labor. From the analysis of the intermediate share equation, indications are that residuals may follow an autoregressive process pattern of order one or two or even a mixed autoregressive moving average process pattern (Box and Jenkins 1976, Mcleod et. al 1977). Therefore, residuals from the fitted share equations for the homogeneous and symmetric static model are not randomly distributed. Normal probability plots (Figure 3, Appendix 2) appear to be satisfactory, since the plotted points are very close to the straight line.

The above diagnostic checks indicate that the homogeneous symmetric static model does not fit the Canadian data adequately since residuals from the fitted equation seems to be autocorrelated and may follow autoregressive or mixed autoregressive moving average processes. In addition, the economic hypotheses of homogeneity and symmetry are also rejected. Therefore, this model does not fit the data generating process for the Canadian agricultural production sector adequately and economic analysis based on this model could be misleading.

3.1.2 PARTIAL ADJUSTMENT MODEL

For iteration two of the model building stage, the partial adjustment model is selected. The selection of the partial adjustment model over autoregressive process of order one for errors is arbitrary, since both models involve the same number of parameters. The system of share equations for the partial adjustment model, after dropping the fourth equation for non-singularity of the system (from Equation (20)), can be written as

$$S^4(t) = (I-D)\ \alpha^4 + D\ S^4(t-1) + (I-D)\ \Pi^4\ X(t) + (I-D)\ \theta^4\ \tau + \varepsilon^4(t)$$

The restrictions of homogeneity and symmetry are imposed only on the long-run parameters α, Π and θ. From Table 3.1a the maximum log-likelihood estimates for the unrestricted, homogeneous and symmetric partial adjustment models are 738.09, 733.70 and 726.39 respectively. The likelihood ratio test statistic for the simultaneous test of homogeneity and symmetry is 23.40, which is rejected at the 1% level of significance. Homogeneity, when tested alone, is not rejected at the 1% level of significance. However, if homogeneity is assumed, symmetry is not rejected at the 1% level of significance. Therefore, rejection of the economic restrictions of homogeneity and symmetry, when tested simultaneously at the 1% level of significance is due to the rejection of symmetry and not homogeneity. However, the objective is to obtain a model which does not reject homogeneity and symmetry simultaneously, but which is not the case here.

Further, diagnostic tests based on residuals (Figures 4, 5, 6, Appendix 2) suggest that the model is inadequate. Residual and normal probability plots do not indicate any significant deficiency. However, the residual autocorrelation and partial autocorrelation plots for the share equations of intermediate goods and labor indicate that the residuals do not follow white noise processes. Instead, the residuals from the share equations may follow either an autoregressive or a mixed autoregressive moving average processes.

Residual autocorrelation plots and partial autocorrelation plots and rejection of the hypothesis of homogeneity and symmetry suggest that the partial adjustment model does not represent the data generating process of the Canadian agricultural sector. Therefore a more sophisticated model is needed.

3.1.3 AUTOREGRESSIVE PROCESS OF ORDER ONE FOR DISTURBANCES

From Equation (21), the system of share equations after dropping the fourth equation (land and building structures) can be written as

$$S^4(t) = (I-D)\alpha^4 + DS^4(t-1) + \Pi^4 X(t) - D\Pi X^4(t-1) + (I-D)\theta^4\tau + \varepsilon^4(t)$$

This model is a slight improvement over the above two models, but still does not fit the data adequately. The maximum likelihood estimates for the unrestricted, homogeneous and symmetric model are 806.65, 800.44 and 796.50, respectively. The simultaneous hypothesis of homogeneity and symmetry is rejected at the 1% level of significance. The likelihood ratio estimates ($-2\log\lambda$) for the tests of the hypotheses of homogeneity and symmetry are 12.42 and 7.89, respectively. Homogeneity is rejected at the 1% level of significance. The hypothesis of symmetry, if homogeneity is assumed is rejected at .05 level of significance.

Diagnostic tests based on Figures 7, 8 and 9, Appendix 2, do not indicate a significant lack of fit. Residual autocorrelation and partial autocorrelation functions appear to be non-significant, indicating that residuals are white noise. The normal probability plots do not indicate deviance from normality. Therefore, it can be concluded from diagnostic check of residuals from a model with autoregressive process of order one for the disturbances, that the model fits the data statistically well.

This model fits the Canadian agricultural data significantly better than the previous two models, however, the rejection of the basic economic hypotheses still remains a problem. Therefore, further refinements of the model are required.

3.1.4 MULTIVARIATE AUTOREGRESSIVE PROCESS OF DEGREE ONE, ARX(1,1)

The system of share equations for multivariate autoregressive process with the fourth equation (land and building structure) dropped can be written as

$$S^4(t) = (I-D)\alpha^4 + D\ S^4(t-1) + \Gamma^4\ \Delta\ X(t) + (I-D)\ \Pi^4\ X(t-1) + (I-D)\theta^4\ \tau + \varepsilon^4\ (t)$$

Estimated results and diagnostic tests indicate that the ARX(1,1) provides a reasonable estimate of the data generating process of the Canadian agricultural sector. The likelihood ratio test statistic for the simultaneous test of homogeneity and symmetry is 15.95, which is less than 16.812 ($\chi_6(.01)$). Therefore, the hypothesis of homogeneity and symmetry is not rejected at 1% level of significance. The hypotheses of homogeneity and symmetry, when tested separately, are not rejected at 1% level of significance. Therefore, it can be concluded that homogeneity and symmetry restrictions are satisfied by the multivariate autoregressive model of system of share equations of translog form.

Residual plots (Figure 10, Appendix 2) of the multivariate autoregressive process of order one, ARX(1,1) for the homogeneous symmetric model does not show any significant non-randomness. Residual autocorrelation and partial autocorrelation plots (Figure 11, Appendix 2) suggest that, the residuals follow a white noise process, since the autocorrelation and partial autocorrelation functions are not significant. Normal probability plots (Figure 12, Appendix 2) also suggest that the residuals are normally distributed.

3.1.5 GOODNESS OF FIT TESTS FOR NESTED MODELS OF ARX(1,1)

The model of a system of share equations desired is one which satisfies economic restrictions and has a good fit on the basis of statistical tests of the residuals. The above tests indicate that a multivariate autoregressive model fits the data generated from the Canadian agricultural production sector. There are other tests that can be performed to further check whether the model fits the data generating process of the Canadian agricultural sector. Goodness of fit tests will give an indication as to whether the ARX(1,1) model is a good fit compared to the nested homogeneous and symmetric models. The likelihood ratio test and Akaike Information Criterion (AIC) will be used to test whether this model is an improvement over the static model, the partial adjustment model, and the model with autoregressive process of order one for the disturbances.

The AIC can be used for testing nested as well as non-nested hypotheses (Harvey 1981). The decision rule is to select the model for which the AIC is minimum, AIC (Harvey 1981) is defined as:

$$AIC = -2 \log lik(\hat{\Theta}) + 2K$$

where K is the number of parameters and $\log lik(\hat{\Theta})$ is the maximum log-likelihood estimate. This test is a test of "Goodness of Fit" of various models with appropriate allowance made for parsimony (Harvey 1981) since it involves both maximum log-likelihood as well as number of parameters estimated for a model. The AIC and maximum log-likelihood estimates for the various models (with symmetric and homogeneity restrictions) are presented in Table 3.1b below.

Table 3.1b: Results on Goodness of Fit Tests of the Canadian Models.

Model	Maximum Log-likelihood	AIC
ARX(1,1)	827.50	-1577.00
AR(1) ERROR	796.50	-1544.00
PARTIAL ADJUSTMENT	726.39	-1404.78
STATIC	678.32	-1296.64

Based on the AIC, ARX(1,1) is the best model. Now taking the ARX(1,1) model as the maintained hypothesis, the likelihood ratio statistics to test the hypotheses that the AR(1) error model, the partial adjustment model and the static model fit the data better are 62.0 (D.F[6] 15), 202.22 (D.F. 15), and 298.37 (D.F. 24) respectively. The hypotheses of all the nested models are rejected at 1% level of significance, since the critical values are $\chi^2_{15}(.01) = 30.58$ and $\chi^2_{24}(.01) = 42.98$. Therefore, the multivariate autoregressive process of order one fits the data for the Canadian agricultural sector adequately and the above analysis suggests that this model can be used for further economic analysis.

The estimated values of the parameters and their asymptotic standard errors for the ARX(1,1) model for Canada are presented in Table 3.1c.

The numbers in the subscripts in the notations of the parameters in Table 3.1c represent 1 for capital, 2 for intermediate goods, 3 for labor, and 4 for land and building structures.

[6] D.F. denotes number of independent restrictions to obtain the nested model from the maintained hypothesis model, ARX(1,1).

Table 3.1c: Estimates of the Parameters of the Homogeneous-Symmetric ARX(1,1) Model for Canada.

Parameter	Estimated Value	Standard Error	Parameter	Estimated Value	Standard Error
D_{11}	0.9383*	0.1773	Γ_{14}	-0.0136	0.0157
D_{12}	0.0547	0.1329	Γ_{1q}	-0.0069	0.0180
D_{13}	0.0493	0.1380	Γ_{21}	0.0080	0.0142
D_{21}	0.6764	0.4562	Γ_{22}	0.2484*	0.0245
D_{22}	0.8666*	0.3407	Γ_{23}	-0.1754*	0.0269
D_{23}	0.2416	0.3566	Γ_{24}	-0.0520	0.0426
D_{31}	-0.8489*	0.3387	Γ_{2q}	0.1240*	0.0480
D_{32}	-0.1786	0.2600	Γ_{31}	-0.0478*	0.0107
D_{33}	0.5091	0.2771	Γ_{32}	-0.1849*	0.0185
Γ_{11}	0.0494*	0.0053	Γ_{33}	0.1889*	0.0200
Γ_{12}	-0.0281*	0.0090	Γ_{34}	0.0277	0.0319
Γ_{13}	-0.0155	0.0099	Γ_{3q}	-0.1181*	0.0358
		Long-Run Parameters			
α_1	0.0568	0.0576	Π_{14}†	-0.0683	0.0127
α_2	0.5393*	0.0496	Π_{22}	0.1899*	0.0192
α_3	0.2725*	0.1115	Π_{23}	-0.1437*	0.0303
α_4†	0.1315	0.0237	Π_{24}†	-0.3078	0.0459
Π_{11}	0.0372	0.0264	Π_{33}	0.0952	0.0762
Π_{12}	0.0228	0.0163	Π_{34}†	-0.1986	0.0174
Π_{13}	0.0083	0.0406	Π_{44}†	0.5747	
	Scale Parameters			Technical Change Parameter	
Π_{1q}	-0.0287	0.0691	θ_1	0.0054	0.0955
Π_{2q}	0.3183*	0.0574	θ_2	0.0105	0.0082
Π_{3q}	-0.2787*	0.1344	θ_3	-0.0071	0.0185
Π_{4q}†	-0.0109	0.0286	θ_4†	-0.0088*	0.0039

[1] The estimated values marked with asterisk indicate the estimated values are significant at 5% level of significance. (t(.05)=1.96).

[2] The parameters marked with † indicate that estimated values are obtained using additivity restrictions.

The long-run parameters are α, π, and θ (Chapter 2, equation 15).

3.2 TECHNOLOGICAL CHANGE AND HOMOTHETICITY

In this section the share equations, estimated from the multivariate autoregressive process with the restrictions of homogeneity of order one in prices and symmetry, are used to test the hypotheses of factor neutral technical change and of homotheticity of the production process. The following two hypothesis are tested:

H_{OT}: Technological change in the Canadian agricultural sector for the period 1926 to 1988 is factor neutral;

H_{OY}: Data for the Canadian agricultural sector for the period 1926 to 1988 are generated by a homothetic production process.

Table 3.2: Tests of Neutral Technical Change and Homotheticity For Canada

Model	Estimated Max. Log-Likelihood	$-2\log\lambda_3$	Decision $\chi_3(.01) = 11.3$
ARX(1,1)	827.50		
ARX(1,1)[1]	820.98	13.05	H_{oT} is rejected
ARX(1,1)[2]	813.87	27.27	H_{oY} is rejected
ARX(1,1)[3]	802.99		

[1] ARX(1,1) model under H_{OT} i.e., without time variable.
[2] ARX(1,1) model under H_{OY} i.e., without output variable.
[3] ARX(1,1) model without time and output variables.

3.2.1 TECHNOLOGICAL CHANGE

The hypothesis H_{OT} is tested using the likelihood ratio test. The system of share equations of the homogeneous-symmetric ARX(1,1) model of translog form are estimated with and without a time trend variable. The maximum likelihood estimates are given in the Table 3.2. The hypothesis H_{OT} of factor neutral technical change is rejected, since $-2\log\lambda_3 = 13.05$ is greater than the 1% critical level of $\chi_3^2(.01) = 11.345$. Therefore, technical progress in the Canadian agriculture is factor biased.

The technical change is factor using/saving if the sign of the estimated coefficient of the time trend variable, $\hat{\theta}$ of the respective factor share equation is positive/negative, and provided, the estimated value is statistically significant. From Table 3.1c, the estimated values of the bias of the technical change parameters for capital and labor are non-significant. The bias of technical change (estimated using the additivity restriction) for land and building structures is significant. The significance level for bias of technical change for intermediate goods is 20%. The sign of the estimates of the biases indicate technical change is intermediate goods using and land saving. Therefore, it can be concluded that the technical change in the Canadian agricultural production process is factor biased and is land and building saving and may be intermediate goods using.

3.2.2 HOMOTHETICITY

The hypothesis H_{OY} is tested by dropping the output index variable from the system of share equations. The maximum likelihood estimate for this model is 813.87 with a corresponding likelihood ratio statistic of 27.27 ($-2\log\lambda$). The hypothesis H_{OY} is rejected since the value of 27.29 is statistically significant. Therefore, the production process for the

Canadian agricultural sector is non-homothetic. This implies technology of Canadian agricultural sector does not exhibit constant returns to scale. As discussed in the methodology chapter, a hypothesis of constant returns to scale is automatically rejected when the hypothesis of homotheticity is rejected. The relationship between scale and the factors of production is discussed below.

From Table 3.1c the long-run coefficients of scale of production for intermediate goods and labor are statistically significant. Scale of production is intermediate goods using since, the long-run coefficient is positive, while the scale of production is labor saving since the coefficient is negative.

3.3. OWN-PRICE AND SUBSTITUTION ELASTICITIES

Estimates of substitution and own-price elasticities are presented in Tables 3.3.1 and 3.3.2, respectively. Elasticities are estimated for the time periods 1959-68, 1969-78, 1979-88, and 1926-88. The expected values of shares to be used in equations (30) and (31) [Chapter 2] are calculated using equations (28) and (29) for their respective time periods in order to estimate their elasticities. Using the maximum likelihood estimates of the long-run parameters and the variance-covariance matrix, a sample of the size of one thousand is simulated. Long-run expected shares are calculated for each value of the sample.The elasticities are then calculated for each time period as described above. The average and standard deviations of the simulated set of one thousand elasticities are calculated. Further, by applying the Central Limit Theorem, 95% and 90% asymptotic confidence intervals of the elasticities are constructed using the simulated results.These results are presented in the Tables 3.3.1 and 3.3.2 below. The economic analysis based on the estimates and their confidence intervals is presented in the subsections below.

3.3.1 ELASTICITIES OF SUBSTITUTION

The relationship between the factors of production is determined on the basis of the signs and magnitudes of the statistically significant estimates of the elasticity of substitution. If an estimate of elasticity of substitution is not significant, then it can be concluded that the pair of factors does not exhibit substitution or complementary properties.

From Table 3.3.1, the estimates of elasticities of substitution between labor and land and building structures and between intermediate goods and land and building structures are statistically significant at the 5% level of significance for all periods under consideration. The elasticity of substitution between capital and intermediate goods is significant at the 10% level of significance for the period 1979-88 only. The rest of the estimates of elasticities of substitution are not different from zero even at the 10% level of significance.

The elasticity of substitution between labor and land and building structures is positive and largest among all of the estimates. These estimates also increased from approximately 2.46 in the earlier periods to 3.41 for the last period of 1979-88. Therefore, labor and land and building structures are substitutes and the degree of substitution has increased for the last decade. This result supports the observation that farm size is increasing and farm employment is decreasing, which is generally accredited to the farm mechanization.

Intermediate goods and land and building structures are substitutes but the degree of substitutability is not very large, since the estimate of the elasticity of substitution is approximately .5.

The rest of the elasticities of substitution are not statistically different from zero. The conclusion that capital and labor are not substitutes for each other is a surprising result, since earlier studies, Adamowicz (1986) and Lopez (1980) concluded that capital and labor were substitutes. However, if either a point estimate or standard error of coefficient (Π_{ij}) were used in this study to obtain significance levels, then it would be concluded that capital and labor are substitutes since the estimate of elasticity of substitution between labor and capital is 1.3511. Furthermore, following the same line of thought capital and land would be viewed as complements. Hence, conclusions based on point estimates alone can be misleading.

The rest of the estimates of the elasticities of substitution are not statistically significant from zero and, therefore, they are taken to be independent of each other. Independence here means that these factors cannot be substituted in response to changes in their relative prices. These inputs are therefore used in fixed proportions.

Table 3.3.1: Elasticities of Substitution for Canada

	ESTIMATED ELAST.	SIMULATED MEAN ELAST	S.E. ELAST.	CONFIDENCE-INTERVALS 95% LOW	95% HIGH	90% LOW	90% HIGH
			Sample for the Years 1959-68				
CAP-INT	0.4706	0.4956	0.3678	-0.2252	1.2164	-0.1094	1.1005
CAP-LAB	1.3304	1.3433	1.6756	-1.9409	4.6274	-1.4131	4.0996
CAP-LND	-2.0648	-2.0775	1.6963	-5.4022	1.2472	-4.8679	0.7129
INT-LAB	0.0985	0.1023	0.1745	-0.2397	0.4442	-0.1847	0.3893
INT-LND †	0.5041	0.5131	0.1658	0.1880	0.838[illegible]	0.2403	0.7859
LAB-LND †	2.4616	2.4950	0.6589	1.2036	3.7865	1.4111	3.5789
			Sample for the Years 1969-78				
CAP-INT	0.4913	0.5203	0.3501	-0.1654	1.2070	-0.0551	1.0968
CAP-LAB	1.3420	1.2905	1.7989	-2.2354	4.8165	-1.6687	4.2498
CAP-LND	[illegible]	-1.7489	1.4421	-4.5754	1.0777	-4.1211	0.6234
INT-LAB	[illegible]	0.0677	0.1675	-0.2606	0.3960	-0.2079	0.3432
INT-LND †	0.5373	0.5472	0.1515	0.2502	0.8443	0.2980	0.7965
LAB-LND †	2.4695	2.5158	0.6871	1.1690	3.8626	1.3854	3.6462
			Sample for the Years 1979-88				
CAP-INT ‡	0.5805	0.5788	0.3229	-0.0541	1.2118	0.0476	1.1100
CAP-LAB	1.4264	1.5296	2.1739	-2.7313	5.7904	-2.0465	5.1056
CAP-LND	-2.4119	-2.6640	2.3053	-7.1824	1.8544	-6.4563	1.1282
INT-LAB	-0.0574	-0.0652	0.2547	-0.5644	0.4341	-0.4841	0.3538
INT-LND †	0.4983	0.5023	0.1825	0.1445	0.8600	0.2020	0.8025
LAB-LND †	3.4087	3.4556	1.0631	1.3720	5.5392	1.7069	5.2044
			Sample for the Years 1926-88				
CAP-INT	0.4156	0.4396	0.4109	-0.3658	1.2450	-0.2364	1.1155
CAP-LAB	1.3511	1.3558	1.7839	-2.1406	4.8523	-1.5787	4.2904
CAP-LND	-2.2602	-2.2644	1.7919	-5.7765	1.2478	-5.2121	0.6834
INT-LAB	0.1167	0.1199	0.1737	-0.2204	0.4603	-0.1657	0.4056
INT-LND †	0.5137	0.5222	0.1634	0.2019	0.8425	0.2534	0.7910
LAB-LND †	2.3800	2.4106	0.6201	1.1951	3.6260	1.3904	3.4307

[1] Symbol † indicates the elasticity is significant at 5% level of significance i.e., zero does not belong to the 95% confidence interval.

[2] Symbol ‡ indicates the elasticity is significant at 10% level of significance i.e., zero does not belong to the 90% confidence interval.

3.3.2 OWN-PRICE ELASTICITIES

The signs of the estimates of own-price elasticities are negative as expected. The estimates of own-price elasticities for intermediate goods and land and building structures are significant at 5% level of significance. Factor price elasticity of land is largest and is approximately equal to -.84. Own price elasticities of capital and intermediate goods are not significant at 10% level of significance. However, all of the factor price elasticities are negative and greater than minus one implying that all four of the factors of production are inelastic to their own prices.

Table 3.3.2: Own-Price Elasticities for Canada

	ESTIMATED ELAST.	SIMULATED MEAN ELAST	SIMULATED S.E. ELAST.	CONFIDENCE-INTERVALS 95% LOW	95% HIGH	90% LOW	90% HIGH
			Sample for the Years 1959-68				
CAP	-0.4658	-0.4640	0.3510	-1.1521	0.2240	-1.0415	0.1135
INT †	-0.1143	-0.1164	0.0354	-0.1857	-0.0470	-0.1746	-0.0582
LAB	-0.3830	-0.3989	0.2582	-0.9049	0.1071	-0.8236	0.0257
LND †	-0.8449	-0.8473	0.1037	-1.0504	-0.6441	-1.0178	-0.6768
			Sample for the Years 1969-78				
CAP †	-0.4734	-0.4395	0.3969	-1.2175	0.3384	-1.0925	0.2134
INT	-0.1111	-0.1129	0.0339	-0.1794	-0.0464	-0.1687	-0.0571
LAB	-0.3817	-0.4090	0.2765	-0.9509	0.1329	-0.8638	0.0458
LND †	-0.8434	-0.8445	0.0987	-1.0379	-0.6510	-1.0068	-0.6821
			Sample for the Years 1979-88				
CAP †	-0.4899	-0.5117	0.2990	-1.0978	0.0743	-1.0037	-0.0198
INT	-0.0763	-0.0784	0.0321	-0.1412	-0.0155	-0.1311	-0.0256
LAB	-0.3484	-0.3459	0.3655	-1.0623	0.3705	-0.9471	0.2554
LND †	-0.8469	-0.8511	0.1234	-1.0929	-0.6093	-1.05[illegible]	-0.6482
			Sample for the Years 1926-88				
CAP †	-0.4303	-0.4240	0.3912	-1.1907	0.3427	-1.0675	0.2194
INT	-0.1157	-0.1178	0.0359	-0.1882	-0.0474	-0.1769	-0.0587
LAB	-0.3829	-0.3980	0.2511	-0.8902	0.0942	-0.8111	0.0151
LND †	-0.8441	-0.8468	0.1010	-1.0447	-0.6489	-1.0129	-0.6807

[1] Symbol † indicates the elasticity is significant at 5% level of significance i.e., zero does not belong to the 95% confidence interval.

3.4 SUMMARY

A multivariate autoregressive process ARX(1,1) model of a system of share equations of the translog functional form is found to fit the data on the Canadian agricultural sector adequately for the period 1926-88. Technology of the production sector is non-homothetic and the technical change that occurred is factor biased (non-neutral). Scale of production is labor saving and intermediate goods using, while technical change is land saving and could be intermediate goods using.

One significant contribution of this study is that standard errors and confidence intervals of estimates of the elasticities are obtained using a statistical simulation procedure. Earlier studies either did not calculated standard errors of estimates of elasticities or utilized standard errors of estimates of coefficients (Π_{ij} 's), which are crude approximations. Further, in this study asymptotic 95% and 90% confidence intervals for elasticities are constructed using the simulated results.

The long-run production process for Canada has shown the tendency to substitute between pairs of factors; labor and land and building structures, and intermediate goods and land and building structures. Factor inputs are found to be inelastic to their own prices.

Chapter 4

MODEL FOR ALBERTA AGRICULTURAL SECTOR

In this chapter, a model of the Alberta agricultural sector is constructed. The model is developed by applying the model specification and building techniques described in Chapter 2. In section 4.1, the results of the model building procedure are presented. The simplest model, among those outlined in Chapter 2, for which the homogeneity and symmetry restrictions hold, along with the tests of statistical adequacy not being rejected, is the one which will be selected for economic analysis of the Alberta agricultural sector. Homogeneity and symmetry are tested simultaneously as well as separately. When testing separately, homogeneity is tested first because homogeneity is automatically imposed due to additivity when symmetry restrictions are applied. The motive for testing homogeneity first and then symmetry is to determine whether the economic restrictions are rejected due to homogeneity and/or symmetry, since a situation could arise when only one of the restrictions is rejected. Estimated values of maximum likelihood estimates and likelihood ratio test statistics for the various tests are presented in the Table 4.1

Hypotheses of homotheticity and neutral technical change are tested in section 4.2. Economic analysis and structural parameters are presented in section 4.3.

4.1 MODEL SPECIFICATION AND ESTIMATION

Data on the prices of inputs are aggregated into four categories by employing the Tornquivst indexing procedure, which is an approximation of the Divisia continuous index as described in Chapter 2. The four input categories are capital, intermediate goods, labor, and land and building structures. Output quantities are aggregated into one output quantity index. The following notations will be used through the model building stages;

$p_1(t)$ = aggregate price of capital at time t;

$p_2(t)$ = aggregate price of intermediate goods at time t;

$p_3(t)$ = aggregate price of labor at time t;

$p_4(t)$ = aggregate price of land at time t;

$q(t)$ = aggregate quantity index at time t; and

τ = time trend index.

4.1.1 STATIC MODEL

Following the model building procedure described in Chapter 2, a system of static translog share equations is identified as a tentative model for iteration one. From equation (7) the system of share equations can be written as

$$S(t) = \alpha + \Pi\ X(t) + \theta\ \tau + v(t)$$

where n = 4 and t = 1,2, • • •, 62.(i.e, years 1926 to 1987). Because of addititvity the share equation corresponding to land and building structures (the fourth equation) of the system of share equations is arbitrarily dropped and the above can be written as

$$S^4(t) = \alpha^4 + \Pi^4\ X(t) + \theta^4\ \tau + v^4(t)$$

And from the additivity restriction, we have

$$\alpha_4 = 1 - \alpha_1 - \alpha_2 - \alpha_3,$$

$$\beta_{4j} = -\beta_{1j} - \beta_{2j} - \beta_{3j},\ j = 1,2,3,4.$$

and

$$\theta_{4\tau} = -\theta_{1\tau} - \theta_{2\tau} - \theta_{3\tau}.$$

The above model is the unrestricted static model. Homogeneity in prices imposes the following restrictions,

$$\beta_{i4} = -\beta_{i1} - \beta_{i2} - \beta_{i3},\ i = 1,2,3,4.$$

The model with the above restriction is the homogeneous model.

Symmetry imposes three further restrictions to the homogeneous model

$$\beta_{ij} = \beta_{ji}\ ,\ i,j = 1,2,3,4.$$

The homogeneous model with the above restriction is the symmetric model. The above three models are estimated using the maximum likelihood estimation procedure with the computer package, Shazam. The maximum likelihood estimates and the results of the tests of hypotheses for homogeneity and symmetry are presented in Table 4.1.

From Table 4.1, the hypothesis of homogeneity and symmetry, when tested simultaneously, is rejected. The likelihood ratio test statistic is 86.97, which is highly significant. The likelihood ratio statistic for hypothesis of homogeneity is 44.69, which is statistically significant where $\chi_3(.01) = 11.341$. Therefore, homogeneity is rejected and the hypothesis of symmetry is also rejected.

To test whether the static homogeneous-symmetric model fits the data adequately based on testing statistical assumptions alone, diagnostic checks of the estimated residuals are performed. Residual autocorrelation and partial autocorrelation plots (Figure 14, Appendix 3) from the equation for capital indicates that the residuals follow an autoregressive process of order one. The residuals from the equations for intermediate goods and labor seem to follow the pattern of mixed autoregressive- moving average of order one, ARMA (1,1), and of autoregressive process of order one, respectively. Therefore, from the residual autocorrelation and partial autocorrelation plots, it can be concluded that the estimated residuals from each equation do not follow a white noise process. Normal probability plots (Figure 15) appear to be adequate. Therefore, the symmetric-homogeneous static translog model does not statistically fit the Alberta agricultural data adequately.

Since tests of economic restrictions were rejected and the static translog does not adequately fit the Alberta agricultural sector, a more refined model should be fitted to the data.

4.1.2 PARTIAL ADJUSTMENT MODEL

For iteration two of the model building stage, a partial adjustment model is selected. From Equation (21), the system of share equations of the partial adjustment model, after dropping the equation for land and building structures, can be written as:

$$S^4(t) = (I-D)^4\alpha + DS^4(t-1) + (I-D)\,\Pi^4X(t) + (I-D)\,\theta^4\tau + \varepsilon^4(t)$$

Estimates of the maximum log-likelihood of unrestricted, homogeneous, and homogeneous and symmetric models, along with the likelihood ratio statistics for the tests of the hypotheses of homogeneity and symmetry of the partial adjustment model, are presented in Table 4.1.

The hypothesis of homogeneity and symmetry (simultaneous) is rejected, since the likelihood ratio test statistic of 41.76 is statistically significant. The hypothesis of homogeneity is rejected, since the corresponding likelihood ratio statistic of 19.02 is also statistically significant. Testing symmetry is irrelevant, since the homogeneous model itself is rejected. Nevertheless, if symmetry was tested, it is also rejected at the 1% level of significance.

The plots of the residual autocorrelation and partial autocorrelation functions (Figure 17, Appendix 3) of the symmetric model of the three fitted equations indicate the presence of autoregressive and/or moving average processes. The residuals from the three estimated share equations appear to follow the pattern of an autoregressive moving average of order one, ARMA (1,1). However, the residual plots (Figure 16, Appendix3) for the partial adjustment model indicate a more random distribution of the residuals as compared to those for the static model. Normal probability plots (Figure 18, Appendix 3) do not indicate any significant inadequacy although they are not as good as those for the static model.

The partial adjustment model does not fit the data for Alberta agricultural sector adequately, since the residuals from each equation do not follow a white noise process and the homogeneity and symmetric restrictions are rejected.

4.1.3 AUTOREGRESSIVE PROCESS OF ORDER ONE FOR DISTURBANCES

The system of share equations for this model, after dropping the fourth equation, can be written as

$$S(t) = (I-D)\,\alpha^4 + DS^4(t-1) + \Pi^4\,X(t) - D\Pi\,X(t-1) + (I-D)\theta\,\tau + \varepsilon^4(t)$$

The maximum likelihood estimates for the unrestricted, homogeneous, and homogeneous and symmetric system of share equations with errors following autoregressive process of order 1 are presented in the Table 4.1.

The hypothesis of homogeneity and symmetry is rejected, when tested simultaneously, since the likelihood ratio test statistic of 39.62 is significant. The hypothesis for homogeneity is not rejected at the 1% level of significance, but is rejected at the 5% level of significance. The restrictions of symmetry, when tested on the homogeneous model are rejected, since the likelihood ratio test statistic of 29.89 is highly significant. However, it should be noted, that there is no evidence against the hypothesis homogeneity at the 1% level of significance.

Plots of the estimated residuals, residual autocorrelation and partial autocorrelation functions, and normal probability (Figures 19, 20, 21, Appendix 3) do not indicate any significant deficiency of the model of autoregressive process of order one for the disturbances of the system of share equations of translog technology for the Alberta agricultural sector. Although the model of a system of share equations of autoregressive process order one for disturbances fits the data adequately based on statistical diagnostic tests, the economic restrictions of symmetry and homogeneity when tested simultaneously is rejected. In addition, when tested separately there is significant evidence against the symmetry restrictions. Therefore, further refinements to the model are required.

4.1.4 MULTIVARIATE AUTOREGRESSIVE PROCESS OF ORDER ONE, ARX(1,1)

From model (19) or (27), the system of share equations with the equation for land and building structures dropped (fourth equation) for the ARX(1,1) can be written as

$$S^4(t) = (I-D)\ \alpha^4 + D\ S^4(t-1) + \Gamma_0\ \Delta\ X\ (t)$$
$$+ (I-D)\ \Pi^4\ X(t-1) + (I-D)\ \theta^4\tau + \varepsilon^4(t)$$

Maximum likelihood estimates of the unrestricted, homogeneous and symmetric models are presented in the Table 4.1 below.

The hypothesis of homogeneity and symmetry, when tested simultaneously is not rejected at the 5% significance level. The hypothesis of homogeneity, when tested separately is not rejected at the 5% level of significance. The likelihood ratio test statistic of 9.27 for the hypothesis of symmetry, when homogeneity is assumed, is not rejected at the 1% level of significance. Since the hypotheses of homogeneity and symmetry when imposed simultaneously are not rejected at the 5% level of significance, it can be concluded that economic restrictions are not rejected for ARX(1,1) model, when fitted to the Alberta agricultural sector.

Diagnostic tests of the estimated residuals do not reveal any serious deficiency with the fitted model. Autocorrelation and partial autocorrelation plots (Figures 22,23,24, Appendix 3) of estimated residuals, from each of the share equations, indicate that the residuals are distributed as a white noise process. Inspection of residuals and normal probability plots also do not indicate any inadequacy with the model.

Based on the above analysis, the multivariate autoregressive model of share equations fits the data on the Alberta agricultural sector adequately. Therefore, it can be concluded that the input shares of the Alberta agricultural sector for the period 1926-87 are generated by a dynamic system of share equations of translog technology of the form of a multivariate autoregressive process of order one. Therefore, the ARX(1,1) system of share equations will be used for further economic analysis of the Alberta agricultural sector.

Table 4.1a: Maximum Likelihood Estimates and Likelihood Ratio Statistic for Alberta Agricultural Aector.

Model		Estimated Max. Log Likelihood	Likelihood ratio statistics $-2\log\lambda_3$	$-2\log\lambda_6$
STATIC	UNRESTRICTED	658.80		
	HOMOGENEOUS	636.45	44.69	86.97
	SYMMETRIC	615.31	42.28	
PARTIAL ADJUSTMENT	UNRESTRICTED	669.85		
	HOMOGENEOUS	660.34	19.02	41.76
	SYMMETRIC	648.97	22.74	
AR(1) ERROR	UNRESTRICTED	706.17		
	HOMOGENEOUS	701.31	9.72	39.62
	SYMMETRIC	686.36	29.89	
ARX(1,1)	UNRESTRICTED	697.71		
	HOMOGENEOUS	696.33	2.04	11.31
	SYMMETRIC	690.62	9.27	

$\chi^2_3(.05) = 7.815$, $\chi^2_3(.01) = 11.345$, $\chi^2_6(.05) = 12.592$ and $\chi^2_6(.01) = 16.812$

4.1.5 GOODNESS OF FIT TESTS FOR THE NESTED MODEL OF ARX(1,1)

From above analysis, ARX(1,1) is selected to model the Alberta agricultural sector. However, "Goodness of Fit" tests can be utilized to further check whether the ARX(1,1) model fits the data for the Alberta agricultural sector better than the nested models of ARX(1,1). Homogeneity and symmetry restrictions are imposed on all the models for comparison. The maintained hypothesis model is the ARX(1,1) model, since it fits the data statistically well and economic restrictions are not rejected by the model. Likelihood ratio tests and the Akaike Information Criterion (AIC) are used as "Goodness of Fit" tests. The AIC is defined as

$$AIC = -\ 2\log\ lik(\hat{\Theta})\ +2K$$

where K is the number parameters estimated and $lik(\hat{\Theta})$ is estimated maximum likelihood. The decision criterion is to select the model with the minimum AIC. Maximum log-likelihood estimates and their AIC for various models are presented in Table 4.1b below:

Table 4.1b: Results on Goodness of fit Tests of the Alberta Models

Model	Estimated Max. Log-Likelihood	AIC
ARX(1,1)	718.48	-1358.96
AR(1) Error	686.36	-1324.72
PARTIAL ADJUSTMENT	648.97	-1249.94
STATIC	615.31	-1200.62

The ARX(1,1) model based on AIC from Table 4.1b is the best model among all of the models under consideration. The likelihood ratio test statistics ($-2\log\ \lambda$) for the AR(1) process for disturbances model, partial adjustment model and static model are 64.25 (D.F.[7] 15), 139.02 (D.F. 15), and 206.34 (D.F. 25) respectively. In all cases, the hypothesis that a nested model fits the data better than the ARX(1,1) model is rejected at the 1% level of significance, since the critical values for the tests are χ^2_{15} (.01) = 30.58 and χ^2_{24} (.01) = 42.98. Therefore, multivariate autoregressive process of order one ARX(1,1) is the best model among the models considered and the analysis suggested that this model can be used for further economic analysis.

4.2 TECHNOLOGICAL CHANGE AND HOMOTHETICITY

The system of share equations of the homogeneous-symmetric ARX(1,1) model is used to test whether technological change is factor neutral and whether the long term production function is homothetic for the Alberta agricultural sector. The following three hypotheses are tested:

H_{OT}: The technological change in the Alberta Agricultural the period 1926-1987 is factor neutral; and

H_{OY}: The long run production function for the Alberta agricultural sector is homothetic.

H_{OTY}: The long-run neutral technical change production function is homothetic for the Alberta agricultural sector.

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[7] D.F. denotes the number of independent restrictions to be imposed on ARX(1,1) model to obtain the nested model.

Table 4.2: Tests of Neutral Technical Change and Homotheticity for Alberta

Model	Estimated Max. Log-Likelihood	$-2\log\lambda_3$	Decision $\chi_3(.01) = 11.3$
ARX(1,1)	718.48		
ARX(1,1)[1]	717.48	2.00	H_{OT} is not rejected
ARX(1,1)[2]	712.97	11.03	H_{OY} is rejected
ARX(1,1)[3]	706.76	21.44	H_{OTY} is rejected

[1] ARX(1,1) model under H_{OT} i.e., without time variable.

[2] ARX(1,1) model under H_{OY} i.e., without output variable.

[3] ARX(1,1) model under H_{OTY} i.e., without time and output variable.

4.2.1 TECHNOLOGICAL CHANGE

In this section the hypothesis that technological change for the Alberta agricultural sector for 1926-87 is factor neutral is tested. The likelihood ratio test is utilized to test this hypothesis. The maximum log-likelihood estimates of the homogeneous-symmetric ARX(1,1) with and without a time variable are 718.48 and 717.48, respectively. The likelihood ratio test statistic ($-2\log\lambda_3$) is 2.00, which is less than the critical point, $\chi_3(.05) = 7.815$. Therefore, the hypothesis of neutral technical change for Alberta for 1926-87 is not rejected.

4.2.2 HOMOTHETICITY

The hypothesis of homotheticity is tested by dropping the output index terms from the long-run part (i.e., $\theta_{iy} = 0$, i = 1,2,3) of the system of share equations of the neutral technical change, ARX(1,1) model. The estimates of maximum log likelihood with and without an output index are 717.48 and 706.76 respectively. The corresponding

$-2\log\lambda_3$ statistic is 21.44, which is significant at the 1% level of significance ($\chi^2_3(.01)$= 11.345). It should be noted that the hypothesis of homotheticity is tested for non-neutral technical change production process and is rejected at the 5% level of significance ($-2\log\lambda_3$= 11.03). Therefore, the hypothesis of a homothetic cost function is rejected. In other words, a nonhomothetic, neutral technical change ARX(1,1) model fits the data from Alberta agriculture satisfactorily.

The residual plots, autocorrelation and partial correlation plots, and normal probability plots (Figures 25, 26 and 27, Appendix 3) do not indicate any deficiency against homogeneous and symmetric, nonhomothetic and neutral technical change ARX(1,1) model. Therefore, this model will be used to obtain the estimates of own-price and substitution elasticities for the Alberta agricultural sector.

The estimated parameters of the system of share equations with homogeneous and symmetric restrictions of the non-homothetic and neutral technical change ARX(1,1) model are given in the Table 4.2 below. This model will be used for further economic analysis.

The estimated coefficients of output from the capital and intermediate goods equations are positive and significant at the 5% level of significance. Therefore, scale is capital and intermediate goods using. The estimated coefficient of output from the share equation for labor is also significant and negative, implying that scale is labor saving.

Table 4.2: Estimates of the parameters of Model for Alberta

Parameter	Estimated Value	Standard Error	Parameter	Estimated Value	Standard Error
D_{11}	0.8715*	0.1546	Γ_{14}	-0.0218*	0.0087
D_{12}	0.2997*	0.1287	Γ_{1q}	-0.0191	0.0116
D_{13}	0.2949*	0.1374	Γ_{21}	-0.0339	0.0262
D_{21}	-0.0204	0.5196	Γ_{22}	0.1963*	0.0284
D_{22}	-0.2085	0.3952	Γ_{23}	-0.0917*	0.0168
D_{23}	-0.8269*	0.3712	Γ_{24}	-0.0761*	0.0286
D_{31}	-0.0366	0.4786	Γ_{2q}	0.0409	0.0420
D_{32}	0.6451	0.3878	Γ_{31}	-0.0048	0.0213
D_{33}	1.3139*	0.3508	Γ_{32}	-0.1385*	0.0243
Γ_{11}	0.0518*	0.0066	Γ_{33}	0.1028*	0.0130
Γ_{12}	-0.0353*	0.0077	Γ_{34}	0.0528*	0.0232
Γ_{13}	-0.0063	0.0052	Γ_{3q}	-0.0251	0.353
			Long-Run Parameters		
α_1	0.1131*	0.0026	Π_{14}†	-0.0401*	0.0097
α_2	0.5991*	0.0139	Π_{22}	0.1499*	0.0229
α_3	0.2057*	0.0160	Π_{23}	-0.0974*	0.0286
α_4†	0.0821*	0.0045	Π_{24}†	-0.0196	0.0137
Π_{11}	0.0811*	0.0101	Π_{33}	0.1102*	0.0299
Π_{12}	-0.0329*	0.0751	Π_{34}†	-0.0047	0.0123
Π_{13}	-0.0080	0.0062	Π_{44}†	0.064425	
	Scale Parameters				
Π_{1q}	0.0205*	0.0048			
Π_{2q}	0.2323*	0.0248			
Π_{3q}	-0.2466*	0.0278			
Π_{4q}†	-0.0062	0.0080			

[1] The estimated values marked with asterisk indicate the estimated values are significant at 5% level of significance ($t_{\infty}(.05)=1.96$).

[2] The parameters marked with † indicate that estimated values are obtained using additivity restrictions.

4.3 ELASTICITIES OF SUBSTITUTION AND OWN-PRICE

Estimated mean elasticities of substitution and of own-prices based on equations (30) and (31), respectively are listed in Tables 4.3.1 and 4.3.2 respectively. Also, listed in these tables are the averages of a set one thousand simulated elasticities and their standard errors, along with asymptotic 90% and 95% confidence intervals. Inferences regarding the degree of substitutability or complementarity are dependent on whether individual confidence intervals contain zero and the magnitudes and signs of the confidence limits.

4.3.1 ELASTICITIES UBSTITUTION

From Table 4.3.1, elasticities of substitution between capital and labor as well as capital and land and building structures are significant at the 5% level of significance for all four periods; 1959-1968, 1969-1978, 1979-1987 and 1926-1987. The magnitude of elasticity of substitution for capital and land and building structures is the largest among all of the estimates of elasticities of substitution for each period. In addition, its sign is negative as expected and therefore, capital and land and building structures are strong complements.

The elasticity of substitution between capital and labor is significant at the 5% level of significance for all four periods and is the largest estimated value among all the positive elasticity estimates except those for labor and land and building structures. However, the estimate of elasticity of substitution for labor and land and building structures is only significant at the 10% level of significance for the periods 1959-1968 and 1926-1987. Therefore, capital and labor are the most significant and consistent substitutes among all of the pairs of factor inputs. The magnitude of the elasticity of substitution between capital and labor decreased from .74 for the period of 1959-1968 to .61 for the period of 1979-1987. Therefore, there is evidence that the degree of substitution between capital and labor is decreasing over time.

Estimates of the elasticity of substitution for capital and intermediate goods are statistically significant (5% level of significance) for all periods, except 1926-1987. The magnitude of elasticity increased over time from .36 to .41 and then to .58 for the periods 1959-1968, 1969-1978 and 1979-1987, respectively.

The elasticity of substitution between intermediate goods and land and building structures for the period of 1959-1978 is significant at the 10% level of significance and those for the periods 1969-1978 and 1979-1988 at the 5% level of significance. The magnitude of elasticity also increased sightly for later periods.

Increasing substitution between capital and intermediate goods as well as intermediate goods and land and building structures, implies that the Alberta agricultural sector has shifted towards larger, highly capitalized and, in later periods, intensified farming practices.

The elasticity of substitution between intermediate goods and labor is significant at the 5% level of significance for period 59-68 only and the 1% level of significance for the period 69-78. The magnitude of the elasticity is low and deceasing over time. The elasticity of substitution between labor and land and building structures is significant at the 1% percent level of significance for the periods 59-68 and whole period 26-87.

Table 4.3.1: Elasticities of Substitution for Albert

	ESTIMATED ELAST.	SIMULATED MEAN ELAST.	SIMULATED S.E. ELAST.	CONFIDENCE-INTERVALS 95% LOW	95% HIGH	90% LOW	90% HIGH
		Sample for the Years 1959-68					
CAP-INT †	0.3583	0.3603	0.1477	0.0708	0.6499	0.1174	0.6033
CAP-LAB †	0.7488	0.7514	0.1993	0.3608	1.1421	0.1236	1.0793
CAP-LND †	-3.5019	-3.5080	1.1170	-5.6973	-1.3187	-5.3454	-1.6706
INT-LAB †	0.3722	0.3695	0.1811	0.0146	0.7245	0.0716	0.6674
INT-LND ‡	0.5500	0.5527	0.3096	-0.0541	1.1596	0.0434	1.0620
LAB-LND ‡	0.8245	0.8154	0.4606	-0.0874	1.7183	0.0577	1.5732
		Sample for the Years 1969-78					
CAP-INT †	0.4132	0.4142	0.1384	0.1430	0.6854	0.1865	0.6418
CAP-LAB †	0.7207	0.7221	0.2239	0.2833	1.1609	0.3538	1.0903
CAP-LND †	-3.3037	-3.3056	1.0382	-5.3405	-1.2707	-5.0135	-1.5977
INT-LAB ‡	0.3297	0.3278	0.1895	-0.0437	0.6992	0.0160	0.6395
INT-LND †	0.5870	0.5892	0.2846	0.0313	1.1471	0.1210	1.0574
LAB-LND	0.8041	0.7911	0.5159	-0.2200	1.8021	-0.0575	1.6397
		Sample for the Years 1979-87					
CAP-INT †	0.5728	0.5737	0.1000	0.3777	0.7697	0.4092	0.7382
CAP-LAB †	0.6173	0.6190	0.3078	0.0157	1.2222	0.1126	1.1253
CAP-LND †	-3.2538	-3.2771	1.1004	-5.4340	-1.1202	-5.0873	-1.4669
INT-LAB	0.0934	0.0670	0.3230	-0.5662	0.7001	-0.4644	0.5984
INT-LND †	0.5971	0.5882	0.2964	0.0073	1.1691	0.1006	1.0757
LAB-LND	0.6402	0.6332	0.9548	-1.2383	2.5047	-0.9375	2.2039
		Sample for the Years 1926-87					
CAP-INT	0.2668	0.2693	0.1700	-0.0640	0.6026	-0.0105	0.5490
CAP-LAB †	0.7242	0.7283	0.2171	0.3028	1.1539	0.3712	1.0855
CAP-LND †	-3.9101	-3.9687	1.2100	-6.3403	-1.5972	-5.9592	-1.9783
INT-LAB †	0.3909	0.3873	0.1790	0.0365	0.7381	0.0928	0.6817
INT-LND ‡	0.5664	0.5620	0.3046	-0.0351	1.1590	0.0609	1.0630
LAE-LND ‡	0.8374	0.8311	0.4306	-0.0129	1.6752	0.1227	1.5395

[1] Symbol † indicates the elasticity is significant at 5% level of significance.

[2] Symbol ‡ indicates the elasticity is significant at 1% level of significance.

4.3.2 OWN-PRICE ELASTICITY

Estimates of own-price elasticities, their mean simulated values, standard errors, and 95% and 90% confidence intervals are presented in Table 4.3.2. All of the own-price elasticities are negative as expected. However, own-price elasticity of land is not significantly different from zero. Own-price elasticity of capital is significant for the period 1979-1987. Own-price elasticity of labor is significant for the periods 1959-1968, 1969-1978 and 1926-1987. Own-price elasticity of intermediate goods is significant for all of the periods. However, all of the estimated elasticities are very small and therefore, it can be concluded that factor inputs are inelastic to their own-prices.

Table 4.3.2 Own-Price Elasticities for Alberta

	ESTIMATED ELAST.	SIMULATED MEAN ELAST.	SIMULATED S.E. ELAST.	CONFIDENCE-INTERVALS 95% LOW	95% HIGH	90% LOW	90% HIGH
			Sample for the Years 1959-68				
CAP	-0.1072	-0.1102	0.0966	-0.2995	0.0790	-0.2691	0.0486
INT ✝	-0.2000	-0.1983	0.0461	-0.2887	-0.1079	-0.2742	-0.1224
LAB ✝	-0.3347	-0.3332	0.0985	-0.5264	-0.1401	-0.4953	-0.1712
LND	-0.1717	-0.1695	0.2787	-0.7158	0.3767	-0.6280	0.2889
			Sample for the Years 1969-78				
CAP	-0.1237	-0.1254	0.1020	-0.3254	0.0746	-0.2933	0.0424
INT ✝	-0.1852	-0.1836	0.0424	-0.2667	-0.1005	-0.2533	-0.1139
LAB ✝	-0.3231	-0.3222	0.1100	-0.5379	-0.1066	-0.5032	-0.1412
LND	-0.1851	-0.1823	0.2735	-0.7183	0.3537	-0.6321	0.2676
			Sample for the Years 1979-87				
CAP ✝	-0.2153	-0.2174	0.0807	-0.3755	-0.0593	-0.3501	-0.0847
INT ✝	-0.1321	-0.1315	0.0445	-0.2187	-0.0443	-0.2047	-0.0583
LAB	-0.1837	-0.1596	0.2222	-0.5951	0.2759	-0.5251	0.2059
LND	-0.0871	-0.0838	0.3161	-0.7033	0.5357	-0.6037	0.4361
			Sample for the Years 1926-87				
CAP	-0.0112	-0.0142	0.1150	-0.2396	0.2113	-0.2034	0.1750
INT ✝	-0.2009	-0.1996	0.0479	-0.2934	-0.1058	-0.2783	-0.1209
LAB ✝	-0.3359	-0.3332	0.0957	-0.5207	-0.1458	-0.4906	-0.1759
LND	-0.1984	-0.1914	0.2646	-0.7101	0.3272	-0.6267	0.2439

[1] Symbol ✝ indicates the elasticity is significant at 5% level of significance.

[2] Symbol ‡ indicates the elasticity is significant at 1% level of significance.

4.4 SUMMARY

A dynamic, ARX(1,1), system of share equations of the translog functional form fits the Alberta data adequately for the period of 1926-87. Estimates of the long-run parameters are easily available.

The long-run production process is non-homothetic and technological change is factor neutral. Scale of production is capital and intermediate goods using and labor saving.

Capital and land and building structures are strong complements, while capital and labor are substitute with the degree of substitution decreasing over time. Capital and intermediate goods as well as intermediate goods and land and building structures are substitutes. Furthermore, the degree of substitutability of these two factor input pairs increased in later periods indicating that the Alberta agricultural sector may have shifted towards larger, more highly capitalized and more intensified farms.

Chapter 5

ASSESSMENT AND COMPARISON OF EMPIRICAL RESULTS

In this chapter, a comparison is made between the empirical results obtained from this study and the earlier studies of this nature on the Canadian agricultural sector by Lopez (1980), Islam and Veeman (1980) and Adamowicz (1986). The empirical results obtained in this study for the Canadian agricultural sector are also compared to the results from the Alberta agricultural sector.

5.1 EMPIRICAL RESULTS ON CANADIAN AGRICULTURAL SECTOR

5.1.1 TECHNICAL CHANGE

Technical change in this study is found to be factor biased for the Canadian agricultural sector. The bias of technical change is land and building structures saving and there is some evidence, that it is intermediate goods using. Technical change is neutral to capital and labor.

In Lopez (1980), the hypothesis of factor neutral technical change is not rejected. Therefore, it was concluded that technical change is factor neutral for the Canadian agricultural sector. However, it was pointed out in that study that, when homotheticity was imposed, technical change was found to be factor biased. Lopez (1980) observed that, "The assumption of a homothetic production function is a crucial assumption when testing for technical progress. When homotheticity is imposed, the output expansion effects on input shares are incorrectly attributed to biased technical change".

Islam and Veeman (1980) concluded in their study that technical change is factor biased. Technical change was inferred to be land and labor saving, and machinery, fertilizer and energy using. However, it should be noted that they imposed homotheticity without testing and the hypothesis of factor neutral technical change was not tested. Their conclusions are based on the significance of the estimated values of the coefficients of time in the share equations alone.

Adamowicz (1986) tested and rejected the hypothesis of factor neutral technical change. It was found that technical change was capital and material (intermediate goods) using and land and labor saving. However, the results of this study indicate that technical change is neutral to capital, is labor and land saving and there is weak evidence that it is intermediate goods using.

5.1.2 SCALE EFFECTS

In this study, the hypothesis of homotheticity is tested and rejected, while scale of production is intermediate goods using and labor saving.

Lopez (1980) also rejected the hypothesis of a homothetic production function, but found that scale was saving for all factors. It was concluded, "as scale of production is expanded efficiency in the use of factors increases". Lopez (1980) results are surprising, since he both rejected homotheticity and found that scale is factor saving for all factors. In general, for non-homothetic production functions, one would expect that scale be factor using or neutral for at least one factor.

Islam and Veeman (1980) imposed homotheticity without testing and so no comparisons can be made.

Adamowicz (1986) also rejected the hypothesis of homotheticity. Adamowicz found that scale of production was labor saving and neutral for capital, which is consistent with the results of this study. However, he also found that scale was land using and neutral with respect to material (intermediate goods); which were results not found in this study.

5.1.3 ELASTICITY OF SUBSTITUTION

In this section, estimates of the elasticities of substitution from the ARX(1,1) model are compared to estimates from the static model (see Table 5.1.1) with the same economic restrictions imposed as for the ARX(1,1) model.

It should be first noted that the elasticities of substitution are significantly different from zero for more pairs of inputs for the static model as compared to those for the ARX(1,1) model. Secondly, the elasticities are smaller in magnitude for the static model as compared to that for the ARX(1,1) model. The exceptions are those for the intermediate goods and land and building structures, which are almost equal in magnitude. Therefore, the two general conclusions that can be drawn. Firstly, long-run elasticities from the ARX(1,1) model are larger than the elasticities from the static model i.e., the static model tends to under estimate the elasticities. Secondly, the elasticities from the static model appear to be statistically significant from zero for more factor input pairs as compared to the long-run elasticity estimates from the ARX(1,1) model. These results indicate that the elasticities of substitution from the static model are sensitive to changes in relative prices but the degree of responsiveness is limited. This infers that the estimates of elasticities may also contain some short-run responses.

It is difficult to directly compare the elasticities estimated in different studies, since these studies were undertaken for different time periods. Furthermore, different aggregations of the data are used. The only results that can be adequately compared, are those which are statistically significant.

The estimates of elasticity of substitution for intermediate goods and land and building structures are significant for this study, in both the static and dynamic models. It was also found to be significant by Adamowicz (1986). The magnitude of the estimates of elasticities of substitution also appear to be very close in all three models (ARX(1,1), static, and Adamowicz).

The estimates of the elasticity of substitution for labor and land and building structures are large in magnitude and significantly different from zero for the ARX(1,1) and the static model estimated in this study, but are very small in Lopez (1980) and Adamowicz (1986). Lopez (1980) did not provide any significance level calculations for the estimates of the elasticities and therefore, comparing the results to this study is difficult.

Table 5.1: Comparison of Elasticities of Substitution for Canada

	ARX(1,1) ESTIMATED ELAST.	STATIC ESTIMATED ELAST	Lopez	Adamowicz	Islam and Veeman
1926-88			1946-77	1940-81	1961-78
CAP-INT	0.4156	0.2170‡	1.555	0.0889	
CAP-LAB	1.3511	0.3209‡	1.779	0.5535•	
CAP-LND	-2.2602	-0.5549	0.234	-0.4003	
INT-LAB	0.1167	-0.0476	0.875	1.3925•	
INT-LND	0.5137†	0.6491†	0.991	0.4420•	
LAB-LND	2.3800†	1.8888†	0.113	-0.1383	0.3176
1959-68					
CAP-INT	0.4706	0.3013†			
CAP-LAB	1.3304	0.3656†			
CAP-LND	-2.0648	-0.4375			
INT-LAB	0.0985	-0.0722			
INT-LND	0.5041†	0.6446†			
LAB-LND	2.4616†	1.9426†			
1969-78					
CAP-INT	0.4913	0.2923†			
CAP-LAB	1.3420	0.3451†			
CAP-LND	-1.8550	-0.4258			
INT-LAB	0.0652†	-0.0794			
INT-LND	0.5373†	0.6562†			
LAB-LND	2.4695	1.9292†			
1979-88					
CAP-INT	0.5805‡	0.4859†			
CAP-LAB	1.4264	0.1983			
CAP-LND	-2.4119	-0.4266			
INT-LAB	-0.0574	-0.2988‡			
INT-LND	0.4983†	0.6618†			
LAB-LND	3.4087	2.5400†			

[1] Symbols † and ‡ denote that the estimated elasticities are significant at the 5% and 10% levels of significance. The significance of the estimates are determined on the basis of confidence intervals constructed using simulated results. For the confidence of simulated results of static model see Table A4.1 Appendix 4.

[2] Symbol • for the Adamowicz (1986) model indicates estimates are greater than twice their standard error. The standard errors of the estimates are approximated with the standard errors of the π_{ij}'s parameters.

5.1.4 OWN-PRICE ELASTICITIES

Most of the estimates of own-price elasticities from the ARX(1,1) model are larger, almost twice the size, in absolute value as compared to those estimated from the static model (see Table 5.1.2). The exception is for the estimate of own-price elasticity for land and building structures, which are fairly close. This type of relationship between own-price elasticity estimates from the two models is expected (Nakamura, 1985). Estimates of own-price elasticities from the ARX(1,1) model are long-run estimates, whereas the estimates from the static model may include short-run responses. However, as in the case with elasticities of substitution, own-price elasticities are statistically significant for more inputs from the static model as compared to those from ARX(1,1) model. It should also be noted, that the own-price elasticity estimates for land and building structures are almost equal for both the static and ARX(1,1) models in this study. This implies that there may not be significant short-run responses to changes in the prices of land and building structures.

As stated previously, it is difficult to compare the estimates of own-price elasticities from this study to those from earlier studies by Lopez (1980), Islam and Veeman (1980) and Adamowicz (1986). Except for signs which are negative as expected, there does not appear to be much similarity among the estimates of this study and the earlier ones.

Table 5.1.2: Comparison of Own-Price Elasticities for Canada

	ARX(1,1) ESTIMATED ELAST.	STATIC ESTIMATED ELAST	Lopez	Adamowicz	Islam and Veeman
1926-88			1946-77	1940-81	1961-78
CAP	-0.4303	-0.1666†	-0.347	-0.1680	
INT	-0.1157†	-0.0581†	-0.410	-0.2396	
LAB	-0.3829	-0.1689†	-0.517	-0.3441	-0.3315
LND	-0.8441†	-0.9170†	-0.422	-0.0938	-0.0626
1959-68					
CAP	-0.4658	-0.2332†			
INT	-0.1143†	-0.0572†			
LAB	-0.3830	-0.1626†			
LND	-0.8449†	-0.9194†			
69-78					
CAP	-0.4734†	-0.2215†			
INT	-0.1111	-0.0567†			
LAB	-0.3817	-0.1601†			
LND	-0.8434†	-0.9168†			
1979-88					
CAP	-0.4899	-0.3073†			
INT	-0.0763†	-0.0286			
LAB	-0.3484	-0.0328			
LND	-0.8469†	-0.9306†			

[1] Symbols † and ‡ denote that the estimated elasticities are significant at the 5% and 10% levels of significance. The significance of the estimates are determined on the basis of confidence intervals constructed using simulated results. For the confidence of simulated results of static model see Table A4.2 Appendix 4.

[2] Symbol * for the Adamowicz (1986) model indicates estimates are greater than twice their standard error. The standard errors of the estimates are approximated with the standard errors of the π_{ij}'s parameters.

5.2 EMPIRICAL RESULTS ON THE ALBERTA AGRICULTURAL SECTOR

In this section, the empirical results of this study for the Alberta agricultural sector are compared with the results obtained by Rahuma (1989) on the Alberta grain sector and with the results for the Canadian agricultural sector obtain in this study. Rahuma (1989) analyzed the Alberta grain sector for 1957 to 1983.

5.2.1 TECHNICAL CHANGE AND SCALE EFFECTS

Technical change in this study is found to be factor neutral in Alberta and land and building structures saving and may be intermediate goods using, but capital and labor neutral for Canada. Rahuma (1989) found technical change in the Alberta grain sector to be labor saving but machinery and fertilizer using.

Scale of production in this study is found to be intermediate goods using, labor saving and neutral for land and building structures for both the Alberta and the Canadian agricultural sectors. Scale is capital using for Alberta, but neutral for Canada. Rahuma (1989) found that scale is labor saving, machinery using and weakly land, fertilizer and material using for the Alberta grain sector.

5.2.2 SUBSTITUTION AND OWN-PRICE ELASTICITIES

Capital and labor are found to be substitutes in this study for the Alberta agricultural sector, while capital and land and building structures are strong complements. Whereas, for the Canadian agriculture sector, labor and land and building structures are strong substitutes, while intermediate goods and land and building structures are also substitutes; the degree of substitution is very low.

The above results imply that the substitution of labor for capital and the complimentary relationship between capital and land in Alberta along with the substitution of labor for land and building structures in Canada, are likely due to farm mechanization. As the relative price of labor has increased over time, farms in Alberta and Canada have moved towards becoming larger and more capitalized.

Rahuma (1989) also found that labor and machinery are substitutes, which is consistent with the results of this study. However, Rahuma (1989) found that land and labor are compliments, which is contrary to observed trends in the sector and to the results of this study. From Rahuma's results, it would follow that when the price of labor increased relative to that of machinery, more machinery would be substituted for labor, but less land would be used, since land and labor were found to be compliments. Whereas, the results of this study indicate the scenario, where as the relative price of labor increases, capital is substituted for labor, while more land and building structures are also used, since capital and land are found to be strong compliments.

One further note is that the own-price elasticity for machinery in Rahuma (1989) is positive indicating that non-negativity of the cost function may be violated in the estimates. Rahuma (1989) did impose the hypothesis of symmetry without testing on his cost function model which may account for this contradictory result.

Chapter 6

SUMMARY AND CONCLUSIONS

In this study, data on the Alberta and Canadian agricultural sectors are analyzed. The analysis is based on an estimated system of share equations of translog functional form. Unlike earlier studies, a dynamic form of the system of share equations is selected to model each sector. A static (long-run equilibrium) system of share equations is rejected as representing the two agricultural sectors based on diagnostic tests of adequacy (statistical) and the rejection of economic restrictions applied to the long-run parameters. Two other models, a partial adjustment model, and a model of autoregressive process of order one for disturbances are considered and rejected on the same grounds.

A dynamic multivariate autoregressive process of order one system of share equations of translog functional form adequately fits the data for both the Canadian and Alberta agricultural sectors. This leads to the conclusion that the realized data for the Canadian and Alberta agricultural sectors are generated by dynamic and not static (long-run) production processes. The departures from the long-run production processes can be explained by the inability of the producers to adjust instantaneously to the changes in economy. Lags in adjustment may exists due to the costs of adjustment and of obtaining information regarding changes in the economy.

One of the major findings of this study is that the estimated models of Alberta and Canadian agricultural sectors that fulfill the conditions of economic theory and the statistical assumptions are dynamic. Traditional static econometric models used in past, have made significant contributions to the understanding of agricultural sector change but are inadequate. This study demonstrates that a simple static model, or dynamic models obtained, by simply correcting for errors, such as autoregressive errors or by short run adjustments, such as a partial adjustment model do not fit the data generated from the Alberta and Canadian agricultural sectors. Models estimated in this study are selected by testing underlying statistical and economic hypotheses, rather than imposing these restrictions on the models without testing them first. This study provides an improvement on previous important models of the Canadian agricultural sector and a model for the Alberta agricultural sector.

Another significant result of this study is that simulated standard errors and confidence intervals are obtained for elasticities of substitution and own-price. Conclusions are drawn on the basis of these confidence intervals and not just on the basis of estimated values as had been the case earlier. Inferences which are drawn just on the basis of estimated values can be misleading and improper. As shown in Table 3.3.1, if only a point estimate is used, then capital and labor would be viewed as strong substitutes, since the elasticity of substitution between capital and labor is approximately 1.35. However, the standard error of the estimate is even larger than the estimate of the of elasticity and therefore, the estimate of elasticity of substitution for capital and labor is not significantly different from zero. The same problem would arise in this case, if the standard errors of the estimates of elasticities were approximated by the standard errors of the estimted coefficients used in their calculations.

Further, it should be noted that the simulated standard errors of the estimates of the elasticities are reasonably good estimates, since the mean simulated values of elasticities are very close to the corresponding estimated values from the model.

The following conclusions can be drawn from the results of this study on the Canadian agricultural sector

Technical change for the Canadian agricultural sector is factor biased. The bias of technical change is intermediate goods using and land saving.

The long-run production function for the Canadian agricultural sector is non-homothetic. Scale of production is intermediate goods using and labor saving.

Substitution opportunities exist among the input factors in response to relative price changes. Labor and land and building structures are strong substitutes, while intermediate goods and land and building structures are significant substitutes.

All of the factor inputs are inelastic to their own prices, except for land, which appears to be elastic to its price.

The following conclusions can be drawn from this study for the Alberta agricultural sector

Technology for the Alberta agricultural sector is factor neutral. The long-run production function is non-homothetic. Scale of production is intermediate goods using and labor saving, as was found for the Canadian sector.

The ability to substitute among factor inputs is greater for the

Alberta agricultural sector than is generally found for Canada. Capital and labor are good substitutes, while capital and land and building structures are strong complements.

Capital and intermediate goods are substitutes and the degree of substitution has increased over time. Increasing substitution between capital and intermediate goods as well as intermediate goods and land and building structures, implies that the Alberta agricultural sector has shifted towards larger, highly capitalized farms and in later periods has moved toward more intensified farming practices.

The results of this study provide more accurate estimates of the structural parameters, which define both the Canadian and Alberta agricultural sectors, than in previous studies. There are several policy implications, which can be drawn from these results. Firstly, all of the factor inputs are inelastic to their own prices, except for land and building structures in the Canadian agricultural sector, implying that both sectors are vulnerable to monopolistic suppliers of farm inputs. Secondly, the characteristics of the Canadian agricultural sector are dominated by land and building structures, which as a variable is a substitute for intermediate goods and labor and at the same time is most responsive to variations in its own price. On the other hand, capital is used with other factor inputs in relatively fixed proportions. Agricultural policy researchers and makers should be aware that the effects of interventions into the Canadian agricultural sector will be greatest on the price and use of land and building structures. Finally, the Alberta agricultural sector differs from that for Canada, since capital and labor are substitutes, while capital and land and building structures are strong compliments. This implies that national policies targeted to increase the welfare of rural Canadians may have conflicting or adverse effects on rural Albertans.

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APPENDIX 1

DATA DESCRIPTION AND SOURCES

Table A1.1 : Output Commodities

Output Commodities	Sources
Alfalfa Seed Sold	21-003
Alsike Clover Seed Sold	21-003
Apples[c]	22-003
Apicots	22-003
Barley Produced	21-516, 22-201, HFC, AA
Beans, Dry[c]	21-516, 22-201, HFC, AA
Beans, Fresh and Processing[c]	22-003
Beats, Fresh and Processing[c]	22-003
Bird's-Foot Trefoil Seed[c]	21-512
Blueberries[c]	22-003
Brome Grass Seed Sold	21-003
Buckwheat[c]	21-516, 22-201, HFC, AA
Cabbage Sold	21-512, 22-003
Carrots Sold	21-512, 22-003
Canary Seed	AA
Cattle Sold and Inventories	21-514, 23-203, ADSS, AA
Cauliflower[c]	21-512, 22-003
Celery[c]	21-512, 22-003
Cherries[c]	21-512, 22-003
Chickens Sold and Inventories	21-003, 23-202, ADSS, AA
Corn for Grain Produced	21-516, HFC, ADSS, AA
Corn Fresh Sold	21-512, 22-003
Cranberries[c]	21-512, 22-003
Cucumbers Sold	21-512, 22-003
Creeping Red Fescue Seed[c]	21-003
Crested Fescue Seed[c]	21-003
Ducks Sold and Inventories	21-003, 23-202
Eggs Produced	21-003, 23-202
Fababeans	AA
Fiber-Flax Seed[c]	21-516, HFC
Fescue Seed Sold[a]	21-003
Field Cropd Sold, (NES)	21-003, 21-202, 62-001, 62-501, FNIRM
Field Roots Produced	21-516, HFC
Flaxseed Produced	21-516, HFC
Floriculture and Nursery Sold	21-202
Fodder Corn Produced	21-516, HFC, AA
Forest Products Sold	21-202 SBAA
Forest Products, Income In Kind	21-202, SBAA
Fox Pelts, Farm[c]	23-208
Fox Sold Alive, Farm	23-208
Fruit and Vegetables[c] (NES)	FNIRM, 62-004, 62-534
Geese Sold and Inventories	21-003, 23-202
Hay, Tame Produced	21-516, HFC, AA
Hogs Sold and Inventories	21-514, 23-203, ADSS-AG
Honey Sold	21-003, 23-007, 23-209, 23-211
Hops[c]	21-003, 21-516

Table A1 (Continued)

Income in Kind[c]	FNIRM
Lambs Sold	21-514, 23-203, ADSS-AA
Lentils Produced	22-201, HFC, AA
Livestock & Products Sold, NES	21-003, 21-202, 21-511, 62-011, FNIRM
Loganberries[c]	21-003
Mapple Products[c]	22-204, 23-211, AA
Meadow Fescue Seed[c]	21-203
Meat, Income in Kind	21-202, FNIRM, SBAA
Milk Produced	21-515, 23-001, 23-201
Mink Pelts Sold	23-208
Mink Sold Alive and Inventories	23-208
Mixed Grains	21-516, 22-201, HFC, AA
Mushrooms[c]	22-003
Mustard Seed Produced	21-516, HFC
Oats for Grains Produced	21-516, 22-201, HFC, AA
Onions Sold	21-512, 22-003
Onion Seed[c]	21-003
Peas, Dry Produced	21-516, HFC, AA
Parsnips[c]	22-003
Peaches[c]	22-003
Pears[c]	22-003
Peas, Dry[c]	21-516, 22-201, HFC, AA
Peas For seed[c]	21-003
Peas, Fresh and Processing[c]	22-003
Plums And Prunes[c]	22-003
Potatoes Produced	21-516, HFC, AA
Radishes[c]	22-003
Rapeseed Produced	21-516, 22-201, HFC, AA
Raspberries[c]	22-003
Red Clover Seed Sold	21-003
Russian Wild Rye seed Sold	21-003
Rye, Fall Produced	21-516, 22-201, HFC, AA
Rye, Spring Produced	21-516, 22-201, HFC, AA
Sheep Sold and Inventories	21-514, 23-203, ADSS, AA
Soyabeans[c]	21-516, 22-201, HFC, AA
Spinach[c]	22-003
Strawberries[c]	22-003
Sugar Beets Produced	21-516, 22-201, HFC, AA
Sunflower Seed Produced	21-516, 22-201, HFC, AA
Sweet Clover Seed Sold	21-003
Timthy seed Sold	21-003
Tobacco[c]	21-516, 22-201, HFC, AA
Tomatoes, Fresh and Processing[c]	22-003
Turkeys Sold and Inventories	21-003, 23-202
Turnips Sold	21-516, HFC
Vegetables Sold, NES	21-202, SBAA
Vegetables, Income In Kind	21-202, SBAA
Wheat, Durum Produced	21-516, 22-201, HFC, AA

Table A1 (Continued)	
Wheat, Spring Produced	21-516, 22-201, HFC, AA
Wheat, winter Produced	21-516, 22-201, HFC, AA
Wheat Grass Seed Sold	21-003
Wool Sold	21-514, 23-205, ADAG

Table A1.2: Input Commodities

Input Commodities	Sources
Alfalfa Seed	21-003
Alsike Clover Seed	21-003
Artificial Insemination and Veterinary Expenses	21-511, FNIRM, 62-004, 62-534
Barley for Feed	22-201, HFC, AA
Barley for Seed	22-201, HFC, AA
Beans For seed[c]	22-201, HFC, AA
Bird's-Foot Trefoil Seed[c]	21-003
Breed Association Fees	21-511, FNIRM, 62-004, 62-354
Brome Grass Seed	21-003
Building Depriciation	21-511, FNIRM, 62-004, 62-534
Building Repairs	21-511, FNIRM, 62-004, 62-534
Creeping Red Fescue Seed[c]	21-003
Crested Wheat Grass Seed[c]	21-003
Elecricity	21-511, FNIRM, 62-004, 62-534
Feed Purchased	21-511, FNIRM, 62-004, 62-534
Feeder Cattle and Weanling Pigs	21-511, FNIRM, 62-004, 62-534
Fertilizers	21-511, FNIRM, 62-004, 62-534
Fescue Seed[a]	21-003
Fiber-Flax Seed[c]	21-003
Field-Roots Seed[c]	21-003
Financial Services	21-511, FNIRM, 62-004, 62-534
Flax Seed	22-201, HFC, AA
Fodder Corn Fed	21-516, 22-201, HFC, AA
Fox Bought Alive[c]	23-208
Grass Seed[c]	23-208
Hay Fed	21-516, 22-201, HFC, AA
Irrigation Charges	21-511, FNIRM, 62-004, 62-534
Labor, Hired	21-511, FNIRM, 62-004, 62-534
Labor, Unpaid	Variou Census Reports
Land, Leased	Various Census Reports
Land, Owned	Variou Census Reports
Lime[c]	21-511, FNIRM, 62-004, 62-534
Machinery Depreciation	21-511, FNIRM, 62-004, 62-534
Machinery Repairs	21-511, FNIRM, 62-004, 62-534
Meadow Fescue seed[c]	21-003
Milk Fed to Livestock	21-505
Mink Purchased	23-208
Miscellaneous Expenses	21-511, FNIRM, 62-004, 62-534

Table A2 (Continued)

Oats for Feed	22-201, HFC, AA
Oats for Seed	22-201, HFC, AA
Onions For Seed[c]	21-003
Peas For Seed[c]	21-516, HFC, AA
Pesticides	21-511, FNIRM, 62-004, 62-534
Petroleum Products	21-511, FNIRM, 62-004, 62-534
Rapeseed for Seed	22-201, HFC, AA
Red Cover Seed	21-203
Russian Wild Rye Seed	21-203
Rye for Feed	22-201, HFC, AA
Rye For Seed	22-201, HFC, AA
Seed Purchased	21-511, Fnirm, 62-004, 62,534
Sweet Clover Seed	21-203
Taxes	21-511, FNIRM, 62-004, 62-534
Telephone	21-511, FNIRM, 62-004, 62-534
Timothy Seed	21-203
Twine, Wire, and Containers	21-511, FNIRM, 62-004, 62-534
Vegitable Seed[c] (NES)	21-003
Wheat for Feed	22-201
Wheat for Seed	22-201
Wheat Grass Seed	21-203
Beginning Inventories Of	
Cattle and Calves	23-003
Ducks	21-003, 23-202
Chickens	21-003, 23-202
Fox on Farms[c]	23-208
Geese	21-003, 23-002
Hogs	23-203
Mink	23-203
Sheep and Lambs	23-202
Turkeys	21-003, 23-202

[1] Superscipt c denote data is for Canada.
[2] Superscipt a denotes data is for Alberta

<u>Statistics Canada Data Sources</u>:

21-002 Farm Wages in Canada, (Quaterl 1940- 1986).
21-003 Quaterly Bulletin of Agricultural Statistics (monthly 1908-40, quaterly 1941-78).
21-202 Farm Net Income, (annual 1940-__).
21-511 Handbook of Agricultural Statistics, Part II: Farm Income, 1926-65.
21-512 Handbook of Agricutural Statistics, Part V: Vegetables and Fruits, 1940-1966.
21-514 Handbook of Agricultural Statistics, Part VI: Livestock and Animal Products, 1871-1973.
21-515 Handbook of Agricultural Statistics, Part VII: Diary Statistics, 1920-1973.

21-516 Handbook of Agricutural Staistics, Part I: Field Crops, 1921-1974.
22-003 Fruits and Vegetable Production, (seasonal 1932-—).
22-007 Grains and Oilseed Review (quarterly 1978-—).
22-201 Grain Trade of Canada, (annual 1918-—).
22-204 Production of Maple Products and Value of Maple Products (annual 1938__).
23-001 The Dairy Review (monthly, 1938-__).
23-003 Production and Stock of Eggs aand Poultry, (monthly 1948-—).
23-007 Honey Production, (semi-annual 1938-—).
23-201 Diary Staistics, (annual 1933-77).
23-202 Production of Poultry and Eggs, (anual 1936-—).
23-203 Livestock and Animal Products Statistics (annual 1909 --).
23-208 Report on Fur Farms, (annual 1919-—).
23-209 Production and Value Estimate of Honey, (annual 1970-76).
23-211 Production and Value of Honey and Mapple Products (annual 1987--).
62-002 Prices and Price Indexes, (monthly 1923-75).
62-004 Farm Input Price Indexes, (quaterly, 1944-—).
62-011 Industry Price Indexes, (monthly 1975-—).
62-534 Farm Input Price Indexes, 1961-71.
FNIRM Farm Net Income References Manual (Handbook), 1926-84.
HFC Handbook of Field Crop Area,•••, 1953-1986.
ADSS Agricutural Division, Statistics Canada (unpublished data).
AA Alberta Agricuture (unpublished data)
SBAA Statistics Yearbook. Alebrta Agricuture.

Notes on Data

An updated version of data originally assembled by T. W. Manning for his studies [1985, 1986a, 1986b] on the Alberta and Canadian agricultural sectors, are utilized in this study. The data on both prices and quantities of outputs and inputs are required for this study. Every effort is made to be consistent when updating the data however, for some quantities data is no longer published and for some, it was the case originally and were obtained from series maintained by the staff of Statistics Canada and Alberta Agriculture. For unpublished data every effort is being made to update data consistent to the data obtained before 1984. A list of commodities and their sources are presented in table A1 and A2. A detailed description of the data and their sources is given in Manning (1985, 1986a). A brief discussion of the data is provided below, which is based on Manning (1985, 1986a, 1986b).

A2. Output Data:

For most crops grown in Alberta and Canada, actual production data were published by Statistics Canada (22-201, HFC, 22-516) till 1984. Actual production data referred to quantities produced in the current year and average farm price. Statistics Canada stopped publishing the average farm price of crops produced after 1984 but information on quantities produced are still available. the average farm price for the crops produced in Alberta were obtained from the Statistics and

Marketing Analysis branches of Alberta Agriculture. The average farm price of special crops in Canada were also obtained from these branches of Alberta Agriculture. The average farm prices for major crops for the years 1985-88 in Canada were estimated based on the information available in Catalogue 22-201 (Statistics Canada) using a weighted average mean process. Theses estimates were reasonably close to average farm prices for the years in which they were published. For vegetables, actual production data are still available.

Livestock data were taken from various published sources, augmented by unpublished data from Alberta Agriculture and Statistics Canada. Data on income in kind for various categories were published in 21-202 (Statistics Canada) till 1984. Data were available in terms value in dollars. Otherwise, price indexes for categories, if available, of closely related categories were used as average price. Quantities were calculated by dividing the values by the price indexes. After 1984, information regarding values of income in kind were taken from the Agriculture Statistics Yearbook published by Alberta Agriculture. For Canada, values of total income in kind were used instead of individual categories and the values were obtained from FNIRM. Price indexes of farm products are used as price.

A3. Input Data

Data on inputs were divided into three categories: purchased inputs, produced inputs and entrepreneurial inputs (Manning 1968a, 1986b). A List of all input categories and their sources is provided in table A2.

A3.1 Purchased Inputs

Purchased inputs fall into the following categories: depreciation on buildings and machinery; feed and seed, hired labor; property taxes ; and services etc.,. Data in some of these categories were available as those are measured directly or indirectly (e.g., feed and seed purchased, fertilizer etc.) while for others were calculated or imputed (e.g., repairs and depreciation on buildings, finance and rent on leased land etc.).

Data on purchased inputs were obtained from various publications of Statistic Canada. Data were also available on values and price indexes of the inputs. Quantities of inputs purchased are generally not directly available and proxies were calculated by dividing their values by corresponding price indexes (Manning 1986a). However, a problem arise, since the categories reported have changed over the years with the trend toward reporting more disaggregated and precisely defined categories. Thus for some categories, price indexes were not reported in earlier years and price index of closely related input categories were used for those years.

Some purchased inputs are estimated e.g., taxes, financial charges, and depreciation and repairs on building etc. since reported data correspond only to farms operated by owners only. Estimated values for owner operated and leased farm were calculated based on unpublished information available from Statistics Canada and Alberta Agriculture. Some of these estimation procedures are recognized as being arbitrary.

A2.2 Produced Inputs

Produced inputs are outputs produced in previous years and used as inputs in the current year. Produced inputs are mainly feed, seed, and beginning inventories. Most of these figures were obtained from published data of Statistics Canada and with data for few input categories for a few years augmented by unpublished data obtained from the staffs of Alberta Agriculture and Statistics Canada. Data on the quantities of produced feed and seed provided in 'Grain Trade of Canada (22-201) were converted to a calendar year basis. All seeds produced were assigned to the following year. Feed used quantities were divided between current and the following year on a five to seven ratio. Estimates of quantities of milk fed to livestock were available until 1981 and for later years, they are calculated based on the average proportion to the total milk produced in years for, which the data were published. The price of input categories are the average farm prices of the produced outputs in their input use years.

A3. Entrepreneurial inputs

Unpaid labor and owned land constitutes the entrepreneurial inputs. Values of these inputs are estimated using residual values between total output value and the total value of the rest of the inputs for each year. The underlying assumption of this estimation procedure is that total output and input values should be equal and return to unpaid labor and owned land should not exceed their contribution to total output value (Manning 1986a). Eighty five percent of the residual value was assigned to the unpaid labor and the rest to the owned land. The division is entirely arbitrary, as Manning (1986a) argued that there is no theoretical or practical basis for justifying one procedure from other. The quantities of owned land were taken from various Census Reports and the quantities for non-census years were interpolated. To estimate the quantities of land , quantities of unimproved land were given half the weight of that of improved land. Average prices for unpaid labor and owner operated land were calculated by dividing their values by their respective quantities.

APPENDIX 2

RESIDUAL ANALYSIS PLOTS FOR CANADA

The following abbrevitaions are used to represent the model of the system of share equations:

STCSY	Symetric Static Model.
PADSY	Symetric Partial Adjusment Model.
EARSY	Symetric Autoregressive Process for Disturbances Model.
ARXSY	Symetric Multivariate Autoregressive Proceess Model.

Figure 1: Residual Plots of STCSY for Canada

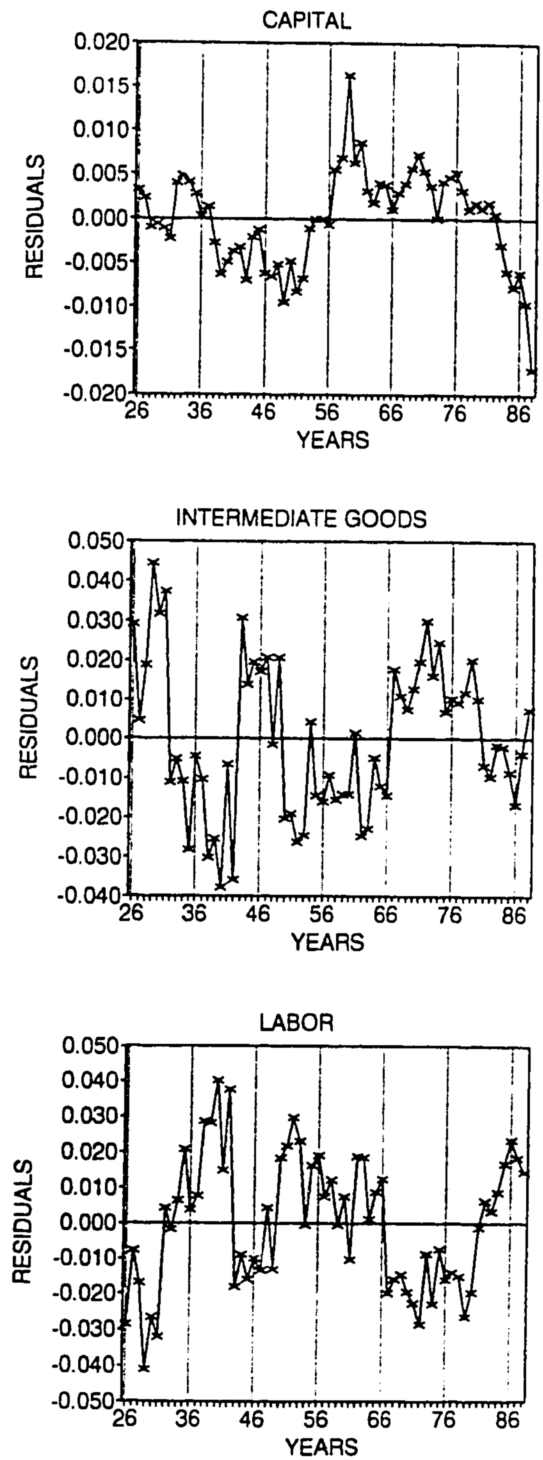


Figure 2: Residual Autocorrelation and Partial Autocorrelation Function of STCSY for Canada.

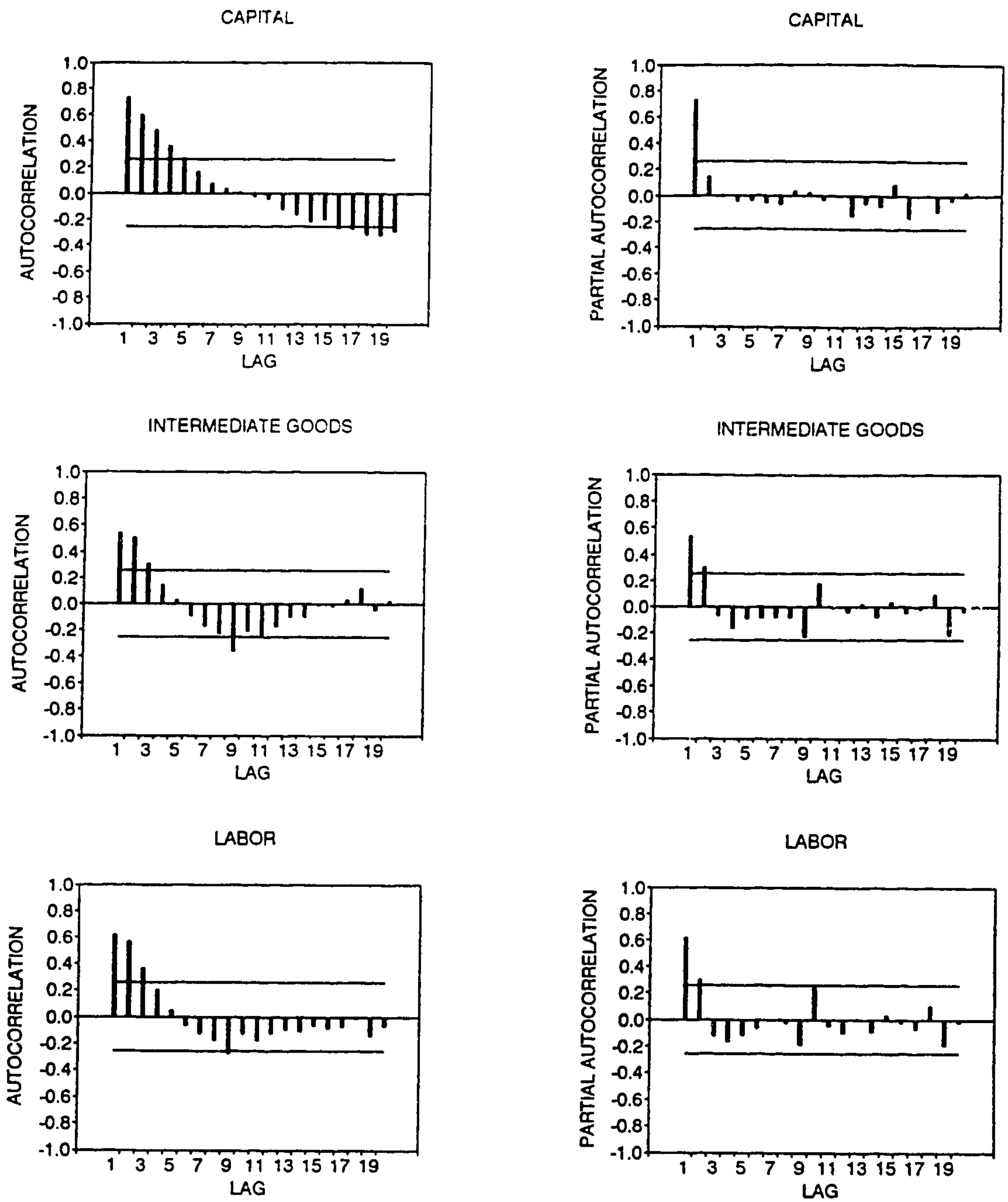


Figure 3: Normal Probability Plots of STCSY for Canada.

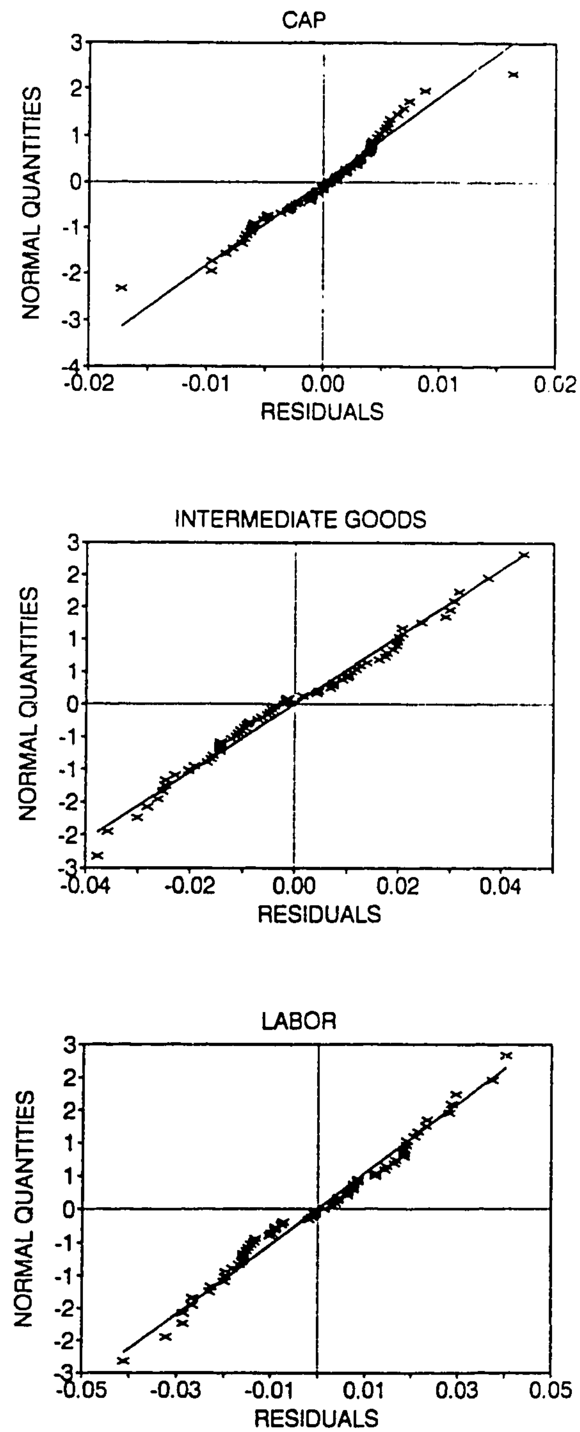


Figure 4: Residual Plots of PADSY for Canada

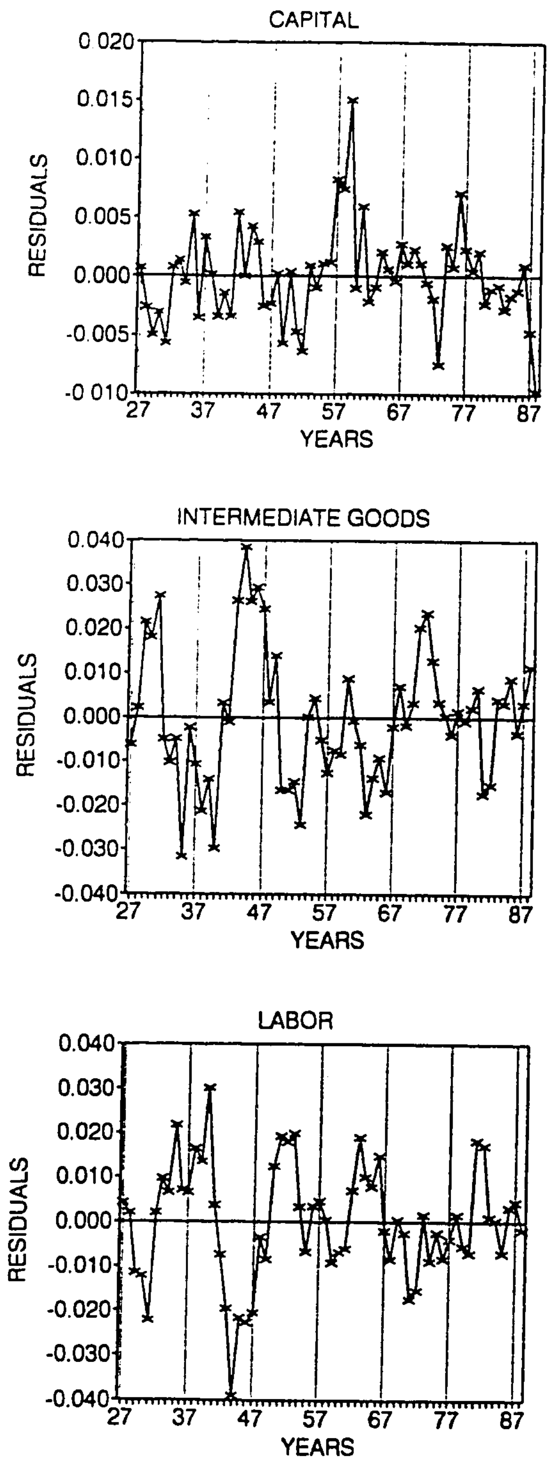


Figure 5: Residual Autocorrelation and Partial Autocorrelation Function of PADSY for Canada.

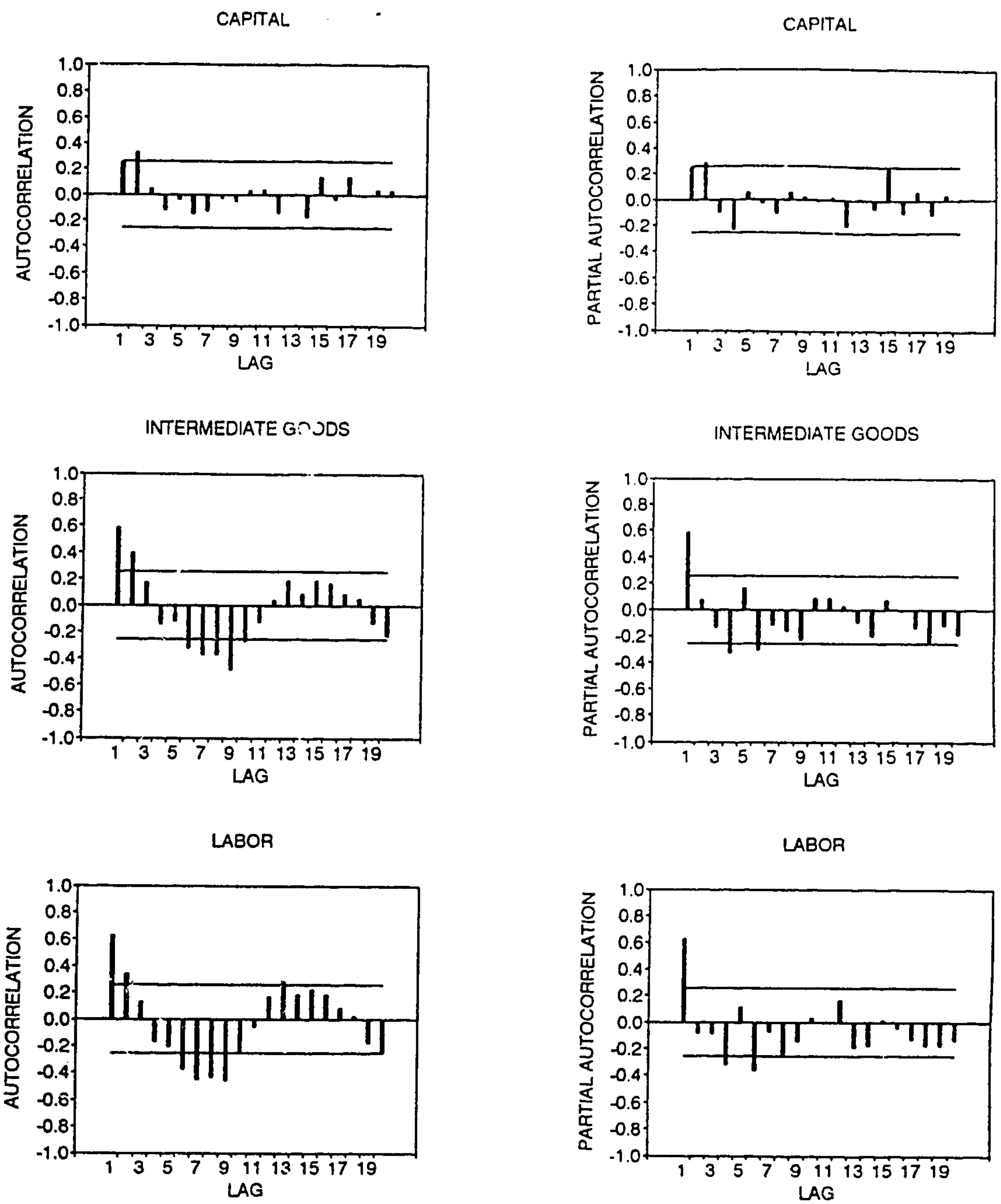


Figure 6: Normal Probability Plots of PADSY for Canada.

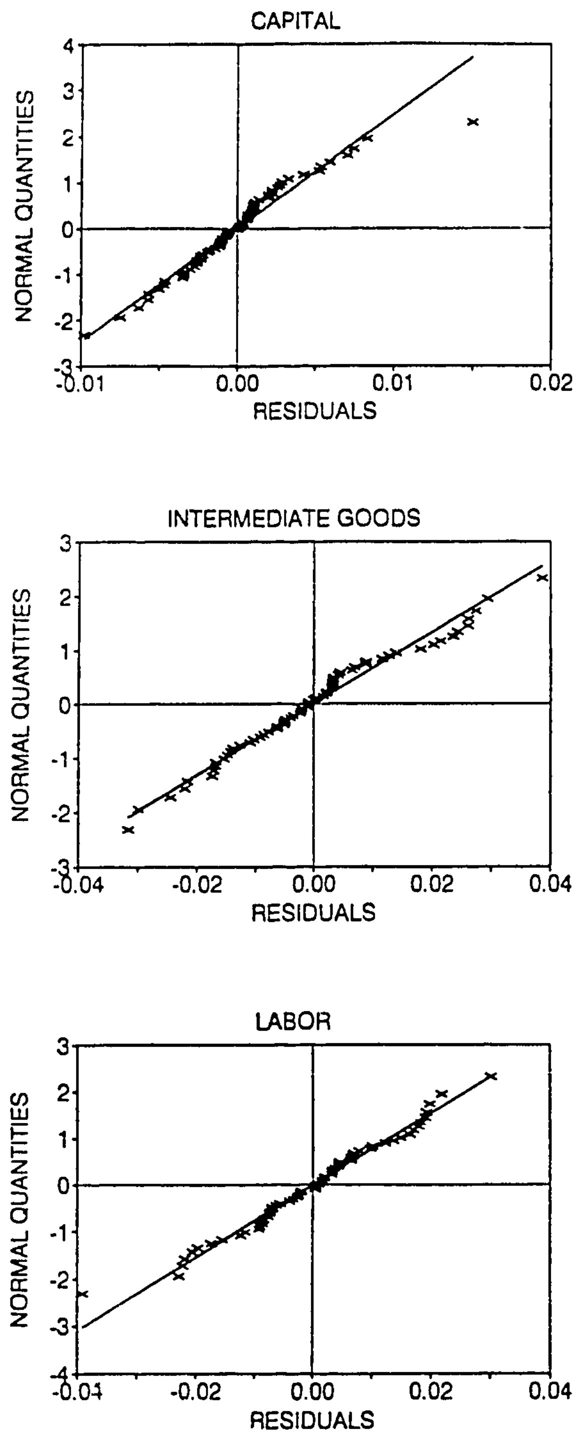


Figure 7: Residual Plots of EARSY for Canada

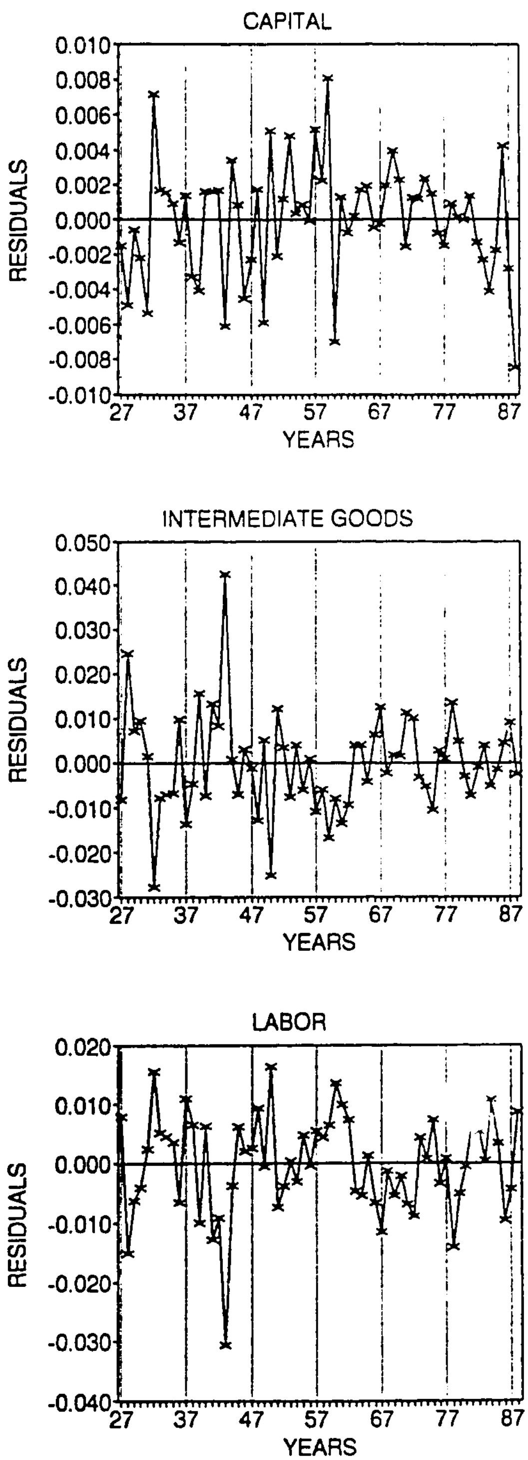


Figure 8: Residual Autocorrelation and Partial Autocorrelation Function of EARSY for Canada.

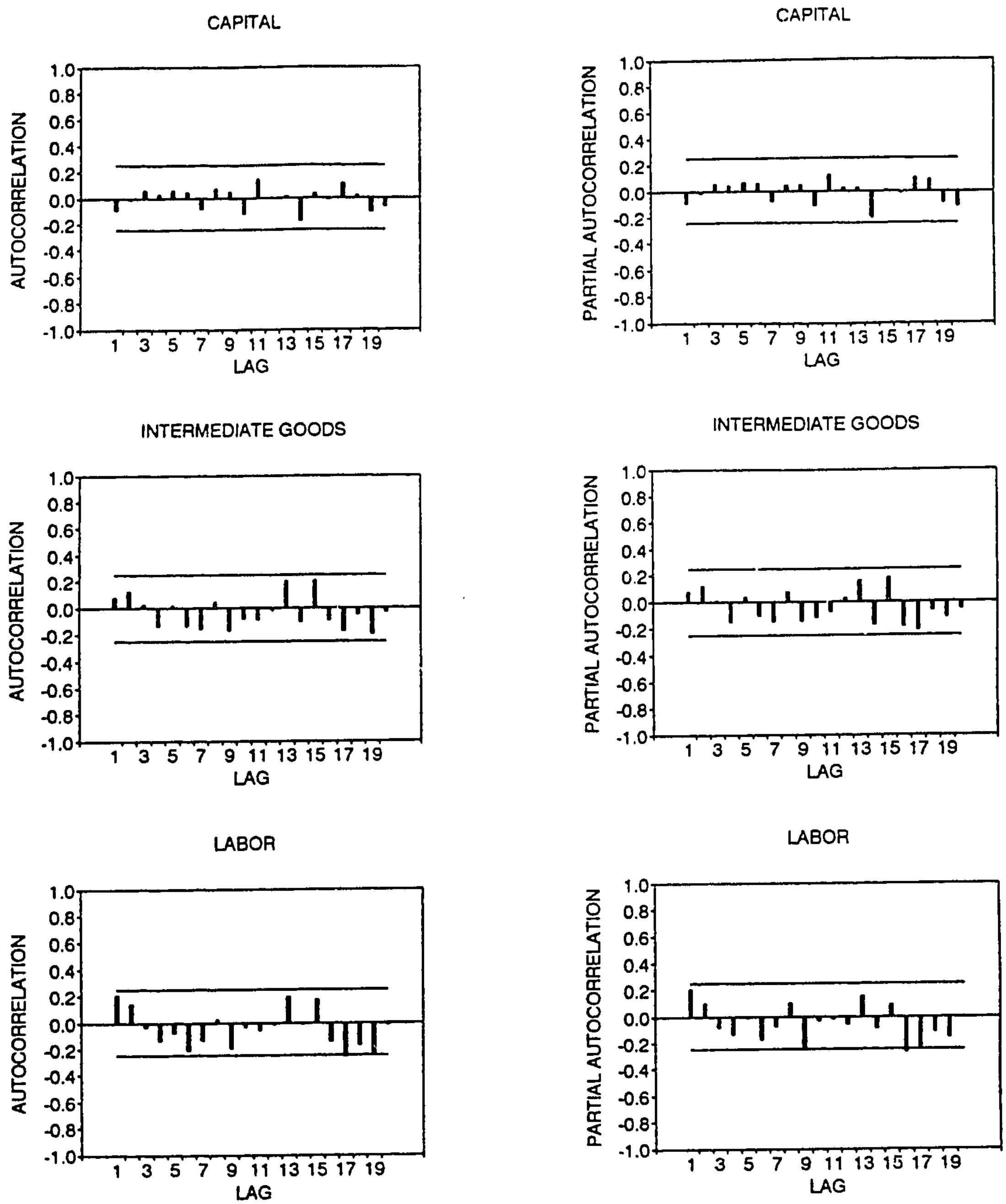
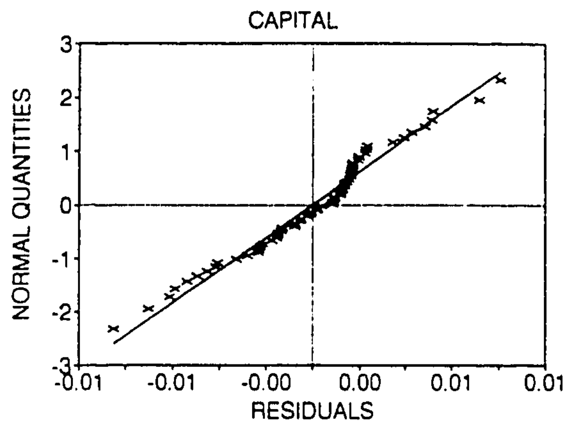
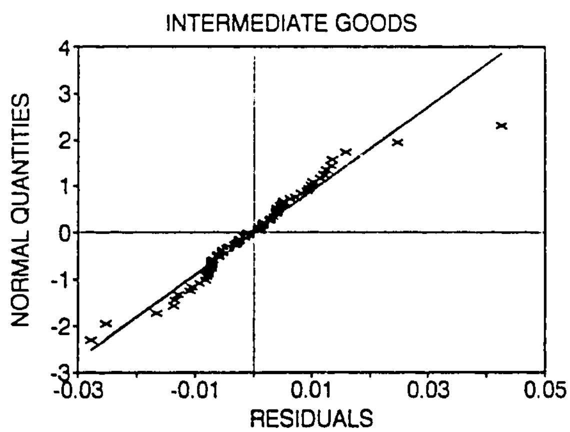


Figure 9: Normal Probability Plots of EARSY for Canada.





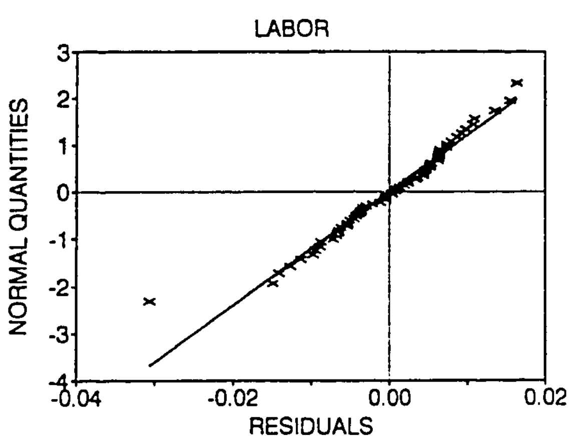


Figure 10: Residual Plots of ARXSY for Canada

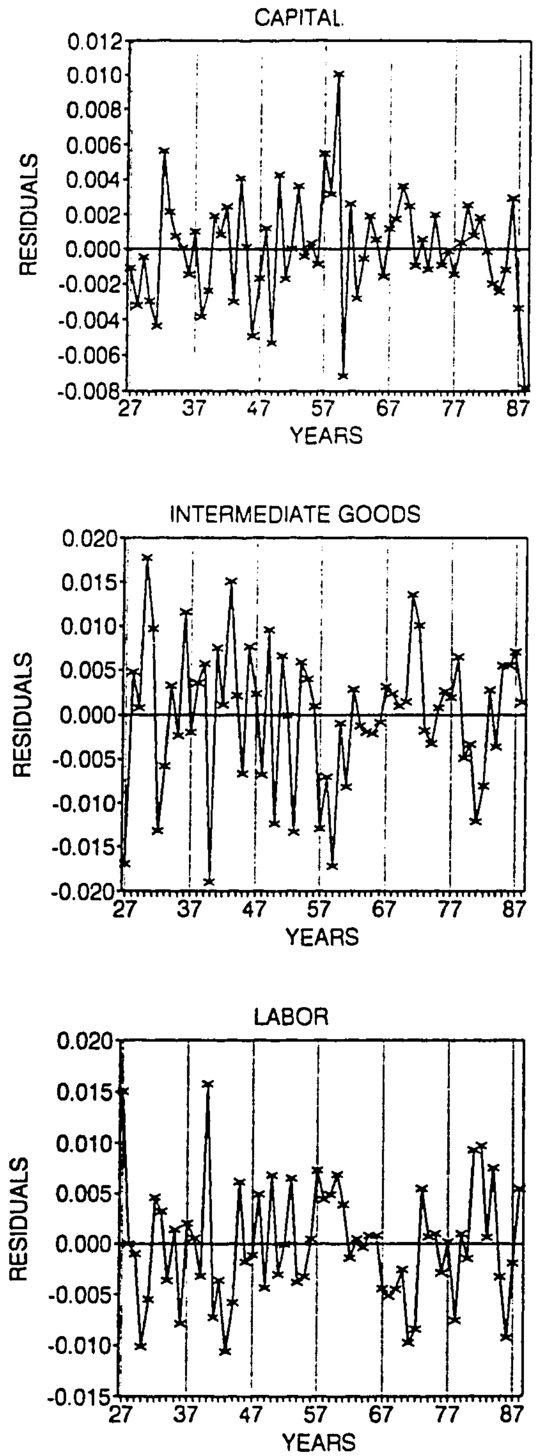


Figure 11: Residual Autocorrelation and Partial Autocorrelation Function of ARXSY for Canada.

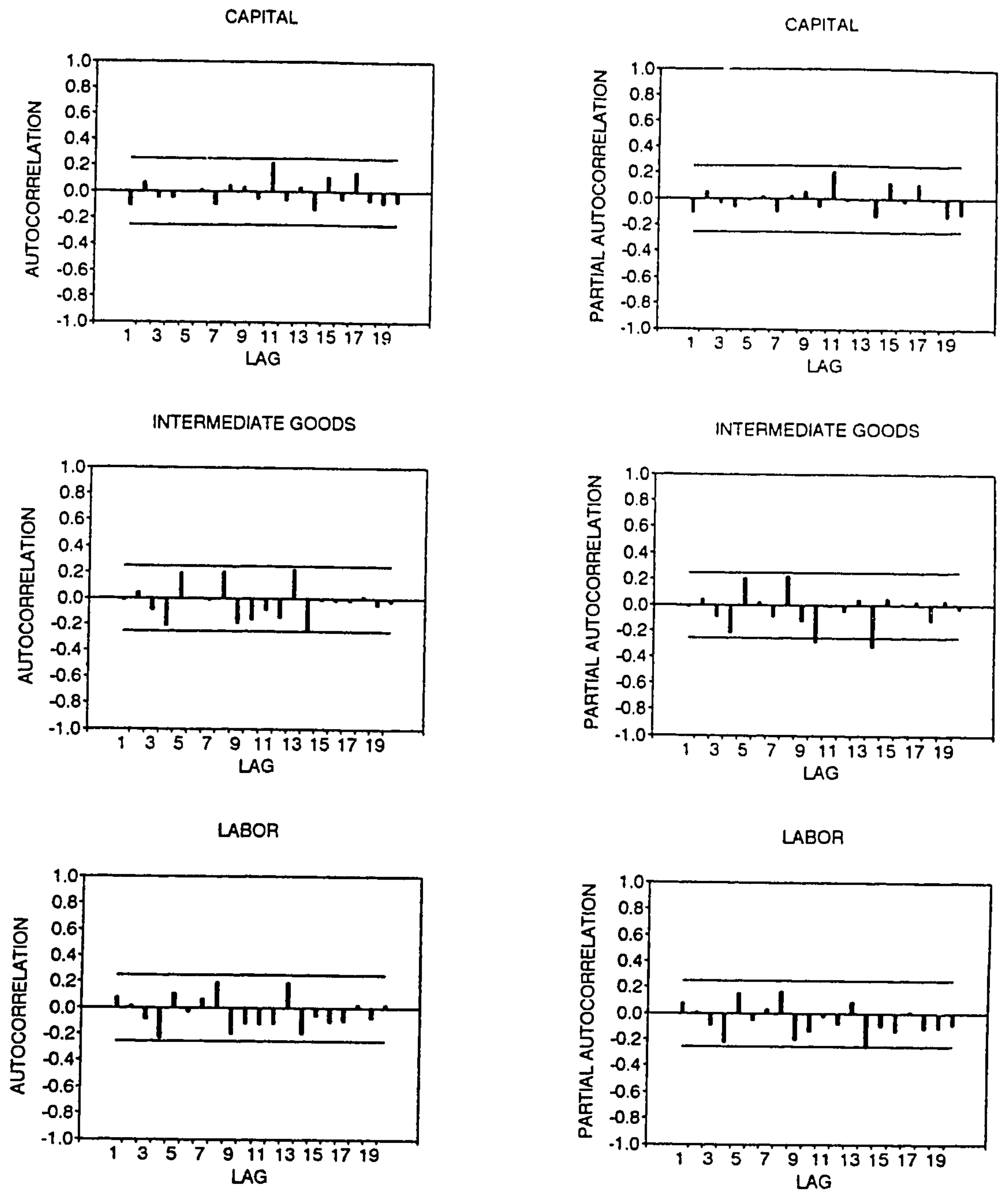
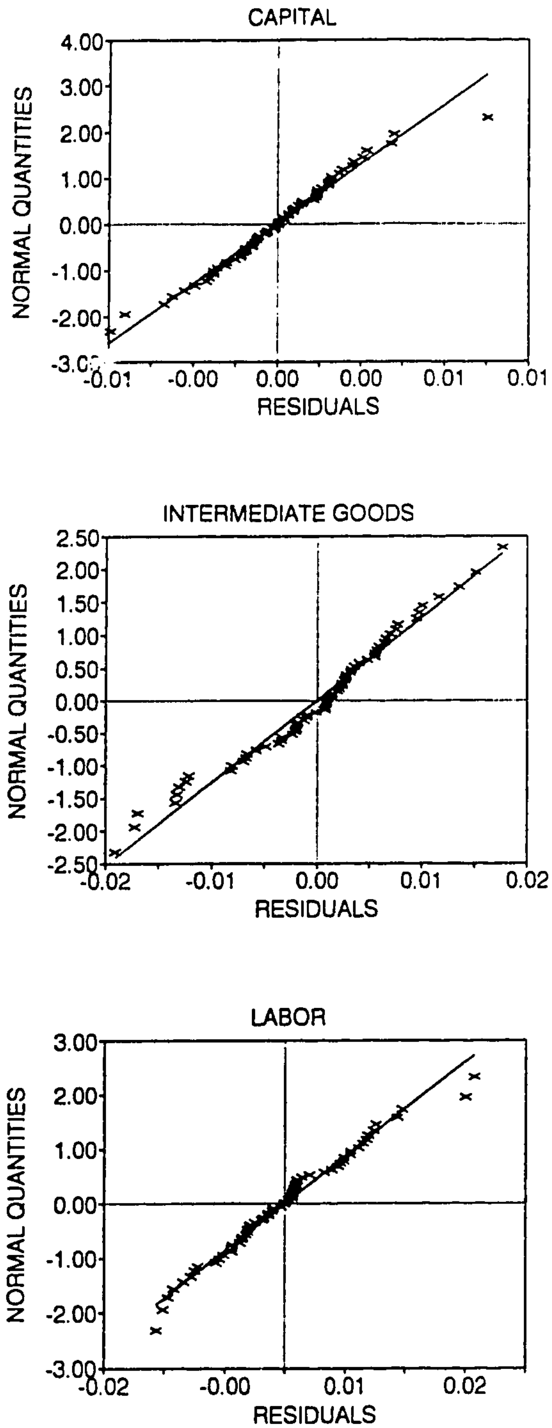


Figure 12: Normal Probability Plots of ARXSY for Canada.



APPENDIX 3

RESIDUAL ANALYSIS PLOTS FOR CANADA

The following abbrevitaions are used to represent the model of the system of share equations:

STCSY	Symetric Static Model.
PADSY	Symetric Partial Adjusment Model.
EARSY	Symetric Autoregressive Process for Disturbances Model.
ARXSY	Symetric Multivariate Autoregressive Proceess Model.
ARXSYOT	Symetric Multivariate Autoregressive Process Model without Time (Neutral Technical Change)

Figure 13: Residual Plots of STCSY for Alberta.

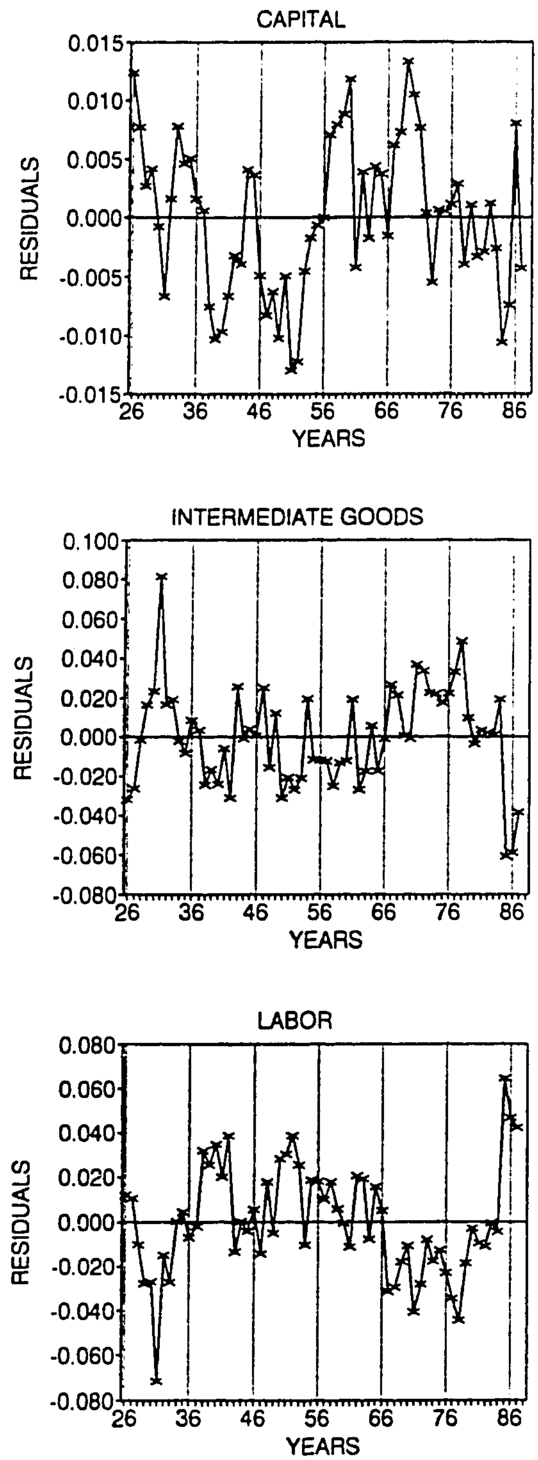


Figure 14: Residual Autocorrelation and Partial Autocorrelation Function of STCSY for Alberta.

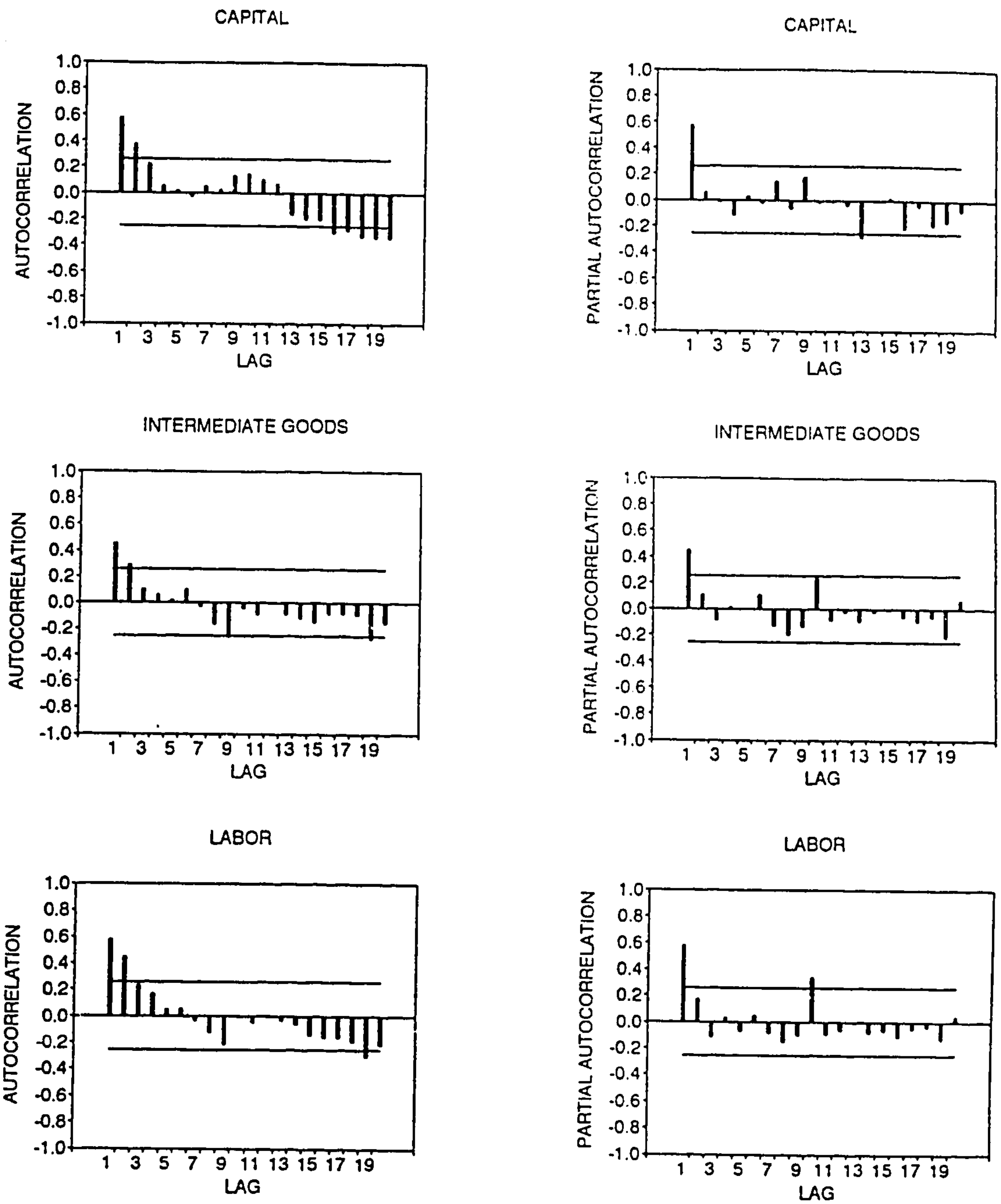


Figure 15: Normal Probability Plots of STCSY for Alberta

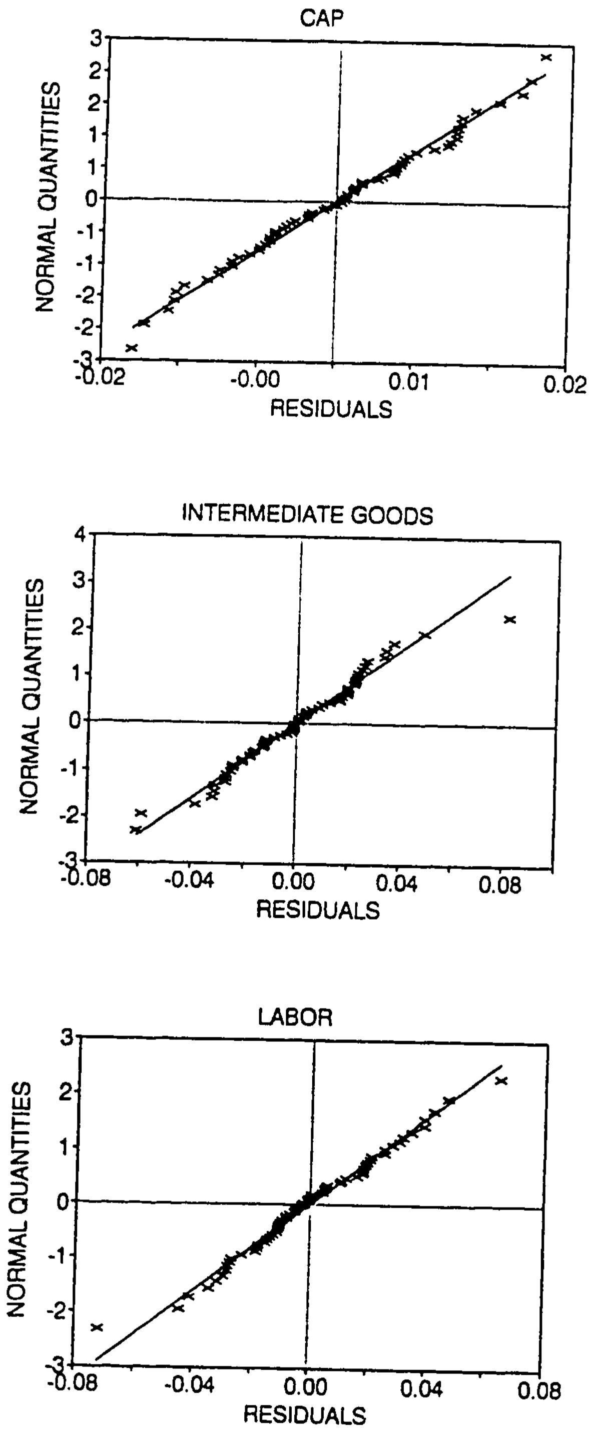
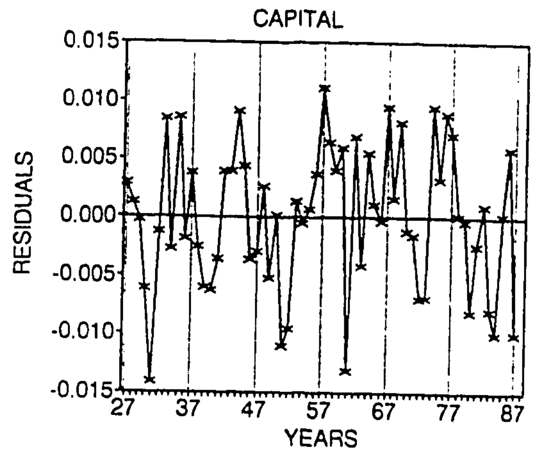
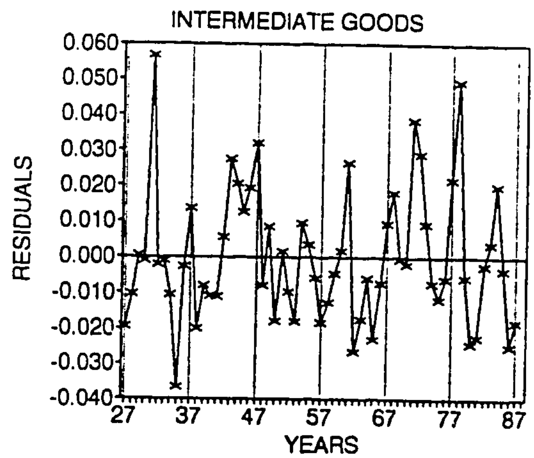


Figure 16: Residual Plots of PADSY for Alberta.





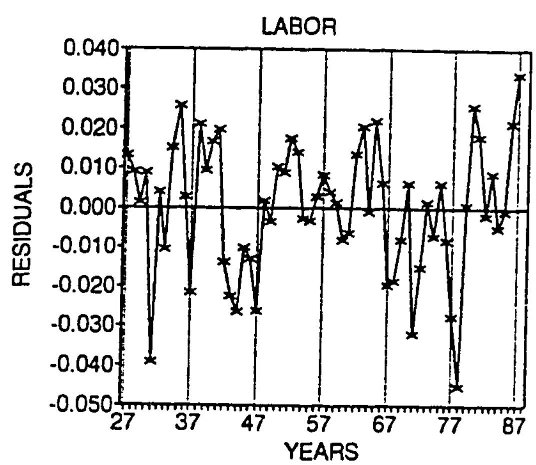


Figure 17: Residual Autocorrelation and Partial Autocorrelation Function of PADSY for Alberta.

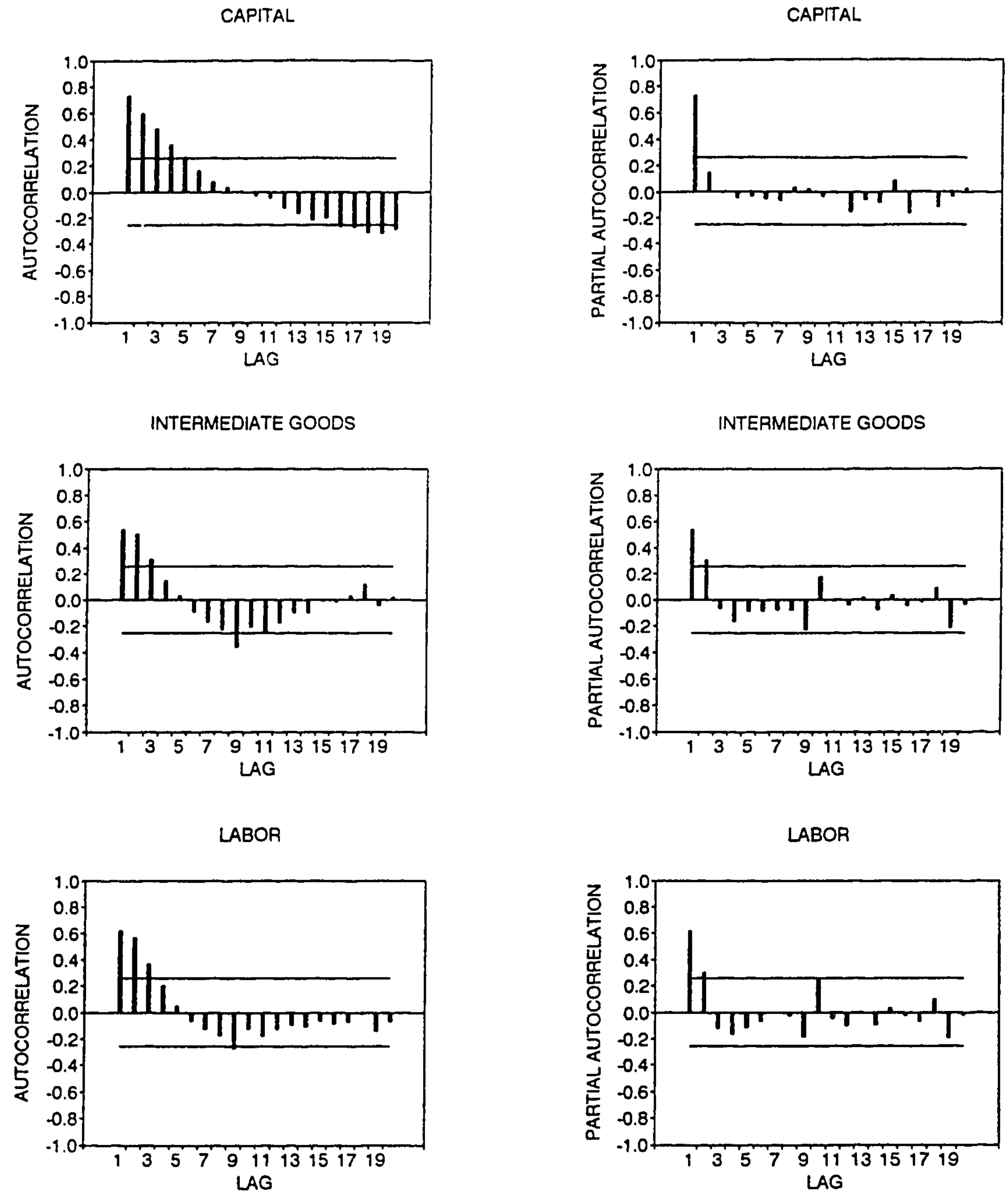
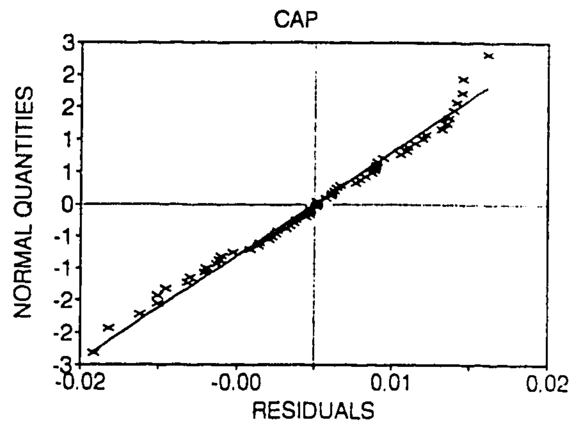
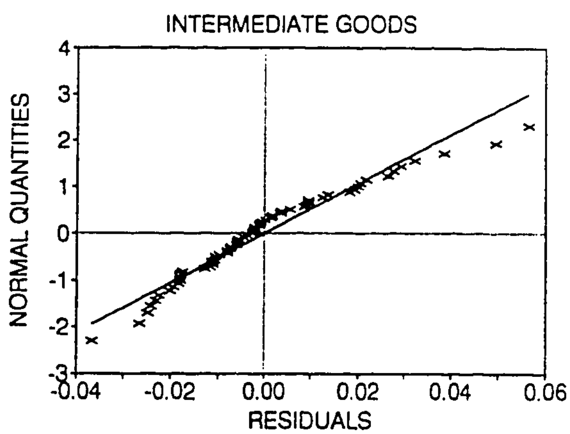


Figure 18: Normal Probability Plots of PADSY for Alberta





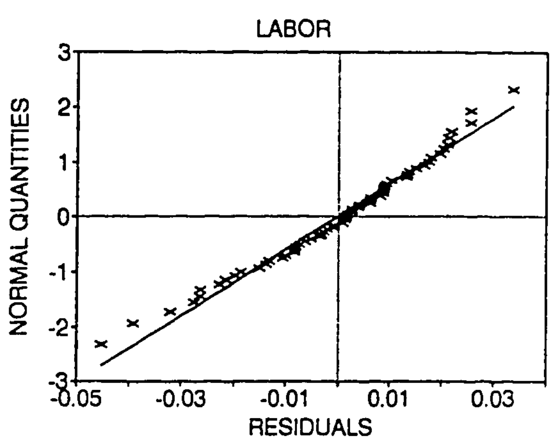


Figure 19: Residual Plots of EARSY for Alberta.

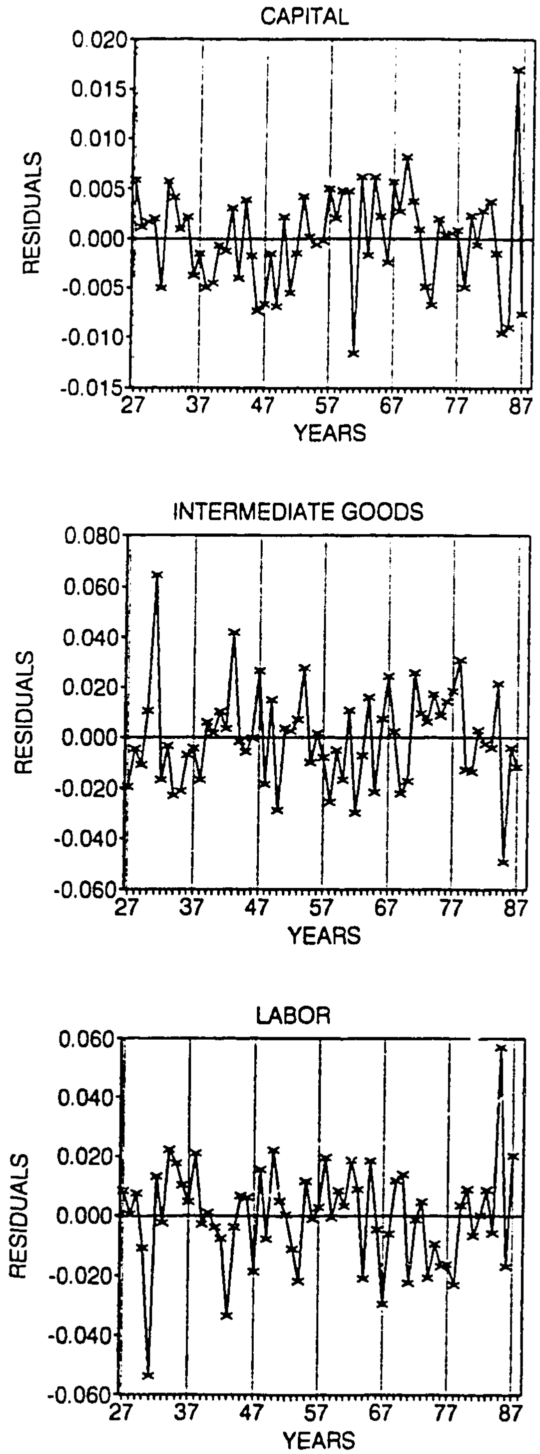


Figure 20: Residual Autocorrelation and Partial Autocorrelation Function of EARSY for Alberta.

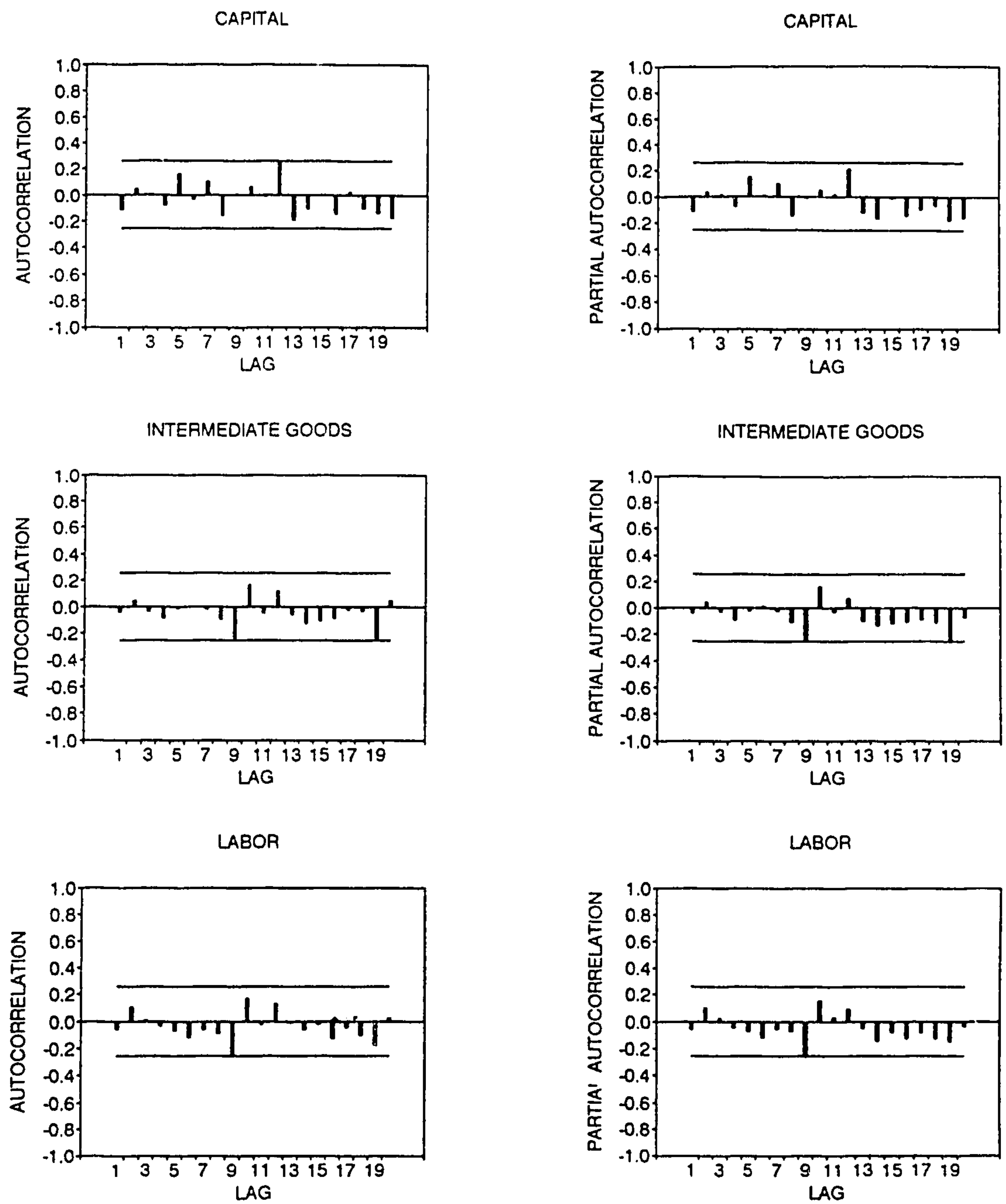


Figure 21: Normal Probability Plots of EARSY for Alberta

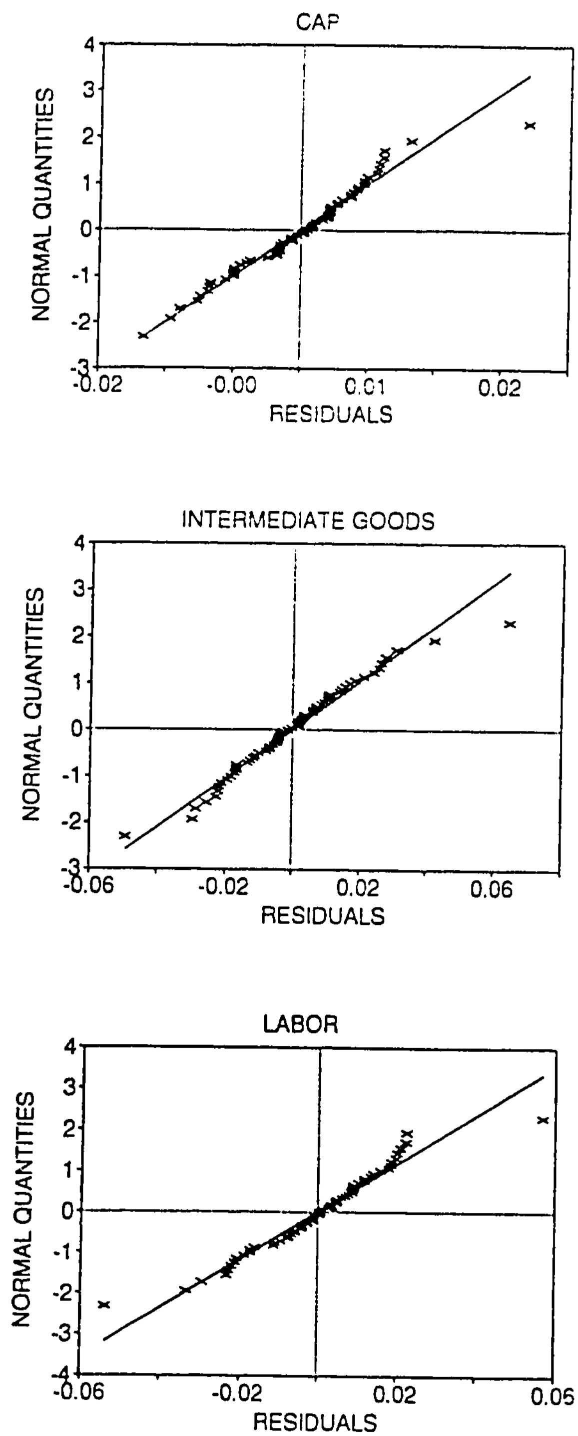


Figure 22: Residual Plots of ARXSY for Alberta.

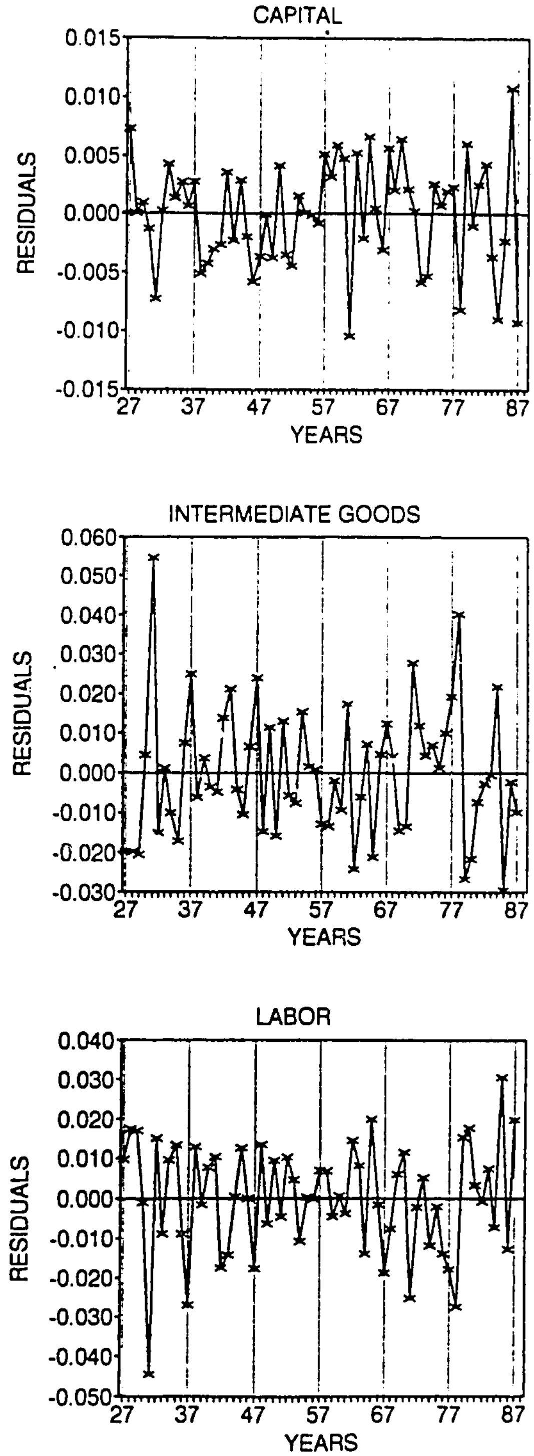


Figure 23: Residual Autocorrelation and Partial Autocorrelation Function of ARXSY for Alberta.

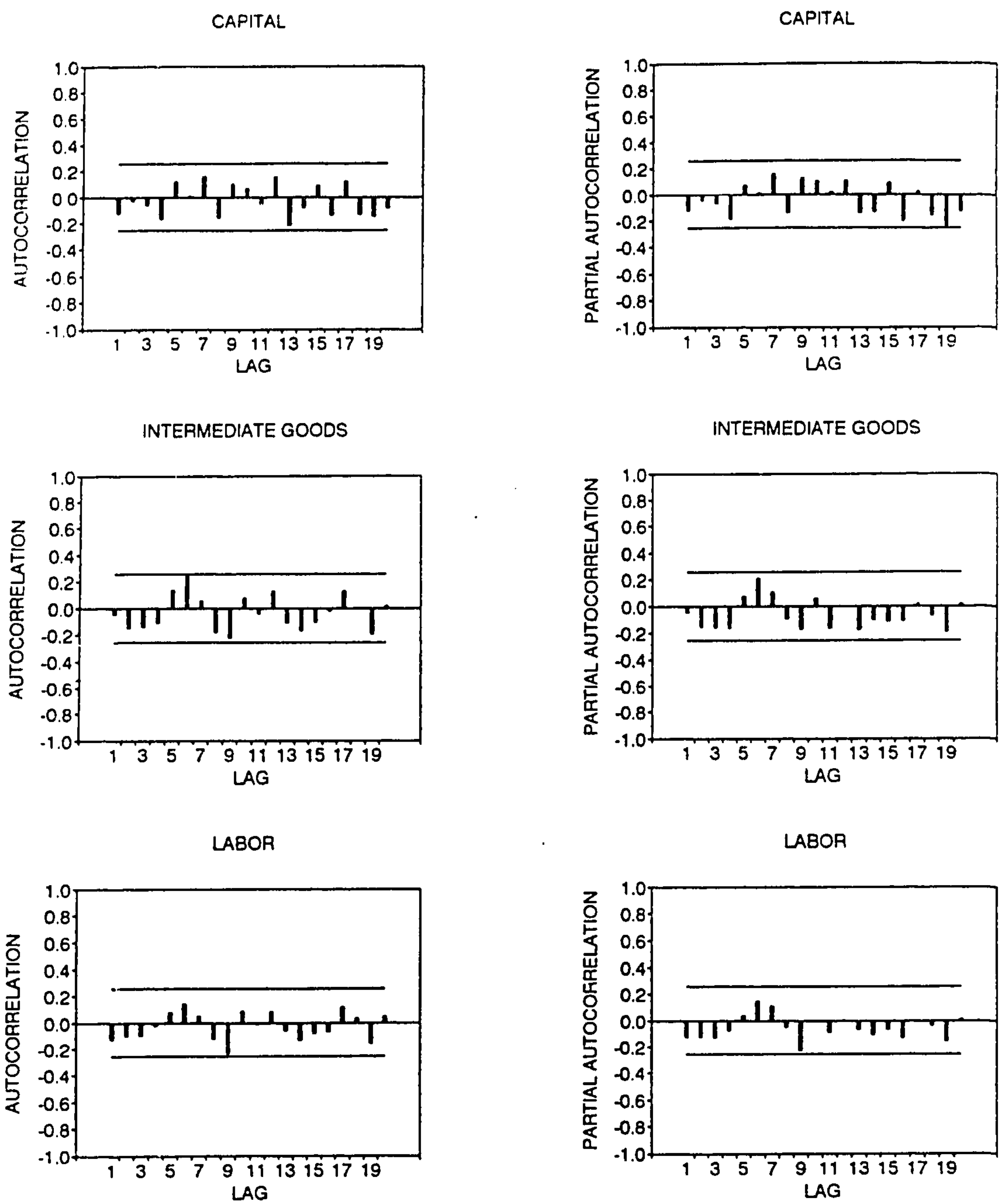


Figure 24: Normal Probability Plots of ARXSY for Alberta

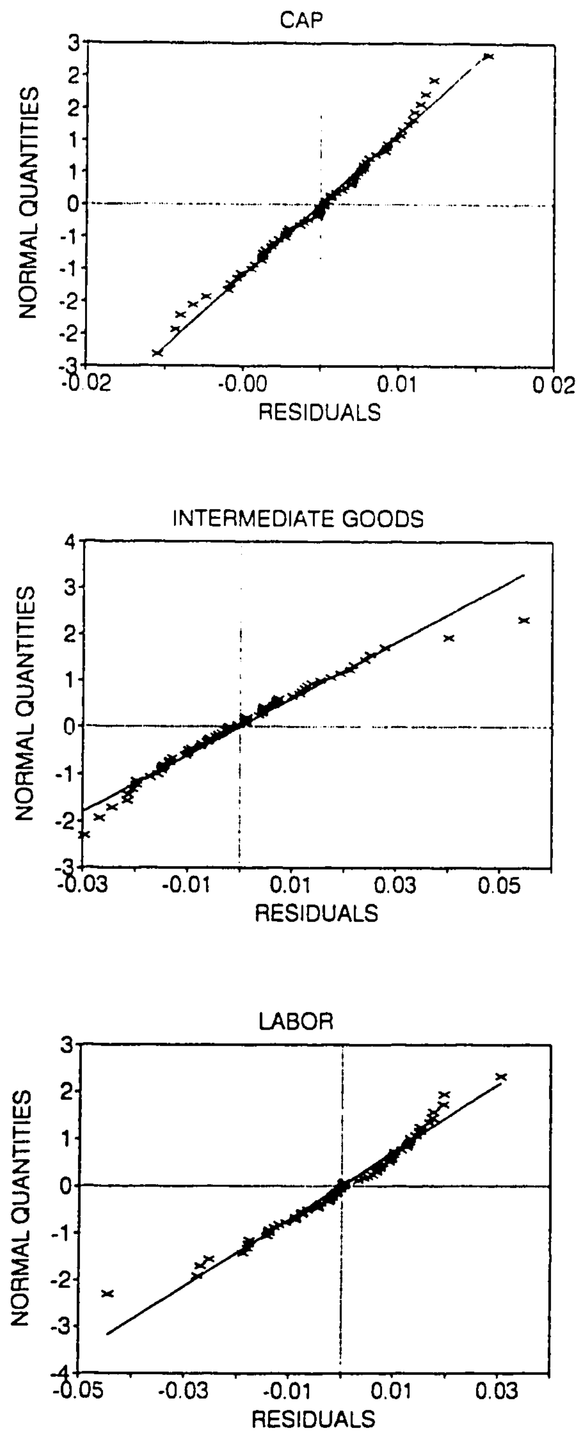
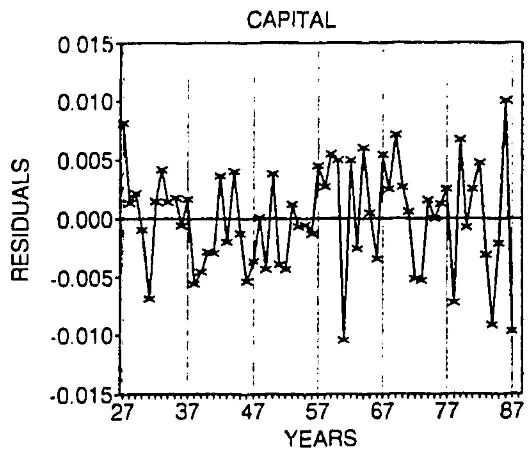
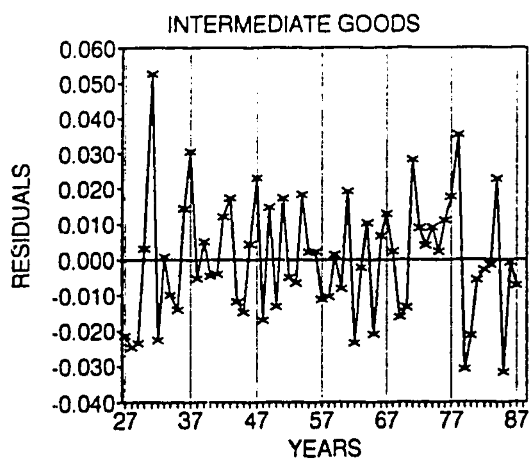


Figure 25: Residual Plots of ARXSYOT for Alberta.





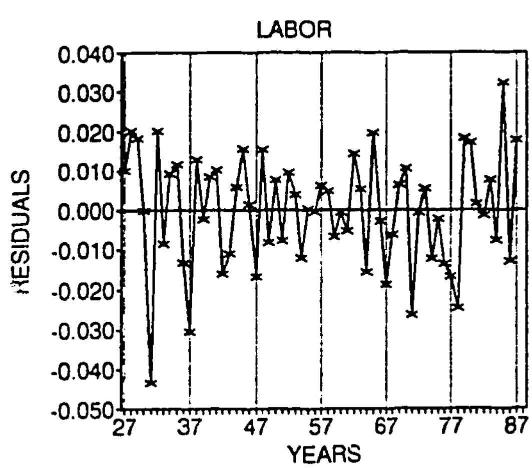


Figure 26: Residual Autocorrelation and Partial Autocorrelation Function of ARXSYOT for Alberta.

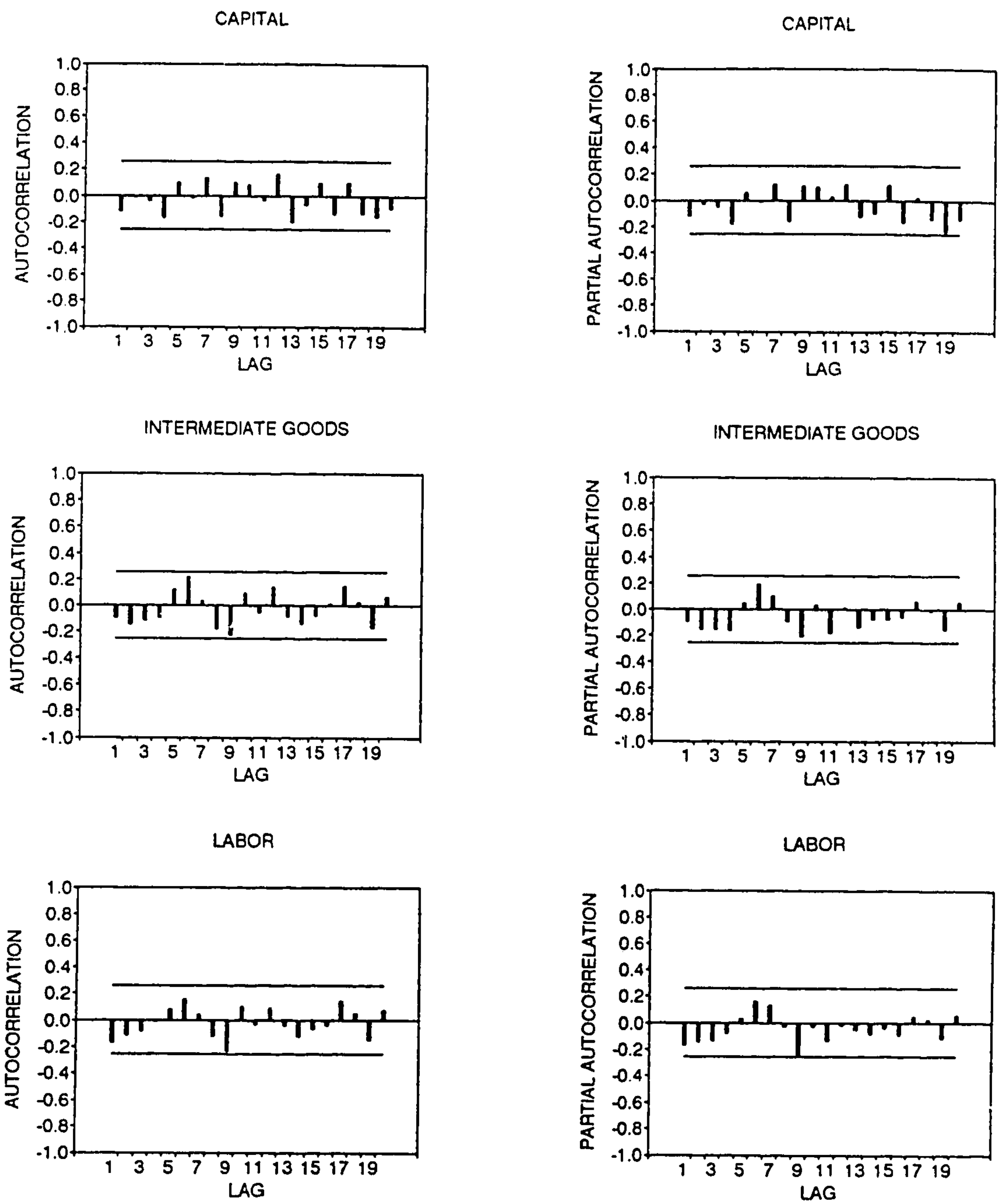
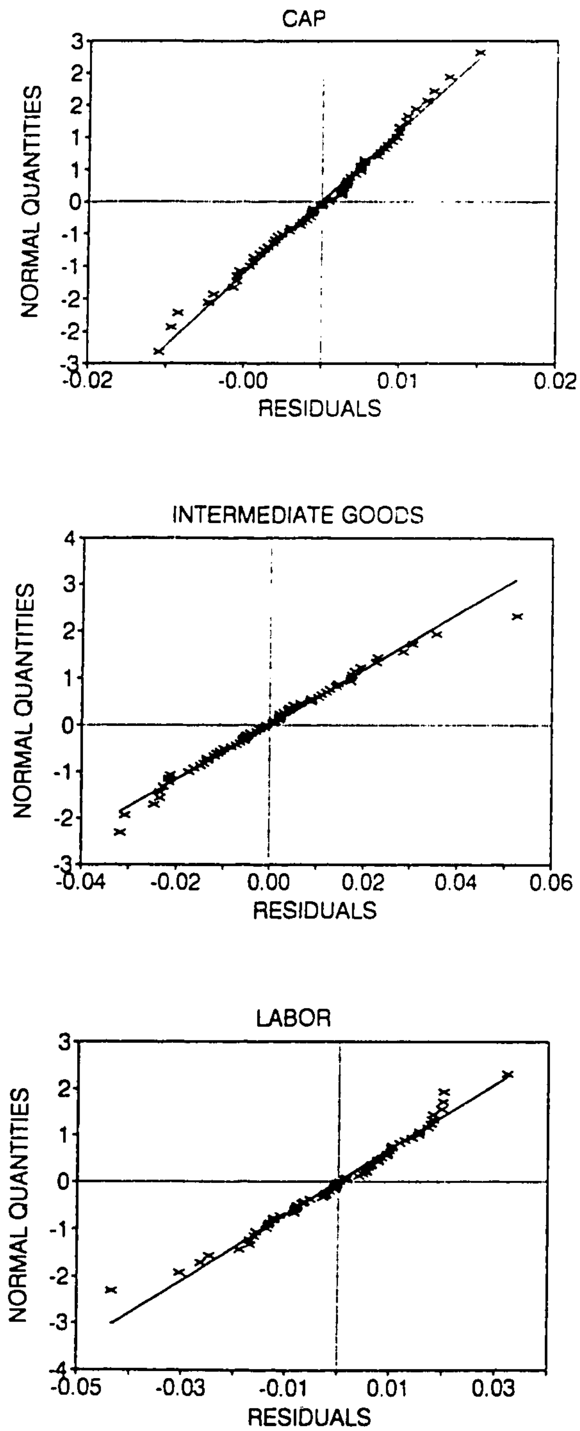


Figure 27: Normal Probability Plots of ARXSYOT for Alberta



APPENDIX 4

FURTHER RESULTS

For the Table in this Appendix the following notations are used

Symbol † denotes the estimate significant at the 5% level of significance

Symbol ‡ denotes the estimate significant at the 10% level of significance

Table A4.1: Elasticities of Substitution for Canada from Static Model

	ESTIMATED ELAST.	SIMULATED ELAST.	S.E.	95% LOW	95% HIGH	90% LOW	90% HIGH
			Sample for the Years 1959-68				
CAP-INT	0.3013†	0.2962	0.0961	0.1079	0.4845	0.1382	0.4542
CAP-LAB	0.3656†	0.3666	0.1571	0.0587	0.6745	0.1082	0.6250
CAP-LND	-0.4375	-0.4423	0.4320	-1.2891	0.4046	-1.1530	0.2685
INT-LAB	-0.0722	-0.0730	0.0600	-0.1906	0.0446	-0.1717	0.0257
INT-LND	0.6446†	0.6446	0.0641	0.5189	0.7704	0.5391	0.7502
LAB-LND	1.9426†	1.9491	0.1687	1.6184	2.2798	1.6715	2.2267
			Sample for the Years 1969-78				
CAP-INT	0.2923†	0.2866	0.1001	0.0903	0.4829	0.1219	0.4513
CAP-LAB	0.3451†	0.3450	0.1659	0.0197	0.6702	0.0720	0.6179
CAP-LND	-0.4258	-0.4283	0.4206	-1.2527	0.3961	-1.1202	0.2636
INT-LAB	-0.0794	-0.0803	0.0598	-0.1976	0.0370	-0.1787	0.0181
INT-LND	0.6562†	0.6561	0.0634	0.5318	0.7804	0.5518	0.7604
LAB-LND	1.9292†	1.9349	0.1627	1.6160	2.2538	1.6673	2.2026
			Sample for the Years 1979-87				
CAP-INT	0.4859†	0.4817	0.0739	0.3368	0.6266	0.3600	0.6033
CAP-LAB	0.1983	0.2001	0.1944	-0.1809	0.5811	-0.1197	0.5198
CAP-LND	-0.4266	-0.4330	0.4306	-1.2769	0.4110	-1.1413	0.2753
INT-LAB	-0.2988‡	-0.3008	0.0840	-0.4655	-0.1362	-0.4390	-0.1626
INT-LND	0.6618†	0.6617	0.0616	0.5411	0.7824	0.5604	0.7630
LAB-LND	2.5400†	2.5551	0.2920	1.9828	3.1273	2.0748	3.0354
			Sample for the Years 1926-87				
CAP-INT	0.2170‡	0.2106	0.1097	-0.0044	0.4256	0.0302	0.3911
CAP-LAB	0.3209‡	0.3219	0.1678	-0.0071	0.6508	0.0458	0.5979
CAP-LND	-0.5549	-0.5605	0.4659	-1.4736	0.3527	-1.3269	0.2060
INT-LAB	-0.0476	-0.0482	0.0590	-0.1638	0.0674	-0.1452	0.0488
INT-LND	0.6491†	0.6491	0.0635	0.5246	0.7736	0.5446	0.7536
LAB-LND	1.8888†	1.8953	0.1608	1.5800	2.2105	1.6307	2.1599

Table A4.2: Own-Price Elasticities for Canada from Static Model

	ESTIMATED ELAST.	SIMULATED ELAST.	S.E.	95% LOW	95% HIGH	90% LOW	90% HIGH
			Sample for the Years 1959-68				
CAP	-0.2332†	-0.2306	0.0604	-0.3490	-0.1123	-0.3300	-0.1313
INT	-0.0572†	-0.0566	0.0215	-0.0987	-0.0144	-0.0920	-0.0212
LAB	-0.1626†	-0.1630	0.0328	-0.2272	-0.0988	-0.2169	-0.1091
LND	-0.9194†	-0.9211	0.0697	-1.0576	-0.7845	-1.0357	-0.8064
			Sample for the Years 1969-78				
CAP	-0.2215†	-0.2182	0.0669	-0.3493	-0.0871	-0.3282	-0.1082
INT	-0.0567†	-0.0560	0.0213	-0.0977	-0.0143	-0.0910	-0.0210
LAB	-0.1601†	-0.1605	0.0325	-0.2242	-0.0968	-0.2140	-0.1071
LND	-0.9168†	-0.9181	0.0674	-1.0502	-0.7860	-1.0290	-0.8072
			Sample for the Years 1979-87				
CAP	-0.3073†	-0.3049	0.0532	-0.4092	-0.2005	-0.3924	-0.2173
INT	-0.0286	-0.0281	0.0192	-0.0658	0.0096	-0.0597	0.0036
LAB	-0.0328	-0.0323	0.0546	-0.1393	0.0747	-0.1221	0.0575
LND	-0.9306†	-0.9331	0.0796	-1.0892	-0.7771	-1.0641	-0.8021
			Sample for the Years 1926-87				
CAP	-0.1666†	-0.1632	0.0692	-0.2988	-0.0276	-0.2770	-0.0494
INT	-0.0581†	-0.0574	0.0218	-0.1002	-0.0146	-0.0934	-0.0215
LAB	-0.1689†	-0.1692	0.0319	-0.2317	-0.1068	-0.2217	-0.1168
LND	-0.9170†	-0.9189	0.0683	-1.0528	-0.7850	-1.0313	-0.8065

Table A4.3: Elasticities of Substitution for Alberta from Static Model

	ESTIMATED ELAST.	SIMULATED ELAST.	S.E.	95% LOW	95% HIGH	90% LOW	90% HIGH
			Sample 1959-68				
CAP-INT	0.4149†	0.4112	0.1003	0.2146	0.6077	0.2462	0.5761
CAP-LAB	0.7040†	0.7078	0.1021	0.5078	0.9079	0.5399	0.8757
CAP-LND	-1.6288†	-1.6425	0.3643	-2.3566	-0.9284	-2.2419	-1.0432
INT-LAB	0.1534†	0.1515	0.0613	0.0313	0.2717	0.0507	0.2524
INT-LND	0.5627†	0.5658	0.0778	0.4132	0.7184	0.4378	0.6939
LAB-LND	1.0289†	1.0311	0.1255	0.7851	1.2771	0.8247	1.2376
			Sample 1969-78				
CAP-INT	0.4687†	0.4649	0.0932	0.2822	0.6475	0.3116	0.6182
CAP-LAB	0.6853†	0.6889	0.1093	0.4747	0.9031	0.5091	0.8687
CAP-LND	-1.5256†	-1.5362	0.3355	-2.1939	-0.8785	-2.0882	-0.9842
INT-LAB	0.1177†	0.1156	0.0632	-0.0083	0.2396	0.0116	0.2196
INT-LND	0.5883†	0.5911	0.0748	0.4445	0.7377	0.4680	0.7142
LAB-LND	1.0319†	1.0338	0.1384	0.7625	1.3052	C.8061	1.2616
			Sample 1979-87				
CAP-INT	0.6258†	0.6227	0.0674	0.4907	0.7548	0.5119	0.7336
CAP-LAB	0.5450†	0.5498	0.1575	0.2412	0.8585	0.2908	0.8089
CAP-LND	-1.4947†	-1.5096	0.3547	-2.2048	-0.8143	-2.0931	-0.9261
INT-LAB	-0.1859†	-0.1914	0.1096	-0.4062	0.0235	-0.3717	-0.0111
INT-LND	0.6219†	0.6247	0.0682	0.4910	0.7584	0.5125	0.7369
LAB-LND	1.0601†	1.0678	0.2630	0.5523	1.5832	0.6351	1.5004
			Sample 1926-87				
CAP-INT	0.3532†	0.3486	0.1133	0.1265	0.5707	0.1622	0.5350
CAP-LAB	0.6742†	0.6785	0.1118	0.4594	0.8976	0.4946	0.8624
CAP-LND	-1.8623†	-1.8780	0.3943	-2.6509	-1.1051	-2.5267	-1.2293
INT-LAB	0.1702†	0.1684	0.0610	0.0488	0.2880	0.0680	0.2688
INT-LND	0.5760†	0.5789	0.0759	0.4302	0.7276	0.4541	0.7037
LAB-LND	1.0279†	1.0305	0.1212	0.7929	1.2681	0.8311	1.2299

Table A4.4: Own-Price Elasticities for Alberta from Static Model

	ESTIMATED ELAST.	SIMULATED ELAST.	S.E.	95% LOW	95% HIGH	90% LOW	90% HIGH
			Sample 1959-68				
CAP	-0.2931†	-0.2916	0.0492	-0.3881	-0.1951	-0.3726	-0.2106
INT	-0.1423†	-0.1415	0.0227	-0.1860	-0.0970	-0.1789	-0.1041
LAB	-0.2318†	-0.2316	0.0303	-0.2910	-0.1721	-0.2814	-0.1817
LND	-0.4590†	-0.4600	0.0557	-0.5691	-0.3509	-0.5516	-0.3685
			Sample 1969-78				
CAP	-0.3121†	-0.3103	0.0506	-0.4094	-0.2111	-0.3935	-0.2271
INT	-0.1356†	-0.1349	0.0212	-0.1764	-0.0933	-0.1697	-0.1000
LAB	-0.2194†	-0.2192	0.0328	-0.2835	-0.1549	-0.2731	-0.1653
LND	-0.4597†	-0.4607	0.0567	-0.5717	-0.3496	-0.5539	-0.3675
			Sample 1979-87				
CAP	-0.3732†	-0.3714	0.0429	-0.4555	-0.2874	-0.4420	-0.3009
INT	-0.0865†	-0.0860	0.0198	-0.1248	-0.0472	-0.1186	-0.0534
LAB	-0.0305†	-0.0273	0.0734	-0.1711	0.1164	-0.1480	0.0933
LND	-0.4092†	-0.4110	0.0603	-0.5292	-0.2927	-0.5102	-0.3117
			Sample 1926-87				
CAP	-0.2335†	-0.2314	0.0569	-0.3429	-0.1199	-0.3250	-0.1379
INT	-0.1416†	-0.1409	0.0228	-0.1855	-0.0962	-0.1784	-0.1034
LAB	-0.2328†	-0.2324	0.0303	-0.2918	-0.1731	-0.2823	-0.1826
LND	-0.4673†	-0.4684	0.0532	-0.5726	-0.3642	-0.5558	-0.3809

Table A4.5: Expected Long-Run Shares for Canada

Capital	Intermediate-Goods	Labor	Land-Building Str.
0.5292952E-01	.4391647	.3932327	.1146730
0.5477465E-01	.4368637	.3917843	.1165773
0.6002661E-01	.4506843	.3784645	.1108246
0.6669847E-01	.4618016	.3743117	0.9718824E-01
0.6939364E-01	.4778100	.3573157	0.9548066E-01
0.6874174E-01	.5528190	.3020045	0.7643481E-01
0.5961055E-01	.5512289	.3038011	0.8535947E-01
0.6190087E-01	.5491871	.3089850	0.7992710E-01
0.5551237E-01	.5515407	.3084115	0.8453541E-01
0.6370889E-01	.4929708	.3490552	0.9426505E-01
0.6006664E-01	.5079761	.3411417	0.9081548E-01
0.6398993E-01	.5032997	.3453851	0.8732525E-01
0.6582455E-01	.4829790	.3560839	0.9511258E-01
0.6408945E-01	.4918838	.3469605	0.9706630E-01
0.6437243E-01	.4830508	.3527802	0.9979652E-01
0.5990783E-01	.5048232	.3398412	0.9542775E-01
0.5133726E-01	.4600169	.3696355	.1190103
0.6510797E-01	.4737814	.3594119	.1016988
0.5864202E-01	.4790817	.3550090	.1072672
0.646901E-01	.4607802	.3708419	.1036873
0.6558964E-01	.4396645	.3857120	.1090339
0.6585776E-01	.4711246	.3625247	.1004930
0.6758637E-01	.4487175	.3782413	.1054548
0.7524489E-01	.4710911	.3623343	0.9132968E-01
0.7654215E-01	.4497132	.3761128	0.9763181E-01
0.8231846E-01	.4077973	.4043697	.1055145
0.7433057E-01	.4383728	.3792520	.1080446
0.7554547E-01	.4642800	.3592566	.1009179
0.7967162E-01	.4980147	.3349417	0.8737200E-01
0.7313457E-01	.4946644	.3353393	0.9686177E-01
0.7072955E-01	.4982745	.3308002	.1001958
0.7761950E-01	.5146519	.3184650	0.8926358E-01
0.8144476E-01	.4971224	.3283054	0.9312735E-01
0.8575606E-01	.5265189	.3058520	0.8187305E-01
0.8177348E-01	.5063438	.3210249	0.9085779E-01
0.8785909E-01	.5462034	.2925736	0.7336390E-01
0.8116489E-01	.4934996	.3287771	0.9655839E-01
0.7882661E-01	.4964698	.3245874	.1001162
0.8110120E-01	.5338155	.2962046	0.8887879E-01
0.7736125E-01	.5267396	.3004382	0.9546093E-01
0.7742347E-01	.5006627	.3172473	.1046665
0.8626786E-01	.5444395	.2847532	0.8453940E-01
0.8668055E-01	.5445093	.2833149	0.8549524E-01
0.9127086E-01	.5091703	.3082754	0.9128349E-01
0.9254559E-01	.5220018	.2980113	0.8744136E-01
0.8920793E-01	.5433084	.2805323	0.8695141E-01
0.9010946E-01	.5096068	.3060927	0.9419104E-01

Table A4.4: Expected Long-Run Shares for Canada (Continued)

Capital	Intermediate-Goods	Labor	Land-Building Str.
0.8211941E-01	.4609199	.3432095	.1137512
0.8241807E-01	.5183891	.3007508	0.9844205E-01
0.7401343E-01	.5453884	.2794264	.1011718
0.7783780E-01	.5777284	.2536517	0.9078208E-01
0.7855789E-01	.5901218	.2438488	0.8747148E-01
0.8351190E-01	.5436983	.2761694	0.9662035E-01
0.9088622E-01	.5549202	.2679517	0.8624195E-01
0.8778790E-01	.5727658	.2543251	0.8512120E-01
0.8708426E-01	.5981937	.2326319	0.8209005E-01
0.8800550E-01	.6225080	.2135673	0.7591921E-01
0.8681797E-01	.6241607	.2146780	0.7434325E-01
0.8871739E-01	.6545220	.1921427	0.6461795E-01
0.8685097E-01	.6579933	.1897604	0.6539535E-01
0.8761931E-01	.6148082	.2198552	0.7771731E-01
0.8825549E-01	.6159270	.2187077	0.7710977E-01
0.9072402E-01	.6350327	.2064392	0.6780413E-01

Table A4.6: Expected Long-Run Shares for Alberta

Capital	Intermediate-Goods	Labor	Land-Building Str.
0.3423351E-01	.3755528	.4708878	.1193259
0.3032464E-01	.3937378	.4428093	.1331282
0.5728491E-01	.4081713	.4235171	.1110268
0.7030682E-01	.4044767	.4425236	0.8269289E-01
0.9733193E-01	.4406974	.3971912	0.6477954E-01
.1010162	.5230404	.3278043	0.4813914E-01
0.7774032E-01	.5242896	.3296553	0.6831471E-01
0.8642498E-01	.5106201	.3448581	0.5809690E-01
0.5966578E-01	.4932565	.3655422	0.8153556E-01
0.8352420E-01	.4659820	.3840089	0.6648485E-01
0.6900674E-01	.4731952	.3900909	0.6770723E-01
0.5724514E-01	.4546624	.3987908	0.8930170E-01
0.7519930E-01	.4440866	.3861713	0.9454281E-01
0.8115391E-01	.4522724	.3729699	0.9360382E-01
0.7646191E-01	.4474759	.3718201	.1042421
0.7051[illegible]2E-01	.4612908	.3748474	0.9334883E-01
0.4141999E-01	.4487842	.3678432	.1419526
0.6299240E-01	.4561750	.3660760	.1147566
0.5722930E-01	.4530934	.3680139	.1216634
.6141078E-01	.4433087	.3861092	.1091713
0.5563847E-01	.4346964	.3901831	.1194820
0.5555074E-01	.4522033	.3795693	.1126766
0.6250048E-01	.4274491	.3954727	.1145777
0.8209819E-01	.4384571	.3902565	0.8918821E-01
0.8352142E-01	.4193896	.4009846	0.9610438E-01
0.9153831E-01	.3994870	.4032872	.1056875
0.8094785E-01	.4171714	.3880124	.1138663
0.8742262E-01	.4385637	.3704038	.1036099
0.9961631E-01	.4745629	.3482926	0.7754817E-01
0.8305895E-01	.4718993	.3466730	0.9836871E-01
0.8236577E-01	.4797771	.3365236	.1013336
0.9874232E-01	.4835450	.3345303	0.8318235E-01
.1004936	.4531107	.3578508	0.8854497E-01
.1057961	.4821623	.3274593	0.8458233E-01
.1052106	.4907138	.3211669	0.8290865E-01
.1000386	.4964936	.3206476	0.8282021E-01
0.9730015E-01	.4758497	.3357422	0.9110790E-01
0.9480807E-01	.4757031	.3327476	0.9674131E-01
.1026226	.5151776	.2981576	0.8404218E-01
0.9170221E-01	.5038900	.3082674	0.9614045E-01
0.9322667E-01	.4941223	.3106773	.1019737
.1167367	.5281188	.2797486	0.7539588E-01
.1182729	.5413889	.2670167	0.7332149E-01
.1268645	.5068397	.2931743	0.7312145E-01
.1264516	.5014008	.2967071	0.7544052E-01
.1278071	.5355451	.2647767	0.7187105E-01
.1161080	.5112043	.2893657	0.8332204E-01

Table A4.6: Expected Long-Run Shares for Alberta (Continued)

Capital	Intermediate-Goods	Labor	Land-Building Str.
0.8847429E-01	.4948598	.3138545	.1028115
0.9068087E-01	.5263094	.2879551	0.9505462E-01
0.7729238E-01	.5677219	.2550851	0.9990070E-01
0.8676851E-01	.5834240	.2340534	0.9575406E-01
0.9806981E-01	.6118014	.2018972	0.8823162E-01
.1124659	.5006939	.2851522	.1016880
.1131045	.5456092	.2532752	0.8801121E-01
.1036314	.5612839	.2434078	0.9167686E-01
.1131081	.5991348	.2056660	0.8209110E-01
.1262005	.6399224	.1626782	0.7119887E-01
.1159983	.6102197	.1922944	0.8148751E-01
.1183666	.6315848	.1736565	0.7639212E-01
.1410757	.7710458	0.3048856E-01	0.5738994E-01
.1280290	.6696950	.1257485	0.7652753E-01
.1418763	.6409800	.1481420	0.6900168E-01