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OLIGOPOLY POWER IN THE CANADIAN FOOD PROCESSING INDUSTRY - FURTHER RESULTS

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Abstract

A conjectural variations model provided measures of the degree of oligopoly power in the Canadian dairy, fruit and vegetable, poultry and red meat processing industries. Results indicate that significant oligopoly power has existed in these industries. In decreasing order of oligopoly power, these industries rank as: red meat, dairy, fruit and vegetable and poultry processors. Overtime, oligopoly power increased in the dairy, poultry and red meat processing industries, but declined in the fruit and vegetable processing industry. Factors contributing to change include increased industry concentration, technological change and the introduction of supply management in the Canadian dairy and poultry production industries.

Oligopoly Power in the Canadian Food Processing Industry - Further Results[1]

Introduction

A typical policy analysis involving the food processing industry makes a simplifying assumption that food processors operate in a perfectly competitive environment. However, observation reveals that some firms may have the ability to influence price. As a result, this simplifying assumption may result in biased results and selection of inappropriate policy measures.

As well, a recent trend in the agri-food sector is that of industry rationalization. Figures 1 and 2 indicate that the number of firms in the Canadian dairy, fruit and vegetable, poultry and red meat processing industries has declined while the value of shipments from the remaining firms has grown. This increased concentration may lead to the conclusion that these remaining firms possess an ability to influence price.

In addition, the recent GATT agreement on agriculture requires that non-tariff barriers be replaced with tariff equivalents. These tariff equivalents are to be reduced over time. In Canada, this means the dairy and poultry industries will eventually face lower priced imports. This may affect the of ability dairy and poultry processors to influence price.

The purpose of this paper is to examine the historical ability of four Canadian food processing industries to affect output price. The industries considered include dairy, fruit and vegetable, poultry and red meat processors. The ability to influence output price will be measured by the Lerner Index. The Lerner Index measures the degree of oligopoly power in these processing industries. To calculate the Lerner Index, a conjectural variations elasticity model will be employed.

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[1] This paper began as a class project for 02-657, Advanced Agricultural Market Analysis, at the University of Guelph in the summer of 1994. Cranfield, Cousineau, Swidinsky and Lai were students in this class and Goddard was the instructor.

Lopez has estimated similar relationships for the food processing sector as a whole. However, given different institutional relationships within industries of the agri-food sector, it is reasonable to hypothesize different market power measures for different industries.

The paper is organized as follows. Section two presents a conceptual framework for measuring the degree of oligopoly power. Section three develops an empirical framework. Section four discusses the data used and manipulations performed to aggregate input and output data. Section five presents the results of the empirical model, while section six summarizes the results and provides some implications.

Conceptual Framework

Following Appelbaum (1982), assume an industry composed of N firms producing a single homogenous output Y. Further assume these firms can influence output price, but not input prices. That is, the industry operates in an oligopolistic manner. Define the jth firms' profit maximization production decision as:

$$\underset{\{Y^j\}}{Max}\ \Pi^j = P \cdot Y^j - C^j(Y^j, W_i\ ) \tag{1}$$

subject to:

$$P = P(Y,Z) \tag{2}$$

$$Y = \sum_{j=1}^{N} Y^j \tag{3}$$

Where P ≡ per unit output price,
Y^j ≡ the jth firms' output of Y,
$C^j(Y^j, w_i)$ ≡ the jth firms' cost function,

$w_i \equiv$ the ith inputs' per unit price,
$Y \equiv$ total industry output,
$P(Y,Z) \equiv$ price dependant demand equation for Y,
$Z \equiv$ exogenous factors affecting consumption of Y.

Substituting (3) into (2), and then (2) into (1) yields:

$$\underset{\{Y^j\}}{Max}\ \Pi^j = P(\sum_{j=1}^{N} Y^j, Z) \cdot Y^j - C^j(Y^j, w_i) \tag{4}$$

Assuming each firm can affect price through its output decision, then the jth firms' first order necessary condition for profit maximization is:

$$\frac{\partial \Pi^j}{\partial Y^j} = P + Y^j \cdot \frac{\partial P}{\partial Y^j} - \frac{\partial C^j}{\partial Y^j} = 0 \tag{5}$$

Equation (5) can be manipulated to produce:

$$P(1 + \frac{\Theta^j}{\eta_{Y,P}}) = MC^j \tag{6}$$

Where:

$$\Theta^j = \frac{\partial Y}{\partial Y^j}\frac{Y^j}{Y}, \ and\ \eta_{Y,P} = \frac{\partial Y}{\partial P}\frac{P}{Y}$$

Θ^j is the jth firms' conjectural variations elasticity, it measures the percentage change in industry output given a one percent change in the jth firms output of Y. $\eta_{Y,P}$ is the own price elasticity of demand, it measures the percentage change in demand for Y given a one percent change in price.

Appelbaum manipulated (6) to show:

$$L = \sum_{j=1}^{N} \left(\frac{P-MC^j}{P}\right) \cdot \frac{Y^j}{Y} = \sum_{j=1}^{N} \frac{\Theta^j}{|\eta_{Y,P}|} \cdot \frac{Y^j}{Y} \qquad j=1,\ldots,N \tag{8}$$

Where L is the Lerner Index for the entire industry and measures the degree of market power in the industry. The interpretation of the Lerner Index is that it represents the percentage difference between price and the firms' marginal cost.

However, accurate measures of individual firms' cost data are difficult to obtain, as are firm specific measures of Θ^j. Therefore, a common approach is to specify an aggregate industry model. This type of model does not depict a representative firm, but aggregates the whole industry. To ensure consistent linear aggregation, each firm is assumed to have a quasi-homothetic cost function. In general this implies the following Gorman polar form:

$$C^j(w_i) = Y^j c(w_i) + G^j(w_i) \tag{9}$$

Note that each firm possesses the same constant marginal cost of $c(w_i)$. Moreover, expansion paths will be linear and parallel, thus the production technology is quasi-homothetic. The desirability of using this functional form becomes apparent when one sums each firms' cost function as so:

$$\sum_{j=1}^{N} C^j = \sum_{j=1}^{N} Y^j c(w_i) + \sum_{j=1}^{N} G^j(w_i) \tag{10}$$

Equation (10) can be expressed as:

$$C(w_i) = Yc(w_i) + \sum_{j=1}^{N} G^j(w_i) \tag{11}$$

Therefore, the problem of unknown and potentially different marginal costs as shown in equation (6) is eliminated since each firm is assumed to possess the same marginal costs. As well, since all firms face the same output price and the same own price demand elasticity, then the implied assumption of constant and equal marginal costs implies that all firms have the same conjectural variations elasticity at equilibrium. Thus, equations (6) and (7) respectively become:

$$P\left(1+\frac{\Theta}{\eta_{Y,P}}\right) = MC \qquad (12)$$

$$L = \frac{P-MC}{P} = \frac{\Theta}{|\eta_{Y,P}|} \qquad (13)$$

As Appelbaum indicated, $\Theta \in [0,1]$ and $L \in [0,1]$. When the conjectural variations elasticity equals zero, firms operate in a perfectly competitive environment. In this case, the Lerner Index equals zero, and output is determined by the rule P=MC. When the conjectural variations elasticity equals one, firms operate in a monopolistic manner. When $\Theta=1$, the Lerner Index equals the inverse of the own price demand elasticity, and output is determined by the rule MR=MC. However, Θ and the Lerner Index may fall on the continuum between 0 and 1. When the latter occurs, a firm acts as an oligopolist who equates marginal cost to 'perceived marginal revenue.' (Appelbaum 1982 p.289).

Empirical Model

In order to facilitate comparison to the earlier work of Lopez (1984), we employ the empirical model employed by Lopez (1984). Specifically, a Gorman polar form Generalized Leontief cost function is assumed for the industry:

$$C = \sum_i \beta_i \cdot w_i + \sum_i \sum_j \beta_{ij} \cdot (w_i \cdot w_j)^{1/2} \cdot Y \qquad i,j = K,L,M \qquad (14)$$

Where $\beta_i, \beta_{i,j}$ ≡ parameters to be estimated,
w_i ≡ ith inputs' per unit cost,
Y ≡ output,
K, L, M ≡ denote capital, labour, raw materials respectively.

Equation (14) is assumed to be a well behaved cost function (i.e. concave and continuous in w_i, non-decreasing in w_i and Y and homogenous of degree one in w_i). It is further assumed that the co-efficients in the second term on the right hand term are symmetric, that is $\beta_{i,j}=\beta_{j,i}$, and that the first term on the right hand side represents fixed costs ($\Sigma G^j(w_i)$ in the aggregate cost function).

Applying Shephard's Lemma to (14) for each input produces an input demand system defined as:

$$\frac{X_K}{Y} = \frac{\beta_K}{Y} + \beta_{KK} + \sum_{j=1}^{k} \beta_{Kj} \cdot \left(\frac{w_j}{w_K}\right)^{1/2} \quad j=K,L,M \tag{15}$$

$$\frac{X_L}{Y} = \frac{\beta_L}{Y} + \beta_{LL} + \sum_{j=1}^{k} \beta_{Lj} \cdot \left(\frac{w_j}{w_L}\right)^{1/2} \quad j=K,L,M \tag{16}$$

$$\frac{X_M}{Y} = \frac{\beta_M}{Y} + \beta_{MM} + \sum_{j=1}^{k} \beta_{Mj} \cdot \left(\frac{w_j}{w_M}\right)^{1/2} \quad j=K,L,M \tag{17}$$

Where X_i ≡ ith input, for i=K, L, M. Since (14) is constrained by theory to be homogenous of degree 1 in w_i, the input demand equations are homogenous of degree zero in w_i.

It is further assumed that the demand for Y can be represented by a semi-log functional form:

$$\ln Y = \alpha_0 + \nu \cdot P + \rho \cdot INC \tag{18}$$

Where α_0, ν, ρ ≡ parameters of the demand equation,
P ≡ output price, and
INC ≡ income.

Equation (18) is also constrained to be homogenous of degree zero in prices and income.

In general, the price rule can be defined as:

$$P = MC - \frac{\Theta}{\nu} \tag{19}$$

Given the Generalized Leontief cost function, equation (19) becomes:

$$P = \sum_{i=1}^{n} \sum_{j=1}^{k} \beta_{ij} \cdot (w_i w_j)^{1/2} - \frac{\Theta}{\nu} \quad i,j=K,L,M \tag{20}$$

Since P is observed, and ν and $\beta_{i,j}$ are parametric estimates, equation (20) allows parametric estimation of Θ.

However, parametric estimation holds Θ constant over the entire sample period. This overly restrictive assumption can be eliminated by defining a structural equation for Θ and substituting this into equation (20). To allow Θ to change with economic conditions, Appelbaum (1982) specified Θ as a function of the exogenous input prices. Lopez (1984) specified Θ as a function of industry concentration and a time trend. Industry concentration was included to represent increased collusion as the number of firms falls. Lopez postulated that increased collusion increased market power. Time was included as a proxy for the effect of technological improvement on data and information processing capabilities. Schroeter (1988) followed Appelbaum, but added time to account for omitted economic variables. However, Azzam and Pagoulatos (1990) specified Θ as a structural parameter in the price rule.

To capture the affect of changing economic conditions on market structure, we specify Θ with a structural equation. We add to Lopez's specification by defining Θ as a function of the relevant Herfindahl Index, a time trend and a dummy variable representing the introduction of supply management in the Canadian dairy and poultry production sectors.

The Herfindahl Index is included as a measure of industry concentration. It is postulated that the more concentrated an industry is, the more oligopoly power exists. This relates back to Lopez's argument that increased concentration may result in increased collusion among firms. This collusion, whether intentional or not, is expected to contribute to increased oligopoly power. Therefore, we expect $\beta_H > 0$.

Time is included as a proxy variable for technological improvement in the various industries over the sample period. Technological improvement in food processing is expected to increase the degree of market power by reducing processing costs. As well, the competitiveness of agri-food markets on an international scale has generally increased. This competition may have forced some higher cost firms to exit their respective industry, with the result being increased rationalization. In this case, the degree of market power held by the remaining firms may have increased. Therefore, we expect $\beta_T > 0$.

The supply management dummy variable is included to indicate the effect of supply management. With the introduction of supply management, resource allocation of inputs in the primary production and processing industries may have combined with output restrictions to influence processing firms' ability to affect price, and hence Θ. These resource allocation decisions may have resulted from shifts in capital investment and management skill. As well, volume ceilings in certain processing industries may have shifted resources towards processing industries with fewer restrictions. As such, all processing industries may have been affected by supply management.

As well, trade restrictions achieved through import quotas for supply managed commodities may have affected the degree of market power through capitalization of import quota benefits into processors' equipment, machinery and buildings. This may have affected firms' cost structure, and hence the degree of market power. Supply management also reduced production and the number of primary level producers. In turn, the number of processors fell as higher procurement costs forced some firms' to exit the industry. However, there are no *a priori* sign expectations for β_{SM}.

Thus, the structural equation for Θ is:

$$\Theta = \alpha_1 + \beta_{SM} \cdot SMD + \beta_H \cdot HFINDX + \beta_T \cdot TR \tag{21}$$

Where α_1, β_{SM}, β_H, β_T ≡ parameters to be estimated,
SMD ≡ supply management dummy variable, 0 from 1965 to 1975, 1 from 1976 to 1990,
HFINDX ≡ Herfindahl Index, and
TR ≡ time trend.

Given the Generalized Leontief cost function, (20) becomes:

$$P = \sum_i \sum_j \beta_{ij} \cdot (w_i \cdot w_j)^{1/2} - \frac{\alpha_0 + \beta_{SM} SMD + \beta_H HFINDX + \beta_T TR}{\nu} \quad i,j=K,L,M \tag{22}$$

Equations 15,16,17,18 and 20 compose the system of simultaneous equations to be estimated. All five equations were estimated for the Canadian dairy, fruit and vegetable, poultry and red meat processing industries. The next section discusses the data used to estimate these equations and any data manipulations performed.

Data and Sources

Annual data covering the period 1965 to 1990 were used. For the red meat, poultry and fruit and vegetable processing industries, all quantities were converted to pounds. For the dairy processing industry all quantities were converted to a milk equivalent of 3.6 kilograms of butterfat per hectolitre of milk, measured in hectolitres. Input costs, output prices and personal disposable income (PDI) were deflated by the Consumer Price Index for all Food Items (CPIF). This imposes homogeneity of degree zero in prices and income in the input and output demand equation. As well, PDI was converted to a per capita basis. The measure of capital flow was scaled by a factor of ten, and deflated by the Gross Domestic Product Implicit Price Index (GDPDEF). The balance of this section provides data sources and describes data aggregation.

Common data

Data common in all four models included CPIF, PDI, population and GDPDEF. Statistics Canada CANSIM database provided CPIF (1981=100), population, and PDI ($ 000,000). GDPDEF (1981=100) came from the Bank of Canada Monthly Review.

Number of Firms and Herfindahl Indices

Statistics Canada publication 31-203, Manufacturing Industries in Canada provided the number of firms in each industry. Industry names and SIC codes were: 1011 - Meat and Meat Products (excluding poultry), 1012 - Poultry Products, 103 - Fruit and Vegetable Industries, and 104 - Dairy Products Industries.

As well, Herfindahl indices based on the value of shipments were collected for each industry. These data came from Statistics Canada publications 31-514, Industrial Organization and Concentration in the Manufacturing, Mining and Logging Industries (1965 and 1968), and 31-402 (same title) (1970 to 1982). SIC codes and industry names for 1965 and 1968 were: 1010 - Slaughtering and Meat Processors, 1030 - Poultry Processors, 1050 - Dairy Factories and 1120 - Fruit and Vegetable Canners and Preservers. For the period 1970 - 1982, the corresponding codes and names were: 1011 - Slaughtering and Meat Processors, 1012 - Poultry Processors, 1031 - Fruit and Vegetable Canners and Preservers and 104 - Dairy Products Industries.

However, Statistics Canada published 31-402 bi-annually, and not for the entire period covered. As such, complete Herfindahl index series were not available. The missing data points were created through regression and interpolation techniques.

For each industry, the reported Herfindahl indices were regressed on the number of firms in that industry. Since firm numbers were available for the entire sample, the regression equations could be used to interpolate missing Herfindahl indices. Values for years in which the Herfindahl indices were known were then computed and compared to actual values.

All co-efficient estimates were negative and significant. As well, Durbin-Watson Statistics indicated failure to detect auto-correlation. The adjusted R^2 showed an excellent fit of all equations. Moreover, the simulated values followed the actual values quite closely. As well, covariance of the independent and dependant variables accounted for almost all of the error in each simulation. Actual and simulated values were then used to construct complete Herfindahl index series for each industry.

Input and Output Data and Sources

Expenditure on construction, machinery and equipment provided a measure of capital input (X_K) for each industry. Statistics Canada publications 61-518, Investment Statistics - Manufacturing Sub-industries, Canada 1960 - 1977 (Occasional paper), and 61-214, Capital and Repair expenditure - Manufacturing Sub-industries (Intentions) provided these data. The Chartered Prime Business Loan Rate, from CANSIM, represented W_M, the cost of capital.

Person hours paid ('000 of hours) provided a measure of labour input (X_L). For W_L, the per hour labour wage rate, the aggregate wages paid to production and related workers ($ '000) was divided by X_L. Statistics Canada publication 31-203, Manufacturing Industries in Canada provided data for both X_L and total wages paid. However, both X_L and wages paid were unavailable in 1987. As such, the 1987 figures were estimated by linearly interpolating between the 1986 and 1988 values.

For each industry, an aggregate measure of the quantity of raw materials used (X_M) was derived. W_M, the per unit cost of raw materials was derived by dividing the aggregate value of raw materials by X_M. Aggregation of various raw material inputs into a single measure (X_M) is describe later, as are the sources of X_M and the aggregate value measures.

Total output (Y) for each industry was a composite measure of each industry's output. Aggregation to derive a single output measure is described later, as are the source of output data.

Note that aggregate output measures were converted to a per capita basis to estimate the output demand equation.

Except for poultry, dividing the value of goods of own manufacture by Y provided the per unit value of each industry's output (P). The total value of goods of own manufacture was found in Statistics Canada publication 31-203, Manufacturing Industries in Canada. For poultry, P equalled the total value of shipments and other revenue divided by Y. These data were from Statistics Canada publication 32-227 Poultry Processors (1965 to 1981), 32-232 Meat and Poultry Industries (1982 to 1984), and 32-250, Food Industries (1985 to 1990).

Composition of Aggregate Input and Output Measures

Dairy

The aggregate measure of raw material inputs (X_M) to the dairy processing industry included unprocessed milk and cream. Each input was weighted by its' share of the total value of milk and cream used. Summing the weighted values provided an aggregate measure of raw material inputs in proportion to the value of the inputs.

However, after 1986 Statistics Canada provided aggregate input data in 3.6 k.g. butterfat per hectolitre equivalence. Therefore, only input data up to and including 1986 was converted before creating X_M. Statistics Canada also began to aggregate the total value of raw material inputs after 1986. However, prior to 1987 the value of raw milk and cream must be added together to form an aggregate input value measure.

Similar to inputs, Statistics Canada also changed the reporting style used for outputs. After 1986, the total quantity of milk and cream produced was available in one measure. Prior to 1987, however, milk and cream were separate measures. The aggregate output measure for the dairy processing industry also included butter, cheddar cheese and ice cream. These measures were converted to pounds of whole milk, and then to hectolitres. Therefore, the aggregate output measure included milk, cream, butter, cheddar cheese and ice cream. Statistics Canada publications 32-209, Dairy Products Industries (1965 to 1984), and 32-250, Foods Industries (1985 to 1990) provided most of the input and output data.

There were some problems regarding missing data. In particular, the quantity of milk and cream used was not available for 1987. Therefore, the total value of these inputs in 1987 was divided by the 1986 per unit value of raw milk and cream. This gave a rough approximation to the quantity of raw milk and cream used in 1987.

Output data were also missing. 1987 butter output was estimated in the same way raw milk and cream input was estimated in 1987. However, all other missing data were available from other sources. Cream output from 1976 - 1978 (inclusive) was found in 32-209, Dairy Products Industries, while ice cream production from 1977 - 1986 (inclusive) and cheddar cheese production for 1987 - 1990 (inclusive) were in Agriculture Canada's Dairy Market Review.

Fruit and Vegetable

Raw material inputs to the fruit and vegetable processing industry include sweet corn, fresh and chilled apples, fresh and chilled peas, fresh and chilled tomatoes and potatoes. Inputs were weighted by their share of the value of the five inputs and summed. However, a simple sum was used to construct the measure of aggregate input value. The sum of apple sauce, cream and whole grain corn, whole and piece tomatoes and frozen vegetables (including french fries) produced provided an aggregate output measure.

Input and output data for the fruit and vegetable processing industry came from Statistics Canada publications 32-218 Fruit and Vegetable Processing Industries (1965 to 1984), and 32-250, Food Industries (1985 to 1990).

Poultry

For poultry, the aggregate measures of the value and quantity of inputs included live chicken, turkey, fowl, all other live poultry, and dressed and eviscerated products of the same birds. A simple summation was used to compose these data measures. Data came from Statistics Canada publications 32-227, Poultry Processors (1965 to 1981), 32-232, Meat and Poultry Industries (1982-1984), and 32-250, Food Industries (1985 to 1990).

Red Meat

The sum of cattle and hogs slaughtered, measured in pounds, constituted the raw material input measure for the red meat processing industry. The sum of the value of cattle and hogs slaughtered composed the measure of aggregate input value. Beef and pork disappearance in Canada measured this industry's output. Input data sources included Statistics Canada publications 32-221, Slaughtering and Meat Packing Industries (1965 to 1981), 32-232, Meat and Poultry Industries (1982 to 1984), and 32-250, Food Industries (1985 to 1990). Output data came from Agriculture Canada's databank.

Estimation and Results

The Full Information Maximum Likelihood (FIML) technique in TSP version 4.2b was used to estimate the parameters for equations 15,16,17,18 and 20. FIML was chosen for a number of reasons. First, FIML provides asymptotically efficient maximum likelihood estimates for non-linear models. Second, even if the assumption of a multi-variate normal distribution of the error terms is violated, FIML has the potential to provide asymptotically efficient parameter estimates. Third, FIML is appropriate due to potential simultaneity of the endogenous variables. The endogenous variables were output, output price, and input of capital, labour and raw materials

Several different standard errors can be obtained when using the FIML command in TSP. The difference lies in the fact that each method calculates the covariance matrix in different ways. Method 1 calculates the covariance matrix from the inverse of the matrix of outer product of the first derivatives of the log-likelihood function. This is the approach suggested by Berndt, Hall, Hall and Hausman, and is referred to as BHHH.

Method 2 calculates the covariance matrix using the Gauss-Newton approach. The approach forms the covariance matrix by using a quadratic form of the analytic gradient (the first derivatives of the likelihood function) and the residual covariance matrix. This method will be referred to as GAUSS.

TSP allows for calculation of another covariance matrix based on direct computation of the Hessian matrix from the log-likelihood function. However, as Calzolari and Panattoni illustrated, standard errors derived from the latter tends to lie in between the two reported standard errors. Therefore, the Hessian based on direct calculation was not calculated.

Calzolari and Panattoni also illustrated that these estimates of the covariance matrix are asymptotically equivalent. However, when small samples are used the BHHH standard errors calculated are almost always the largest, while standard errors calculated by the GAUSS approach are almost always the smallest (Calzolari and Panattoni 1988 p.713). However, they point that their rankings are not enough to conclude that one approach produces a covariance matrix that is either too small or too large compared to another approach.

Since the sample covers only 26 years, we should expect different measures of standard errors. Therefore, t-statistics based on both BHHH and GAUSS are reported.

Before reporting the empirical results, several issues need to be addressed. First, the specification of equations 15, 16 and 17 require they be estimated as implicit equations. Output demand equations were also estimated as implicit equations. Therefore, R^2s can not be calculated and are not reported for these equations.

Second, in order to further compare our results to Lopez's aggregate work, own and cross price elasticities for the three input demand equations will be calculated. To calculate these elasticities, the following formulae were used:

$$\textit{Own price}: \quad \varepsilon_{i,i} = -\frac{Y}{2 \cdot X} \cdot \sum_j \beta_{i,j} \cdot \left(\frac{w_j}{w_i}\right)^{1/2}$$

$$\textit{Cross price}: \quad \varepsilon_{i,j} = \frac{Y}{2 \cdot X} \cdot \beta_{i,j} \cdot \left(\frac{w_j}{w_i}\right)^{1/2}$$

Since the input demand equations are assumed homogenous of degree zero in input prices, one of the cross price elasticities was calculated with an identity:

$$\varepsilon_{i,j} = -\varepsilon_{i,i} - \varepsilon_{i,k} \quad i \neq j \neq k$$

Third, initial estimates indicated significant serial correlation among the error terms. As such, an first order auto-correlation correction was specified. Since the sum of the regressands does not equal one, we followed Berndt (1991) and specified each equation with it's own auto-correlation parameter. The auto-correlation correction parameters were denoted RK,RL,RM,RD and RP for capital, labour and raw material input demands, output demand and the price rule respectively. Tables 1 through 4 show the auto-correlated corrected parameter estimates for the complete models of the Canadian dairy, fruit and vegetable, red meat, and poultry processing industries.

The price equation in the dairy, fruit and vegetable and poultry models had R^2s greater then 0.8. However, the R^2 price equation in the red meat model was 0.624.

Only one of the estimated parameters shown in tables 1 through 4 was significantly different from zero using BHHH standard errors. Given the results of Calzolari and Panattoni, this should not be surprising. However, when the GAUSS standard errors were used to derive t-statistics, most of the parameters estimated were significantly different from zero at 5 %. As such, results reported below use GAUSS t-statistics in determining significance of parameters.

For the Canadian dairy processing industry, 16 of 21 parameters were significant at 5 %, and 1 was significant at 10 %. As well, the own price demand response for output was negative and significant. Both time and the supply management dummy variable were significant variables in the Θ equation, and both were positive. Therefore, factors changing over time, and the introduction of supply management increased the oligopolistic nature of the dairy processing industry. This is confirmed by examining calculated values of Θ for the dairy industry shown in table 5.

Table 6 shows the mean values of Θ, $\eta_{Y,P}$ and the Lerner Index. Also shown are the t-statistics testing to see if Θ is significantly different from zero, the perfectly competitive result, or significantly different from one, the monopoly result. In both cases, we failed to accept the null hypothesis at 5 % significance. Therefore, we can conclude that for the data used and the sample period, the Canadian dairy processing industry exhibited oligopolistic behaviour.

Table 7 shows input demand elasticities for the Canadian dairy processing industry. Labour and raw materials had negative own price responses, while capital had a positive own price response. Cross price elasticities indicate a complementary relationship between capital and labour, and capital and raw materials, while labour and raw materials showed a substitute relationship. Because of the assumed symmetry of the cost function, these relationships also held in the opposite direction. As well, all input demand elasticities were inelastic.

For Canadian fruit and vegetable processors, table 2 shows that 17 of 21 parameter estimates were significant at 5 %, 1 was significant at 10 % and 3 were not significant. The own price demand co-efficient was negative and significant. The only significant parameters in the Θ equation were the Herfindahl Index and time, both of which were negative. This indicates Θ fell over time, and as industry concentration increased. Indeed, table 5 shows the conjectural variations elasticity for the

Canadian fruit and vegetable processing industry declining from 1966 to 1990. Table 6 shows that at the mean, Θ and the Lerner Index were both significantly different from zero and one at 5 % significance.

Input demand elasticities in table 7 show that all three inputs had negative own price responses. Cross price input demand elasticities indicate that capital and materials were complements, while capital and labour, and labour and materials were substitutes in use. Again, elasticities were in the inelastic range.

For the Canadian poultry processing industry, 12 of 21 parameter estimates were significant at 5 %. Output demand had a negative and significant own price response. The time trend was the only significant factor in the Θ equation, and was positive. In fact, a slight increasing trend is present in this industry's conjectural variations elasticity. This indicates movement away from perfectly competitive behaviour.

At the mean, the conjectural variations elasticity for the Canadian poultry processing industry was not significantly different from zero at 5 or 10 %. It was, however, significantly different from 1 at 5 %. In addition, the Lerner Index was significantly different from zero and one at the 5 % significance level. Thus, the poultry processing industry does not act in a monopolistic manner, while the evidence is mixed concerning perfectly competitive behaviour.

Input demand elasticities in table 9 show that labour and raw material had negative own price response, while capital had positive response. As well, capital and labour, and capital and raw materials had complementary relationships, while labour and material showed a substitute relationship.

For the red meat processing industry, the own price demand elasticity was held constant at -0.8. This was imposed to attain convergence of the FIML estimates. The assumed value for $\eta_{Y,P}$ seems reasonable given the previous results reported in table 11. The own price demand elasticity was held fixed by holding the parameter on the price variable in the demand equation constant.

Of the 20 parameters estimated in the red meat model, 7 were not significant, 1 was significant at 10 % and 12 were significant at 5 %. In the conjectural variations equation, the supply management dummy variable was positive and significant, while the Herfindahl Index was negative and significant. Thus introduction of supply management increased red meat processors' conjectural variations elasticity, while increased concentration reduced Θ. Nevertheless, estimates of the conjectural variations elasticity for Canada's red meat processing industry indicate an overall increasing trend. As well, mean values of Θ and the Lerner Index were significantly different from zero and one at 5 %. Therefore, the red meat processing industry exhibits behaviour indicative of imperfect competition.

The capital own price elasticity was positive, while those for labour and raw materials were negative. Cross price elasticities indicated capital and labour, and capital and material were complements, while labour and materials were substitutes.

In terms of comparison to previous work, table 11 provides previously reported demand elasticities, table 12 Θ and Lerner Indices, while table 14 shows Lopez's input demand elasticities. Our reported own price demand elasticities, Θ and Lerner Index were within reason of previously reported values.

However, several differences merit discussion. First, the average of our $\eta_{Y,P}$ was -0.718, which was larger than Lopez's. This may have resulted from a large own price demand elasticity for dairy products. As well, the average of all four conjectural variations elasticities equalled 0.299. Again, this was larger than the 0.192 reported by Lopez. A large Θ for the fruit and vegetable processing industry may account for this. The average degree of oligopoly power in our study was 0.362, which is smaller than Lopez's result of 0.504.

Our input demand elasticities were also within reason of the aggregate input demand elasticises reported by Lopez. However, in this study except for the fruit and vegetable processor industry, capital had a positive own price response. This may have occurred since the amount of capital within a industry of the agri-food sector will tend to be invariant to changes in the cost of capital. However, the amount of capital in the entire sector may be more flexible since a larger number of enterprises are included.

Generalization of cross price relationships proves difficult. However, overall results indicate a complementary relationship between capital and raw material, and capital and labour, but a substitute relationship between labour and material.

Summary and Discussion

Oligopoly power exists in the Canadian dairy, fruit and vegetable, poultry and red meat processing industries. At the mean, and in descending order of their Lerner Indices, these industries rank as red meat, dairy, fruit and vegetable, and poultry. As well, each industry's Lerner Index was significantly different from zero and one. Therefore, these firms operate in neither a perfectly competitive or monopolistic manner. However, there was considerable change in Θ over time. Dairy, poultry and red meat processing industries experienced increased conjectural variations elasticities, while the fruit and vegetable processing industry's conjectural variations elasticity declined.

Several factors account for the change in each industry's Θ. Technological change, as proxied by the time trend, accounted for much of the change in Θ for the dairy, fruit and vegetable and poultry processing industries. Industry concentration measured by the Herfindahl Index also accounted for some of the change in Θ for the fruit and vegetable, and red meat processing industries. Finally, introduction of supply management accounted for some of the change in Θ for the red meat and dairy processing industries.

There are a number of implications from this study. First, the common assumption of a perfectly competitive environment in these food processing industries should be avoided in policy analysis. A consequence of making this assumption when it is not true is that of possibly biased policy results. Another implication is that future policies may affect the degree of oligopoly power in these industries. This is particularly so given the recent NAFTA and GATT agreements.

Table 1: Parameter Estimates and t-statistics for the Canadian Dairy Processing Industry.

Parameter	Estimate	t-stat (BHHH)	t-stat (GAUSS)
RK	0.451098	0.058019	3.10241*
βKK	-0.0004	-0.01617	-1.61107
βKL	-0.00041	-0.08547	-3.46362*
βKM	-0.00429	-0.02447	-1.13447
βK	134553	0.276312	9.9026*
RL	0.304911	0.125296	3.0504*
βLL	0.002451	0.150344	13.0797*
βLM	0.00982	0.080796	3.77193*
βL	-72048.7	-0.504196	-22.895*
RM	0.87762	0.929328	20.2248*
βMM	0.475503	0.039143	4.44849*
βM	48902500	0.094184	14.3839*
RD	0.47883	0.083498	4.53491*
$\alpha 0$	8.31929	4.09263*	146.358*
ν	-7.18456	-0.174767	-20.4804*
ρ	-0.00587	-0.021595	-0.99286
RP	0.361778	0.129788	3.52286*
$\alpha 1$	0.470567	0.049924	10.5317*
βSM	0.009077	0.012428	1.75467**
βH	0.536222	0.018379	0.942898
βT	0.007674	0.150823	8.86661*

	Capital	Labour	Materials	Demand	Price
D.W.	1.732	2.659	2.469	1.599	2.683
R^2	NC	NC	NC	NC	0.822

Log-likelihood function value = -898.230
Number of observations = 25
Degrees of freedom = 104
$t^{crit}_{5\%} = 1.645$, $t^{crit}_{10\%} = 1.960$
* significant at 5 %
** significant at 10 %
NC - not calculated

Table 2: Parameter Estimates and t-statistics for the Canadian Fruit and Vegetable Processing Industry.

Parameter	Estimate	t-stat (BHHH)	t-stat (GAUSS)
RK	0.05818	0.001584	0.461581
βKK	0.05356	0.026416	7.3489*
βKL	0.012885	0.023783	8.08286*
βKM	-0.04124	-0.00787	-2.21384*
βK	14576.6	0.007077	2.7733*
RL	0.448332	0.027928	4.52493*
βLL	-0.02617	-0.01083	-7.2873*
βLM	0.126119	0.010033	5.08858*
βL	16284	0.026272	11.1924*
RM	0.667323	0.096559	5.04981*
βMM	-0.14597	-0.00201	-0.54028
βM	485170	0.016091	5.57038*
RD	0.773266	0.035499	9.89625*
α0	4.18017	0.911981	22.451*
ν	-4373.49	-0.289	-13.649*
ρ	0.035252	0.068402	2.16062*
RP	0.213411	0.010005	1.85176**
α1	1.19437	0.012338	4.82525*
βSM	0.043315	0.03997	1.44977
βH	-8.90171	-0.0068	-2.29029*
βT	-0.01422	-0.01129	-3.85462*

	Capital	Labour	Materials	Demand	Price
D.W.	1.144	1.337	2.151	2.241	1.143
R^2	NC	NC	NC	NC	0.821

Log-likelihood function value = -558.926
Number of observations = 25
Degrees of freedom = 104
$t^{crit}_{5\%}$ = 1.645, $t^{crit}_{10\%}$ = 1.960
* significant at 5 %
** significant at 10 %
NC - not calculated

Table 3: Parameter Estimates and t-statistics for the Canadian Poultry Processing Industry.

Parameter	Estimate	t-stat (BHHH)	t-stat (GAUSS)
RK	0.405455	0.001262	2.75643*
βKK	0.000006	0.001833	3.43462*
βKL	-2.2e-06	-0.00034	-0.78463
βKM	-2.4e-06	-0.000099	-0.21507
βK	-1.5116	-0.000503	-1.16727
RL	0.539622	0.005473	5.40137*
βLL	0.011298	0.002016	5.36698*
βLM	0.04493	0.002173	5.17322*
βL	-6589.44	-0.04442	-3.80045*
RM	0.144194	0.007579	1.1186
βMM	1.22611	0.013929	15.9869*
βM	-60032.2	-0.006979	-1.15716
RD	0.556171	0.006311	4.51255*
α0	3.19236	0.278952	23.7779*
ν	-0.22573	-0.001407	-3.0411*
ρ	0.082958	0.004555	6.16935*
RP	0.015579	0.000206	0.117492
α1	-0.00408	-0.000075	-0.19351
βSM	0.000133	0.000024	0.022103
βH	0.210528	0.000311	0.691108
βT	0.001212	0.026428	2.09882*

	Capital	Labour	Materials	Demand	Price
D.W.	2.026	1.390	0.624	1.808	0.624
R^2	NC	NC	NC	NC	0.624

Log-likelihood function value = -498.952
Number of observations = 25
Degrees of freedom = 104
$t^{crit}_{5\%}$ = 1.645, $t^{crit}_{10\%}$ = 1.960
* significant at 5 %
** significant at 10 %
NC - not calculated

Table 4: Parameter Estimates and t-statistics for the Canadian Red Meat Processing Industry.

Parameter	Estimate	t-stat (BHHH)	t-stat (GAUSS)
RK	0.353661	0.191823	2.14576*
βKK	0.018133	0.002944	1.40066
βKL	-0.01081	-0.001456	-0.70797
βKM	-0.06074	-0.016703	-1.92887**
βK	67923	0.56565	23.3938*
RL	0.995399	0.23507	98.8564*
βLL	-0.03434	-0.003729	-1.31569
βLM	0.197394	0.013125	4.48995*
βL	24383.3	0.015095	3.60203*
RM	0.036228	0.000945	0.365759
βMM	0.763702	0.017857	3.04898*
βM	-610.487	-0.03087	-2.32428*
RD	0.838801	0.031662	14.3289*
α0	-0.26186	-0.004239	-0.93339
ρ	-0.000855	-0.01205	-3.22203*
RP	-0.20089	-0.005746	-1.47455
α1	0.352986	0.096489	4.34838*
βSM	0.038337	0.071789	5.11822*
βH	-0.88198	-0.01626	-2.8354*
βT	0.001008	0.003952	0.750988

	Capital	Labour	Materials	Demand	Price
D.W.	1.732	2.659	2.469	1.599	2.683
R^2	NC	NC	NC	NC	0.822

Log-likelihood function value = -898.230
Number of observations = 25
Degrees of freedom = 105
$t^{crit}_{5\%}$ = 1.645, $t^{crit}_{10\%}$ = 1.960
* significant at 5 %
** significant at 10 %
NC - not calculated

Table 5: Conjectural Variation Elasticity for Major Canadian Food Processing Sectors.

Year	Dairy	Fruit and vegetable	Poultry	Red meat
1966	0.319	0.566	0.006	0.303
1967	0.327	0.554	0.008	0.312
1968	0.333	0.561	0.010	0.305
1969	0.339	0.506	0.012	0.316
1970	0.344	0.434	0.015	0.317
1971	0.352	0.489	0.015	0.324
1972	0.357	0.455	0.018	0.323
1973	0.363	0.441	0.018	0.332
1974	0.370	0.436	0.018	0.339
1975	0.374	0.423	0.021	0.339
1976	0.390	0.452	0.023	0.382
1977	0.390	0.417	0.024	0.369
1978	0.395	0.418	0.025	0.399
1979	0.400	0.407	0.026	0.409
1980	0.406	0.391	0.026	0.405
1981	0.411	0.367	0.028	0.403
1982	0.415	0.372	0.030	0.419
1983	0.421	0.347	0.030	0.407
1984	0.426	0.344	0.032	0.419
1985	0.431	0.329	0.033	0.423
1986	0.436	0.319	0.033	0.429
1987	0.441	0.302	0.035	0.423
1988	0.446	0.302	0.036	0.426
1989	0.451	0.288	0.037	0.423
1990	0.456	0.276	0.038	0.423

Table 6: Θ, $\eta_{Y,P}$ and Lerner Index Mean Values.

		H_0: Θ, LI = 0		H_0: Θ, LI = 1	
Sector	Estimate	BHHH	Gauss	BHHH	Gauss
Dairy	Θ = 0.391	0.045	4.958*	-0.069	-7.695*
	$\eta_{Y,P}$ = -0.837	-0.175	-20.346*	NT	NT
	L.I. = 0.468	0.060	5.346*	-0.068	-6.076*
F & V	Θ = 0.407	0.052	4.407*	-0.076	-6.400*
	$\eta_{Y,P}$ = -0.995	-0.289	-13.649*	NT	NT
	L.I. = 0.409	0.045	4.569*	-0.064	-6.577*
Poultry	Θ = 0.024	0.001	1.187	-0.041	-74.455*
	$\eta_{Y,P}$ = -0.239	-0.001	-3.041*	NT	NT
	L.I. = 0.099	0.004	2.743*	-0.032	-24.857*
Red meat	Θ = 0.374	0.048	3.953*	-0.081	-6.594*
	$\eta_{Y,P}$ = -0.8*	NT	NT	NT	NT
	L.I. = 0.473	0.048	3.953*	-0.054	-4.395*

NT t-test not performed.
* significant at 5 %
** significant at 10 %

Table 7: Input Demand Elasticities for the Canadian Dairy Processing Industry.

	Estimate	t-stat. (BHHH)	t-stat. (Gauss)
ϵKK	0.117439	0.103214	2.40189*
ϵKL	-0.06999	-0.08547	-3.46362*
ϵKM	-0.04745	-0.02447	-1.13447
ϵLK	-0.36098	-0.08547	-3.46362*
ϵLL	-0.07253	-0.00762	-0.66921
ϵLM	0.433511	0.080796	3.77193*
ϵMK	-0.02712	-0.02447	-1.13447
ϵML	0.048023	0.080796	3.77193*
ϵMM	-0.0209	-0.0392	-0.77718

* significant at 5 %
** significant at 10 %

Table 8: Input Demand Elasticities for the Canadian Fruit and Vegetable Processing Industry.

	Estimate	t-stat. (BHHH)	t-stat. (Gauss)
ϵKK	-0.02566	-0.01434	-1.85696**
ϵKL	0.059377	0.023783	8.08286*
ϵKM	-0.03372	-0.00787	-2.21384*
ϵLK	0.287677	0.023783	8.08286*
ϵLL	-0.63568	-0.02814	-11.0706*
ϵLM	0.347997	0.010033	5.08858*
ϵMK	-0.19935	-0.00787	-2.21384*
ϵML	0.424215	0.010033	5.08858*
ϵMM	-0.22486	-0.00333	-1.62874

* significant at 5 %
** significant at 10 %

Table 9: Input Demand Elasticities for the Canadian Poultry Processing Industry.

	Estimate	t-stat. (BHHH)	t-stat. (Gauss)
ϵKK	0.530273	0.010362	2.62241*
ϵKL	-0.40615	-0.00034	-0.78463
ϵKM	-0.12412	-0.0001	-0.21507
ϵLK	-0.0001	-0.00034	-0.78463
ϵLL	-0.38422	-0.00218	-5.17617*
ϵLM	0.384314	0.002173	5.17322*
ϵMK	-4.7e-06	-0.0001	-0.21507
ϵML	0.060989	0.002173	5.17322*
ϵMM	-0.06098	-0.00217	-5.16794*

* significant at 5 %
** significant at 10 %

Table 10: Input Demand Elasticities for the Canadian Red Meat Processing Industry.

	Estimate	t-stat. (BHHH)	t-stat. (Gauss)
ϵKK	0.000655	0.00354	1.71688**
ϵKL	-0.00023	-0.00146	-0.70797
ϵKM	-0.00042	-0.0167	-1.92887**
ϵLK	-0.00048	-0.00146	-0.70797
ϵLL	-0.00182	-0.0118	-2.29837*
ϵLM	0.002305	0.013125	4.48995*
ϵMK	-0.1184	-0.0167	-1.92887**
ϵML	0.312616	0.013125	4.48995*
ϵMM	-0.19422	-0.01161	-1.89837**

* significant at 5 %
** significant at 10 %

Table 11: Previously Reported Demand Elasticities.

<table>
<tr><td colspan="7">Demand Elasticities (reported in Oxley (1994))</td></tr>
<tr><th></th><th>Lopez</th><th>Oxley</th><th>Moschini & Moro</th><th>Johnson & Safyurtlu</th><th>Barewal & Goddard</th><th>Hassan & Johnson</th></tr>
<tr><td>Dairy</td><td></td><td>-.35</td><td>-.35 to -.4</td><td>-.44</td><td>-.59</td><td>-.43</td></tr>
<tr><td>Fruit & vegetable</td><td></td><td>-.70</td><td>-.16 to -.31</td><td>-.77</td><td>-.43</td><td>-.45</td></tr>
<tr><td>Poultry</td><td></td><td>-.35</td><td>-.68</td><td rowspan="2">-.68</td><td rowspan="2">-.7</td><td rowspan="2">-.85</td></tr>
<tr><td>Red meat</td><td></td><td>-.13</td><td>-.41 to -.56</td></tr>
<tr><td>Aggregate industry</td><td>-.381</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th></th><th>Coleman</th><th>Curtin et al</th><th colspan="2">Reynolds & Goddard</th><th colspan="2">Chen & Veeman</th></tr>
<tr><td>Beef</td><td>-0.47</td><td>-0.373</td><td colspan="2">-0.735</td><td colspan="2">-0.77</td></tr>
<tr><td>Pork</td><td>-0.88</td><td>-0.745</td><td colspan="2">-0.676</td><td colspan="2">-0.82</td></tr>
</table>

Table 12: Previously Reported Θ and Lerner Indices

Conjectural Variations Elasticities and Lerner Index (if reported)					
	Lopez	Schroeter (beef)	Azzam & Pagoulatos	Rude (Θ only)	Oxley (Θ only)[2]
Dairy				Soft product .589 - .544, Concentrated milk .283 - .284, Butter .230 - .263, Cheese .222 - .246, Fluid milk .056 - .096.	
Fruit & vegetable					0.161
Poultry					0.052
Red meat		Θ=0.0417 to 0.0190 LI=0.0791 to 0.036	Θ=0.223 LI=0.460		0.079
Aggregate industry	Θ=0.192 LI=0.504				

Table 13: Lopez's Input Demand Elasticities

	Capital	Labour	Raw Materials	Energy
Capital	-.066	.063	.040	-.022
Labour	.051	-.305	.030	.227
Raw Materials	.038	-.036	-.119	.042
Energy	-.023	.278	.049	-.247

[2] Oxley assumed a Cournot solution. Therefore, the conjectural variation elasticity for each industry is measured by the respective Herfindahl Index.

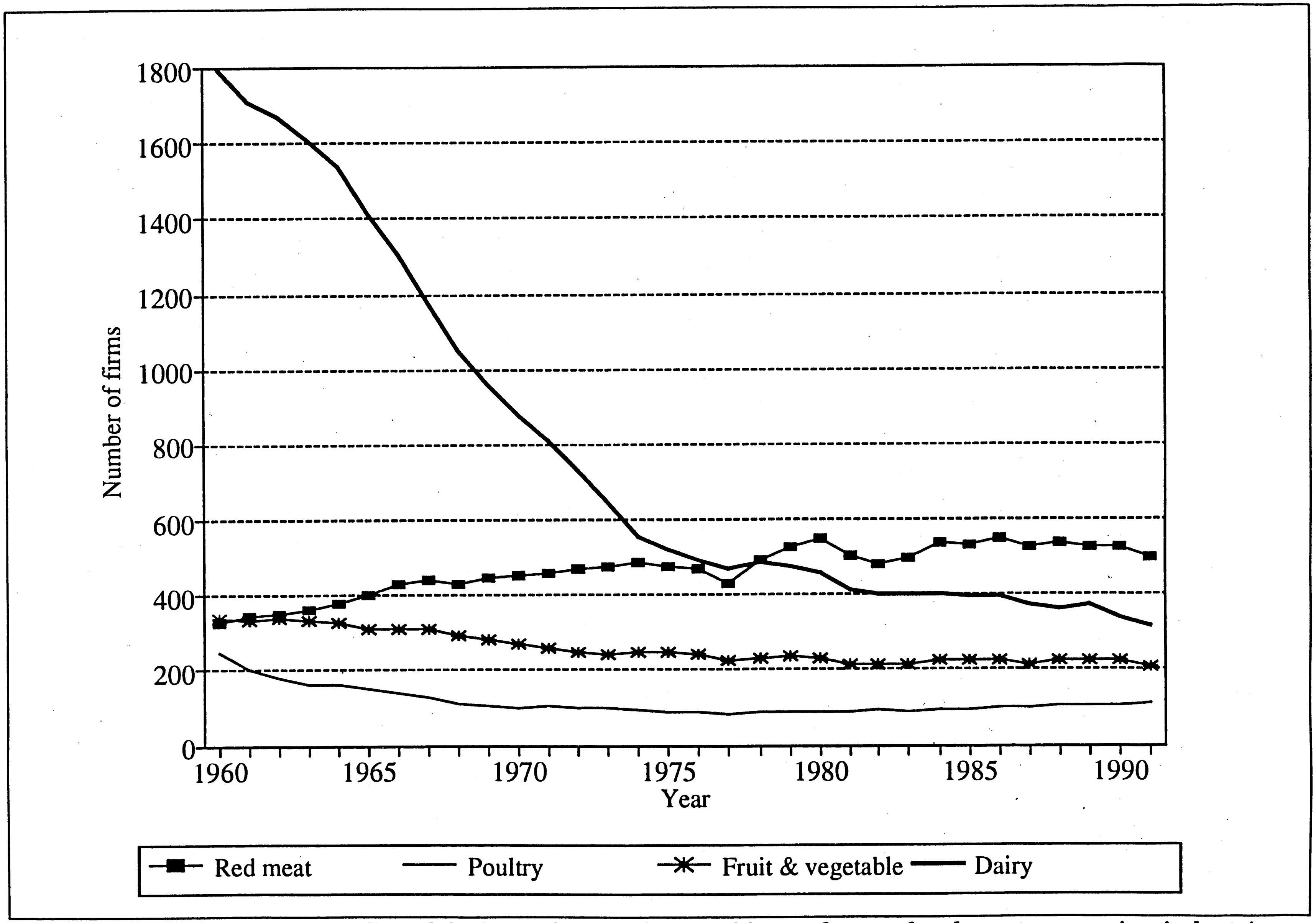

Figure 1: Number of firms in Canada's dairy, fruit and vegetable, poultry and red meat processing industries.

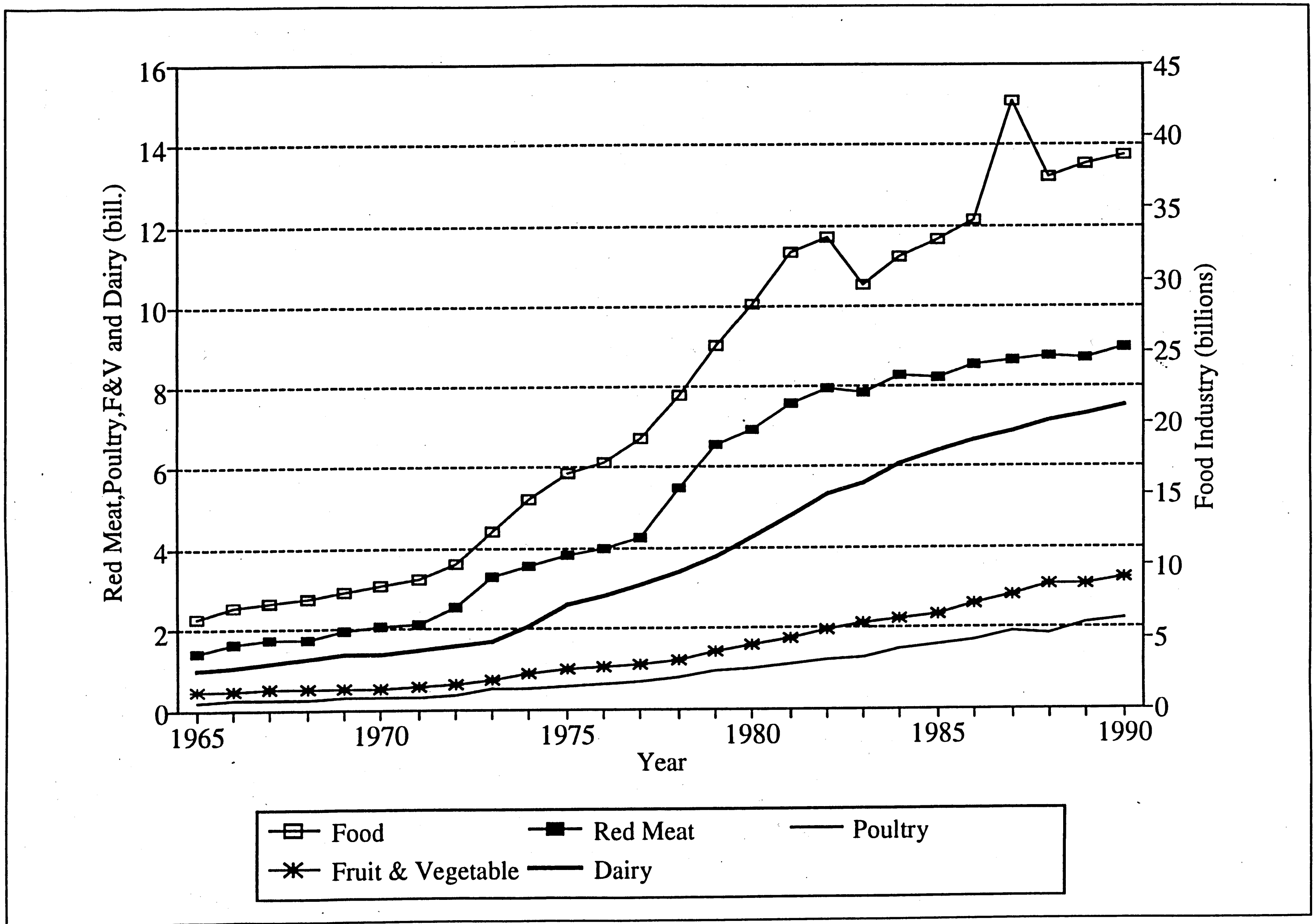

Figure 2: Value of Shipments from Canadian Food Processors.

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