THE IMPACT OF NAFTA ON U.S. AGRICULTURE: AN EX-POST, BINARY VARIABLE APPROACH

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Following the completion of the implementation period for NAFTA, this market integration has influenced economic behavior in these markets. Given this assumption, this study identifies, ex-post, the effects of structural adjustment and tariff elimination on U.S. agriculture.

The North American Free Trade Agreement (NAFTA) came into effect on January 1, 1994 with full implementation occurring on January 1, 2008. A portion of its aim was to promote agricultural market integration between the United States, Canada, and Mexico through the elimination of most trade barriers. This market integration of agricultural economies has induced structural adjustment in member countries.

Many previous studies conducted *ex-ante* analyses about the effects of NAFTA on U.S. agriculture before and during the implementation period of NAFTA (Burfisher, Robinson, Thierfelder, 2001; De Janvry, 1996; Grennes, *et. al*., 1991; Melton and Huffman, 1993; Wainio, *et. al*., 1991). These *ex-ante* analyses have provided a valuable guide for U.S. agriculture development in expecting more open economic markets established by NAFTA. However, the implementation period is a transition period which could not fully represent the effect of the trade policy. Therefore, the previous *ex-ante* analyses conducted in this transition period may provide different conclusions dependent upon what they assumed about macro- and micro-circumstances. As is known, the NAFTA implementation period was completed so it is now an appropriate time for a thorough *ex-post* analysis of the effects NAFTA has had on U.S. agriculture.

This study is conducted as follows. In the next section, the analytical framework is described. The third section is devoted to an empirical application of the model to the U.S. corn industry. In the section, this study illustrates 1) variations in the U.S. corn price for the time periods before and after the implementation of NAFTA, 2) a restricted statistical model, and 3) empirical results. A conclusion and recommendations for further research are included in the final section.

Analytical Framework

Model Assumption

Since the economic benefit to agricultural producers is determined via price and quantity, NAFTA's effects on U.S. agriculture are measured by how much the parameters of price and quantity sold have changed since the implementation of NAFTA. However, market price can be affected by a variety of other economic and policy events, so it is not a simple exercise to isolate the effect of NAFTA on U.S. agriculture. According to Panagariya's survey (2000), as well as their earlier work on customs unions, it is essentially an empirical issue that must be settled by data analysis, because a regional trade agreement may or may not benefit its members depending upon parameter values and initial market structure.

The Partial Equilibrium approach for a specific commodity assumes that price is a key determinant with respect to how much individual consumers purchase given their purchasing power and how much producers supply. The price responsiveness of consumers and producers for the commodity could be changed according to the relative degree of market integration. In this context, this study uses both intercept and interaction binary variables to determine the structural adjustment (if any) induced by NAFTA.

Now, let us define the demand and supply equations for agricultural commodity *j* in country *i* as follows:

(1) $$D_i^j = -a_i^j P_i^j + b_i^j Y_i + c_i^j + \varsigma_i^j B + \xi_i^j \left(P_i^j \times B\right) + \zeta_i^j \left(Y_i \times B\right),$$

(2) $$S_i^j = d_i^j P_i^j - e_i^j + \phi_i^j B + \varphi_i^j \left(P_i^j \times B\right),$$

where *D* and *S* are market demand and supply, *P* is price, *Y* is income, *B* is a binary variable (*B* = 1 after 1994 and *B* = 0 otherwise), *j* represents a specific agricultural product, and *i* represents a specific country. These two equations show that price responsiveness of demand and supply are different in direction and magnitude. Intercept variables, *c* and *e*, represent all other variables affecting demand and supply of agricultural product *j* such as the prices of competing products, consumer demographics, government policies, technologies, and so on.

Equations (1) and (2) will hold if NAFTA has an intercept and marginal effects in the demand and supply of agricultural product *j* in the three North American countries. Therefore, the equilibrium price of agricultural product *j* in country *i* in the relatively less restricted economic circumstances following NAFTA may change. In other words, excess supply (or excess demand) after the implementation of NAFTA would be affected, depending upon how NAFTA affects the intercept and interaction variables in the demand and supply equations. This can be expressed as follows:

(3) $$ES_i^j = \left(a_i^j + d_i^j\right)P_i^j - b_i^j Y_i - \left(c_i^j + e_i^j\right) + \left(\phi_i^j - \varsigma_i^j\right)D + \left(\varphi_i^j - \xi_i^j\right)P_i^j D - \zeta_i^j Y_i D \text{, and}$$

(4) $$ED_i^j = -\left(a_i^j + d_i^j\right)P_i^j + b_i^j Y_i + \left(c_i^j + e_i^j\right) - \left(\phi_i^j - \varsigma_i^j\right)D - \left(\varphi_i^j - \xi_i^j\right)P_i^j D + \zeta_i^j Y_i D \text{.}$$

If NAFTA changes the behaviors of market participants, then these excess supply and demand equations will hold.

Now, in order to examine NAFTA's impact on the equilibrium price of U.S. agricultural product *j* in the world market, we categorize the involved trading countries into two groups: net importers and net exporters. The net exporter group is divided into three subgroups: the United States (*US*), large exporters (*K*), and small exporters (*N*). The net importer group is segmented into three subgroups: Mexico and Canada (*MC*), large importers (*L*), and small importers (*S*).[1] Then, U.S. excess supply of agricultural product *j* is classified into three categories as follows:

(5) $$^{MC}ES_{US}^j = {}^{MC}\beta_{US}^j \times ES_{US}^j$$

(6) $$^{L}ES_{US}^j = \sum_{l=1}^{L} {}^{l}\beta_{US}^j \times ES_{US}^j$$

(7) $$^{S}ES_{US}^j = \left(1 - {}^{MC}\beta_{US}^j - \sum_{l=1}^{L} {}^{l}\beta_{US}^j\right) \times ES_{US}^i$$

where $^{MC}ES_{US}^j$ is U.S. exports to the *MC* market, $^{L}ES_{US}^j$ is U.S. exports to large importer markets (*L*), and $^{S}ES_{US}^j$ is U.S. exports to small importer markets (*S*). $^{MC}\beta_{US}^j$ represents the share of U.S. exports to *MC* of total U.S. exports of agricultural good *j*, and $^{l}\beta_{US}^j$ represents the share of U.S. exports to one of

the large importer markets (l) of total U.S. exports of agricultural good j . The excess supplies of both large and small exporters groups (K and N) are presented in Appendix 1.

Total U.S. excess supply, then, is shown as:

$$(8)\quad ES_{US}^{j} = \left(a_{US}^{j} + d_{US}^{j}\right)P_{US}^{j} - b_{US}^{j}Y_{US} - \left(c_{US}^{j} + e_{US}^{j}\right) + \left(\phi_{US}^{j} - \varsigma_{US}^{j}\right)D + \left(\varphi_{US}^{j} - \xi_{US}^{j}\right)P_{US}^{j}D - \zeta_{US}^{j}Y_{US}D.$$

Also, MC excess demand of agricultural product j is classified into three categories as:

$$(9)\quad {}^{US}ED_{MC}^{j} = {}^{US}\alpha_{MC}^{j} \times ED_{MC}^{j}$$

$$(10)\quad {}^{K}ED_{MC}^{j} = \sum_{k=1}^{K} {}^{k}\alpha_{MC}^{j} \times ED_{MC}^{j}$$

$$(11)\quad {}^{N}ED_{MC}^{j} = \left(1 - {}^{US}\alpha_{MC}^{j} - \sum_{k=1}^{K} {}^{k}\alpha_{MC}^{j}\right) \times ED_{MC}^{i},$$

where ${}^{US}ED_{MC}^{j}$ (or ${}^{MC}ES_{US}^{j}$) represents MC imports of j from the United States, ${}^{K}ED_{MC}^{j}$ (or ${}^{MC}ES_{K}^{j}$) represents MC imports of j from the large exporters group (K), ${}^{N}ED_{MC}^{j}$ (or ${}^{MC}ES_{N}^{j}$) represents MC imports of j from the small exporters group (N), ${}^{US}\alpha_{MC}^{j}$ represents the share of MC imports of j from United States of total MC imports, and ${}^{k}\alpha_{MC}^{j}$ represents the share of MC imports of large exporter (k) of total MC imports. The excess demand for both large and small importer groups (L and S) are detailed in Appendix 1.

Total MC excess demand, then, is expressed as:

$$(12)\quad ED_{MC}^{j} = -\left(a_{MC}^{j} + d_{MC}^{j}\right)P_{MC}^{j} + b_{MC}^{j}Y_{MC} + \left(c_{MC}^{j} + e_{MC}^{j}\right) - \left(\phi_{MC}^{j} - \varsigma_{MC}^{j}\right)D - \left(\varphi_{MC}^{j} - \xi_{MC}^{j}\right)P_{MC}^{j}D + \zeta_{MC}^{j}D.$$

Since there are four different sources of supply for agricultural product j in market MC, the price of agricultural product j in market MC is expressed as follows:

$$(13)\quad P_{MC}^{j} = {}^{US}\alpha_{MC}^{j}P_{US}^{j}(1 + {}^{US}t_{MC}^{j}) + \sum_{k=1}^{K} {}^{k}\alpha_{MC}^{j}P_{k}^{j}(1 + {}^{k}t_{MC}^{j}) + (1 - {}^{US}\alpha_{MC}^{j} - \sum_{k=1}^{K} {}^{k}\alpha_{MC}^{j})\sum_{n=1}^{N} P_{n}^{j}(1 + {}^{n}t_{MC}^{j}),$$

where $P_{US}^{j} = P_{K}^{j} = P_{N}^{J}$ if *MC* imports agricultural good *j* at same price from all exporting countries while $P_{US}^{j} \neq P_{K}^{j} \neq P_{N}^{J}$ if *MC* imports agricultural product *j* at different price from all exporting countries. Also, if the share of local products is large in the *MC* market, then the price of local product produced by *MC* is included in the large exporters group ($^{k}\alpha_{MC}^{j}$), while if the share of local products is small, then the price of local product produced by *MC* is included in the small exporters group. In addition, if *MC* imposes the same import tariff rate on all imported agricultural products *j*, then $^{US}t_{MC}^{j} = {}^{k}t_{MC}^{j} = {}^{n}t_{MC}^{j}$. If *MC* imposes a different import tariff rate, $^{US}t_{MC}^{j} \neq {}^{k}t_{MC}^{j} \neq {}^{n}t_{MC}^{j}$. The two other importers' prices (*L* and *S*) are defined in Appendix 1.

U.S. Price at World Market Equilibrium

At the world market equilibrium of agricultural product *j*, total excess supply is equal to total excess demand as follows:

$$
\begin{aligned}
&ES^{j} = ES_{US}^{j} + ES_{K}^{j} + E_{N}^{j} \\
(14) \qquad &ED^{j} = ED_{MC}^{j} + ED_{L}^{j} + ED_{S}^{j} \,. \\
&ES^{j} = ED^{j}
\end{aligned}
$$

Therefore, the *U.S.* price of agricultural product *j* at the world market equilibrium is defined as follows:

$$
(15) \qquad P_{US}^{j} = \overbrace{A\left({}^{US}t_{MC}^{j} \mid a_{i}^{j}, d_{i}^{j}, {}^{US}\alpha_{i}^{j}, t_{i}^{j}, \varphi_{i}^{j}, \xi_{i}^{j}\right)^{-1}}^{\substack{Tariff \\ Im\,pact}} \times \left(\overbrace{K\left(P_{K}^{j} \mid a_{i}^{j}, d_{i}^{j}, {}^{K}\alpha_{i}^{j}, {}^{K}t_{i}^{j}\right)}^{\substack{L\,arg\,e \\ Group \\ Im\,pact}} \right.
$$

$$
+ \overbrace{N\left(P_{N}^{j} \mid a_{i}^{j}, d_{i}^{j}, {}^{N}\alpha_{i}^{j}, {}^{N}t_{i}^{j},\right)}^{\substack{Smalls \\ Group \\ Im\,pact}} + \overbrace{G\left(Y_{i} \mid b_{i}^{j}\right)}^{\substack{Income \\ Im\,pact}} + \overbrace{C}^{\substack{Cons\tan t \\ Term}}
$$

$$
\left. + \overbrace{S\left(\phi_{i}^{j}, \varsigma_{i}^{j}, \varphi_{i}^{j}, \xi_{i}^{j}, \zeta_{i}^{j} \mid a_{i}^{j}, d_{i}^{j}, \alpha_{i}^{j}, t_{i}^{j}, P_{K}^{j}, P_{N}^{j}, Y_{i}\right)}^{\substack{Structural \\ Adjustment \\ Im\,pact}} \right),
$$

where the specific functional form of impact factors (A, K, N, G, C, and S) are provided in Appendix 2. Equation (15) shows that the *U.S.* price of agricultural product j after NAFTA would be affected by the policy instrument variable (tariff) as well as by the structural adjustment (intercept and interaction binary variables) in NAFTA countries. For example, given the existing parameters of share, tariff, prices, and income of other trading countries, if NAFTA does not change at least one of the intercepts and interaction variables, equation (15) is reduced as follows:

$$(16) \qquad \hat{P}_{US}^{j} = \overbrace{\hat{A}\left({}^{US}t_{MC}^{j} \mid a_i^j, d_i^j, {}^{US}\alpha_i^j, t_i^j\right)^{-1}}^{\substack{Tariff \\ Impact}} \times \left(\overbrace{K\left(P_K^j \mid a_i^j, d_i^j, {}^{K}\alpha_i^j, {}^{K}t_i^j,\right)}^{\substack{Large \\ Group \\ Impact}} + \overbrace{N\left(P_N^j \mid a_i^j, d_i^j, {}^{N}\alpha_i^j, {}^{N}t_i^j\right)}^{\substack{Small \\ Group \\ Impact}} + \overbrace{G\left(Y_i\right)}^{\substack{Income \\ Impact}} + \overbrace{C}^{\substack{Constant \\ Term}} \right).$$

As equations (15) and (16) imply, if NAFTA changes at least one of the intercepts or interaction variables, the *U.S.* price of agricultural product j will be affected by a structural change induced by NAFTA. Furthermore, since NAFTA eliminates (or significantly reduces) the tariff imposed on *U.S.* agricultural product j in market MC and may induce income growth, the real effect of NAFTA is the sum of the effects of changes in tariff, income, and structural adjustment. In addition, equation (15) shows the price effects of both large and small groups on the *U.S.* price of agricultural product j. However, the effects of large and small groups would be weighted by their share parameter. So, the small group's effect on *U.S.* price could be ignored if the share commanded by the small group is significantly small. Also, the greater the share of the large group, the greater the effect the large group would have on the *U.S.* price of agricultural product j and *vice versa*. Finally, no matter what the trade share of other trading countries, a change in the income of these countries will certainly affect the *U.S.* price of agricultural product j.

Empirical Example

An Illustration of U.S. Corn Price

Figure 1 shows movements in the U.S. annual corn price pre- and post-1994. As shown, the U.S. average corn price increased after 1994. However, price variance also increased after 1994, indicating that some of the prices after 1994 were lower than the average price before 1994. U.S. corn price increased to $3.24/bushel in 1994 when NAFTA was implemented. After 1994, the U.S. corn price steadily fell, reaching a low of $1.82/bushel in 1999 with U.S. corn prices remaining relatively weak until 2005. After 2005, the U.S. corn price rebounded, in part because of strong demand induced by the bio-ethanol boom. In actuality, U.S. corn prices are lower than those before 1994 except for two exceptional periods including the beginning year of NAFTA and bio-ethanol boom years of the late 2000s. Therefore, it is not simple to analyze the effect of NAFTA on the U.S. corn industry. Furthermore, it contradicts neo-classical trade theory that U.S. corn prices after 1994 were lower than those prior to 1994, since tariff elimination on the part of an importing country should increase the price in the exporting country.

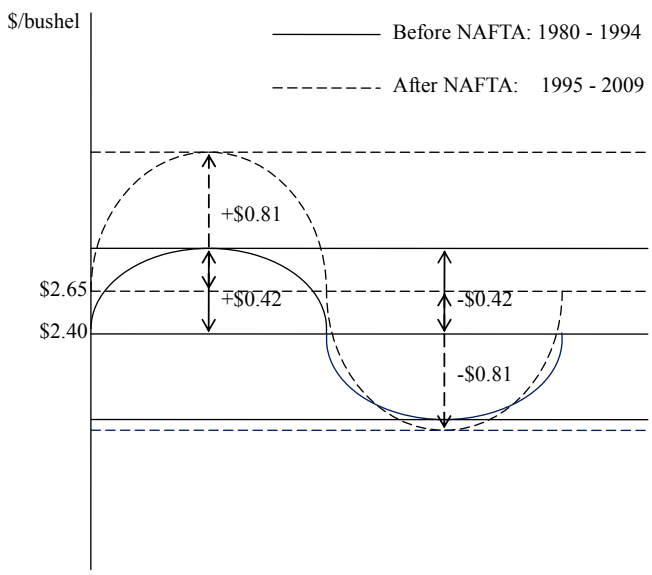

Figure 1. US Annual Corn Price Movements of Before and After NAFTA

Therefore, it is reasonable to consider the possibility of structural change in the economies during the implementation of NAFTA for the trading countries involved. For example, if consumption and/or production response in the involved trading partners became more (or less) sensitive to a change in price

after NAFTA, excess demand and/or excess supply will be more (or less) affected by the same amount of change in price compared to before NAFTA. Therefore, the effect of NAFTA on the U.S. agricultural industry would be influenced by structural adjustment in member countries. In addition, if there are other countries exporting to Canada and Mexico and other countries importing from the United States, then these countries would also affect the U.S. agricultural industry. In the case of corn, Japan and Korea (*JK*) are used as large importers from the United States in this study.

Restricted Statistical Model

Based on the economic framework addressed above, the restricted statistical models of corn demand and supply in country *i* are defined as follows:

(17) $$D_{it}^{corn} = -a_i^{corn} P_{it}^{corn} + b_i^{corn} Y_{it} + c_i^{corn} + \varsigma_i^{corn} D + \xi_i^{corn}\left(P_{it}^{corn} \times D\right) + \zeta_i^{corn}\left(Y_{it} \times D\right) + u_{it}$$, and

(18) $$S_{it}^{corn} = d_i^{corn} P_{it}^{corn} - e_i^{corn} + \phi_i^{corn} D + \varphi_i^{corn}\left(P_{it}^{corn} \times D\right) + v_{it}$$,

where u_{it}^{corn} and v_{it}^{corn} are assumed to be white noise random disturbances.[2]

In the statistical model, this study assumes that 1) the derived demand function is a function of own price and income, 2) the derived supply function is a function of own price, and 3) own price elasticity of demand is different from own price elasticity of supply in direction and magnitude. With this non-sample assumption, we can obtain efficiency in the statistical model whenever this assumption is compatible with sample data. However, if this assumption is not compatible with the sample data, there is a risk of estimation bias. In order to avoid this, we employ the *Lagrange Multiplier* test as suggested by Griffiths, Hill, and Judge, p.454. For example, we conduct a statistical comparison of demand and supply equations with augmented demand and supply equations including cross prices. We then compare the estimated parameters of price elasticities of the restricted statistical models with those of the unrestricted statistical models. The test results are reported in Table 1.

Table 1. Testing the Restriction from the Non-Sample Information

	t-values						*F*-values	
	D_R	D_{UR}	D_A	S_R	S_{UR}	S_A	D_A	S_A
P_{US}^{corn}	-3.20	-4.03	-2.21	3.20	-1.57	-2.03	*Ho*: No cross price effect	
$P_{US}^{soybean}$			0.46			0.09	2.85	1.50
P_{US}^{wheat}			1.74			1.92		
P_{MC}^{corn}	-2.51	-2.21	-2.32	2.51	-1.04	-1.32		
$P_{MC}^{soybean}$			-1.55			-0.11	2.27	2.90
P_{MC}^{wheat}			2.42			1.12		
P_{JK}^{corn}	2.86	2.28	3.12	-2.86	-0.95	-1.82		
$P_{JK}^{soybean}$			0.26			0.38	0.85	1.60
P_{JK}^{wheat}			0.12			-1.12		

$t_c = 1.96$ and $F_c = 3.00$ at $\alpha = 0.05$ when $J = 2$ and $T - K = \infty$.

D_A and S_A are augmented equations with cross prices such as soybean and wheat.

D_{UR} and S_{UR} are unrestricted demand and supply equations, respectively.

D_R and S_R are restricted demand and supply equations, respectively.

F-values and *t*-values of cross price variables in the augmented demand and supply equations are less than the critical values at the 5% significance level. In addition, the restricted equations provide more precise estimations except for the U.S. demand equation. Contrary to expectations, price elasticities of demand and supply of *JK* are positive and negative, respectively. In fact, corn consumption in *JK* has increased with the increase in corn price while domestic production of corn in *JK* have decreased because production costs are much higher than market prices during the sample period of time. Therefore, the restricted models provide more efficient estimates as compared to the other alternatives.

Data Sources

This study used annual time series data from 1991 to 2007 obtained from various sources for our empirical example. The data for corn price, production, consumption, imports, and exports were obtained from the Food and Agriculture Organization (FAO). Gross national income data was obtained from the International Monetary Fund (IMF). Because the IMF reports gross national income in local currency, this study uses the nominal exchange rate to convert local currency values of gross national income into U.S. dollars. Nominal exchange rate data was obtained from the IMF. Tariff data was obtained from the WTO and the USDA (FAS).

NAFTA Effect on U.S. Corn Price at Benchmark Values of Parameters

Due to our open market assumption, the quantity demanded by and supplied in individual countries at a given price are different. Some countries will fall into the excess supply category (*US*) while other countries will fall into the excess demand category (*MC* and *JK*). At the world market equilibrium, the U.S. corn price will be determined as follows:

$$(19) \qquad P_{US}^{corn} = \overbrace{A^{corn}(\cdot)^{-1}}^{\substack{Tariff \\ Im\,pact}} \times \left(\overbrace{G^{corn}(\cdot)}^{\substack{Income \\ Im\,pact}} + \overbrace{S^{corn}(\cdot)}^{\substack{Structual \\ Adjustment \\ Im\,pact}} + \overbrace{C^{corn}}^{\substack{Cons\tan t \\ Term}} \right),$$

where

$$A^{corn}(\cdot) = \begin{bmatrix} \left(a_{US}^{corn} + d_{US}^{corn}\right) + \left(a_{MC}^{corn} + d_{MC}^{corn}\right)^{US}\alpha_{MC,t}^{corn}\left(1 + {}^{US}t_{MC,t}^{corn}\right) + \left(a_{JK}^{corn} + d_{JK}^{corn}\right)^{US}\alpha_{JK,t}^{corn}\left(1 + {}^{US}t_{JK,t}^{corn}\right) \\ + \left(\varphi_{US}^{corn} - \xi_{US}^{corn}\right)D + \left(\varphi_{MC}^{corn} - \xi_{MC}^{corn}\right)D^{US}\alpha_{MC,t}^{corn}\left(1 + {}^{US}t_{MC,t}^{corn}\right) \end{bmatrix},$$

$$G^{corn}(\cdot) = \left[b_{US}^{corn}Y_{US,t} + b_{MC}^{corn}Y_{MC,t} + b_{JK}^{corn}Y_{JK,t}\right],$$

$$S^{corn}(\cdot) = \left[-\left(\phi_{US}^{corn} - \varsigma_{US}^{corn}\right)D - \left(\phi_{MC}^{corn} - \varsigma_{MC}^{corn}\right)D + \zeta_{US}^{corn}Y_{US,t}D + \zeta_{MC}^{corn}Y_{MC,t}D\right], \text{ and}$$

$$C^{corn} = \left[\left(c_{US}^{corn} + e_{US}^{corn}\right) + \left(c_{MC}^{corn} + e_{MC}^{corn}\right) + \left(c_{JK}^{corn} + e_{JK}^{corn}\right)\right].$$

If NAFTA does not change the initial economic structure of the countries involved, then the U.S. corn price equation can be reduced as follows:

$$(20) \qquad \overline{P}_{US}^{corn} = \overbrace{\overline{A}^{corn}(\cdot)^{-1}}^{\substack{Tariff \\ Im\,pact}} \times \left(\overbrace{G^{corn}(\cdot)}^{\substack{Income \\ Im\,pact}} + \overbrace{C^{corn}}^{\substack{Cons\tan t \\ Term}} \right),$$

where $\overline{A}^{corn}(\cdot) = \left[\left(a_{US}^{corn} + d_{US}^{corn}\right) + \left(a_{MC}^{corn} + d_{MC}^{corn}\right)^{US}\alpha_{MC,t}^{corn}\left(1 + {}^{US}t_{MC,t}^{corn}\right) + \left(a_{JK}^{corn} + d_{JK}^{corn}\right)^{US}\alpha_{JK,t}^{corn}\left(1 + {}^{US}t_{JK,t}^{corn}\right)\right]$.

Therefore, the U.S. corn price effect of NAFTA should be examined in terms of how much of the change is due to structural changes and how much is due to tariff and income change in these countries (the United States, Canada, and Mexico) during the implementation period of NAFTA. As *JK* is a large importer of U.S. corn, Japanese and Korean tariffs on U.S. corn can also affect the U.S. corn price.

Table 2 presents point estimates of parameters used as benchmark values, their confidence intervals at the 95% significance level, and tariffs, shares, and gross national incomes of the economies before and after 1994.

Table 2. Parameter values

Parameters	Benchmark values		Confident Interval at α = 0.05	
	1991 - 1994	1995-2007	min	max
a_{US}^{corn}	-1.825		-2.540	-1.110
a_{MC}^{com}	-0.731		-1.254	-0.209
a_{JK}^{corn}	-0.435		-1.043	0.173
b_{US}^{corn}	2.354		0.858	3.849
b_{MC}^{com}	0.698		-0.743	2.140
b_{JK}^{corn}	3.267		2.029	4.506
c_{US}^{com}	13.521		2.311	24.731
c_{MC}^{corn}	16.591		8.333	24.849
c_{JK}^{corn}	0.000		0.000	0.000
ς_{US}^{corn}	7.652		-3.893	19.197
ξ_{US}^{corn}	1.872		1.128	2.617
ζ_{US}^{corn}	-1.838		-3.364	-0.312
ς_{MC}^{corn}	-1.776		-10.179	6.627
ξ_{MC}^{corn}	0.796		0.197	1.396
ζ_{MC}^{corn}	-0.356		-1.803	1.091
d_{US}^{corn}	4.181		4.101	4.261
d_{MC}^{com}	3.255		3.214	3.297
d_{JK}^{corn}	1.898		1.859	1.936
e_{US}^{corn}	0.000		0.000	0.000
e_{MC}^{corn}	0.000		0.000	0.000
e_{JK}^{corn}	0.000		0.000	0.000
$Ø_{US}^{corn}$	18.679		14.545	22.813
φ_{US}^{corn}	-4.029		-4.942	-3.116
$Ø_{MC}^{corn}$	15.996		10.526	21.467
φ_{MC}^{corn}	-3.023		-4.118	-1.927
${}^{US}\alpha_{MC}^{corn}$	0.092	0.237		
${}^{US}\alpha_{JK}^{corn}$	0.908	0.763		
${}^{US}t_{MC}^{corn}$	0.613	0.307		
${}^{US}t_{JK}^{com}$	2.660	1.330		
Y_{US}	1.579	2.533		
Y_{MC}	0.110	0.178		
Y_{JK}	0.566	0.599		

Table 3 shows the values of impact factors calculated at benchmark values of parameters before and after 1994.

Table 3. Values of Impact Factors on U.S. Corn Price at Benchmark Values of Parameters

	NAFTA		
	1991-1994	1995-2007	Δ
A^{corn} =	7.59	0.91	-6.68
G^{corn} =	5.64	8.04	2.40
S^{corn} =		-33.52	-33.52
C^{corn} =	30.11	30.11	0.00
$^{1)}P_{US}^{corn}$ =	4.71		
$^{2)}P_{US}^{corn}$ =		5.08	0.37

P_{US}^{corn}: log corn price per tonne

$^{1)}P_{US}^{corn}$ = $(G^{corn} + C^{corn})/(A^{corn})$

$^{2)}P_{US}^{corn}$ = $(G^{corn} + C^{corn} + S^{corn})/(A^{corn})$

Table 4 shows the U.S. corn price effect due to NAFTA according to structural adjustment and changes in tariff and gross national income.

Table 4. NAFTA Effect on U.S. Corn Price at Benchmark Values of Parameters

	NAFTA Effect													
	Structure Effect									Tariff and Income Effect				
	Intercept			Price Elasticity			Income Elasticity			Tariff	Income Effect			
	US	*MC*	Sum	*US*	*MC*	Sum	*US*	*MC*	Sum		*US*	*MC*	*JK*	Sum
$^{1)}P_{US}^{corn}$							4.71							
$^{2)}P_{US}^{corn}$	3.26	2.37	0.92	21.17	5.09	21.55	4.33	4.71	4.32	4.75	5.01	4.72	4.72	5.03
ΔP_{US}^{corn}	-1.45	-2.34	-3.79	16.46	0.38	16.84	-0.38	-0.01	-0.39	0.04	0.30	0.01	0.01	0.32
(%)	-30.8	-49.7	-80.5	349.4	8.1	357.5	-8.1	-0.1	-8.2	0.9	6.3	0.1	0.3	6.7

P_{US}^{corn} is log corn price

$^{1)}P_{US}^{corn}$ is log corn price before NAFTA

$^{2)}P_{US}^{corn}$ is log corn price calculated by reflecting NAFTA effect

Intercept Effect

Intercept effects on the U.S. corn price are calculated as:

$$\Delta P_{US}^{corn} = \frac{-\left(\phi_i^{corn} - \varsigma_i^{corn}\right)}{\overline{A}(\cdot)}.$$

Estimated intercept dummy variable coefficients for the U.S. are 7.65 for demand and 18.68 for supply. This implies that U.S. corn demand and supply increased and demand increased less than supply during the implementation period of NAFTA. Therefore, the U.S. corn price decreased by 30.8%. Estimated intercept dummy variable coefficients for *MC* are -1.78 for demand and 15.99 for supply, which reduce the U.S. corn price by 49.7%. The total effect of intercepts decreases the U.S. corn price by 80.5%.

Price Elasticity Effect

Price elasticity effects on U.S. corn price are calculated as:

$$\Delta P_{US}^{corn} = \left\{ \begin{array}{c} \dfrac{\overline{G}(\cdot)+\overline{C}}{\left[\begin{array}{l}\left(a_{US}^{corn}+d_{US}^{corn}\right)+\left(a_{MC}^{corn}+d_{MC}^{corn}\right)^{US}\alpha_{MC,t}^{corn}\left(1+{}^{US}t_{MC,t}^{corn}\right)+\left(a_{JK}^{corn}+d_{JK}^{corn}\right)^{US}\alpha_{JK,t}^{corn}\left(1+{}^{US}t_{JK,t}^{corn}\right) \\ +\left(\varphi_{US}^{corn}-\xi_{US}^{corn}\right)D+\left(\varphi_{MC}^{corn}-\xi_{MC}^{corn}\right)D^{US}\alpha_{MC,t}^{corn}\left(1+{}^{US}t_{MC,t}^{corn}\right)\end{array}\right]} \\ \\ -\dfrac{\overline{G}(\cdot)+\overline{C}}{\left[\left(a_{US}^{corn}+d_{US}^{corn}\right)+\left(a_{MC}^{corn}+d_{MC}^{corn}\right)^{US}\alpha_{MC,t}^{corn}\left(1+{}^{US}t_{MC,t}^{corn}\right)+\left(a_{JK}^{corn}+d_{JK}^{corn}\right)^{US}\alpha_{JK,t}^{corn}\left(1+{}^{US}t_{JK,t}^{corn}\right)\right]} \end{array} \right\}$$

Estimated price interaction variable coefficients for the U.S. are 1.87 for demand and -4.03 for supply, implying that U.S. corn demand and supply became more elastic during the implementation of NAFTA. Therefore, the U.S. corn price increased by 349.4%. The estimated price interaction variable coefficients for *MC* are 0.80 for demand and -3.02 for supply, which increases the U.S. corn price by 8.1%. The total effect of price interaction variables increases the U.S. corn price by 357.5%.

Income Elasticity Effect

Income elasticity effects on the U.S. corn price are calculated as follows:

$$\Delta P_{US}^{corn} = \frac{\zeta_{US}^{corn}\overline{Y}_{US}+\zeta_{MC}^{corn}\overline{Y}_{MC}}{\overline{A}(\cdot)} .$$

Income elasticity coefficients for the *US*, *MC*, and *JK* are positive (2.35, 0.70, and 3.27, respectively). The estimated income interaction variable coefficient for the U.S. is -1.84, implying that the income response to corn consumption becomes less sensitive as income increases. This results in the U.S. corn price decreasing by 8.1%. The estimated income interaction variable coefficient of *MC* is -0.356, which decreases the U.S. corn price by 0.1%. The total effect of the income interaction variables decreases the U.S. corn price by 8.2%. This result implies that there is a limitation in specializing U.S. agriculture into corn production depending on consumer preference because, as shown by the empirical result, income response to corn consumption in U.S. and *MC* decreased rather increased.

Tariff and Income Effect

The tariff effect on the U.S. corn price is calculated as:

$$\Delta P_{US}^{corn} = \left\{ \begin{array}{c} \overline{G}(\cdot) + \overline{C} \\ \left[\left(a_{US}^{corn} + d_{US}^{corn}\right) + \left(a_{MC}^{corn} + d_{MC}^{corn}\right)^{US}\alpha_{MC,t}^{corn}\left(1 + {}^{US}t_{MC2,t}^{corn}\right) + \left(a_{JK}^{corn} + d_{JK}^{corn}\right)^{US}\alpha_{JK,t}^{corn}\left(1 + {}^{US}t_{JK,t}^{corn}\right)\right] \\ \overline{G}(\cdot) + \overline{C} \\ -\left[\left(a_{US}^{corn} + d_{US}^{corn}\right) + \left(a_{MC}^{corn} + d_{MC}^{corn}\right)^{US}\alpha_{MC,t}^{corn}\left(1 + {}^{US}t_{MC1,t}^{corn}\right) + \left(a_{JK}^{corn} + d_{JK}^{corn}\right)^{US}\alpha_{JK,t}^{corn}\left(1 + {}^{US}t_{JK,t}^{corn}\right)\right] \end{array} \right\},$$

where ${}^{US}t_{MC2}^{corn} < {}^{US}t_{MC1}^{corn}$. When the tariff imposed on U.S. corn by *MC* is reduced by 50%, the U.S. corn price increases by 0.9%. As this result indicates, NAFTA's effect on U.S. agriculture will be realized through structural adjustment rather than through the tariff itself.

The income effect on the U.S. corn price is calculated as follows:

$$\Delta P_{US}^{corn} = \left[\frac{G\left(Y_{i2} \mid \overline{b}_i\right)}{\overline{A}(\cdot)}\right] - \left[\frac{G\left(Y_{i1} \mid \overline{b}_i\right)}{\overline{A}(\cdot)}\right].$$

During the implementation of NAFTA, the gross national incomes of *US*, *MC*, and *JK* increase by 60%, 63%, and 6%, respectively.[3] An increase in gross national income increases the U.S. corn price. The total effect of gross national income of the *US*, *MC*, and *JK* increases the U.S. corn price by 6.7%.

Monte Carlo Simulation

This study employed a *Monte Carlo* simulation to cover the range of variation of parameter values at the 95% confidence interval. For example, this study estimates coefficients for intercept, price and income elasticities, intercept dummies, price interaction, and income interaction variables through the use of restricted SUR regression based on equations (17) and (18). We then determined the benchmark values of these parameters and calculated 95% confidence intervals for these benchmark values using their relative *t*-distributions. To draw a realization of these parameters between minimum and maximum values, 5000 random draws of parameters in Table 2 were generated using two-sided power probability distributions over the respective ranges of parameters.[4]

The drawn parameters were then used to calculate the U.S. corn price. Table 5 reports the prices obtained through *Monte Carlo* simulation. This result is consistent with those obtained at benchmark values, except that the prices obtained through *Monte Carlo* simulation are slightly higher than those obtained at benchmark values.

Table 5. *Monte Carlo* Simulation of NAFTA Effect on U.S. Corn Price

	NAFTA Effect													
	Structure Effect									Tariff and Income Effect				
	Intercept			Price Elasticity			Income Elasticity			Tariff	Income Effect			
	US	*MC*	Sum	*US*	*MC*	Sum	*US*	*MC*	Sum		*US*	*MC*	*JK*	Sum
1) P_{US}^{corn}								4.92						
2) P_{US}^{corn}	3.36	2.74	2.15	20.49	5.73	21.51	4.56	4.71	4.56	4.78	5.12	4.72	4.73	5.15
ΔP_{US}^{corn}	-1.35	-1.97	-2.56	15.78	1.02	16.80	-0.15	-0.01	-0.16	0.07	0.41	0.01	0.02	0.44
(%)	-27.4	-40.0	-52.0	320.7	20.7	341.5	-3.0	-0.1	-3.2	1.4	8.3	0.2	0.4	8.9

Conclusions

NAFTA has eliminated thousands of tariff and non-tariff barriers to regional trade amongst North American countries, accelerating market integration. Market integration creates a new economic environment for both consumers and producers in the region, an environment in which U.S. agriculture is faced with both new opportunities and new challenges. Since the new market environment eliminated trade barriers, it would be unwise to ignore the possibility that market structure in the member countries may also have changed through the implementation of NAFTA. Thus, NAFTA's effect on U.S. agriculture should be examined in light of these potential structural changes. In addition, the increase in trade among member countries may have influenced trade between the United States and other non-NAFTA countries. For example, U.S. corn exports to member countries have increased, while U.S. corn exports to major non-NAFTA importers have decreased during the implementation of NAFTA. Therefore, it is important that an economic model reflect these aspects in describing NAFTA's effects on U.S. agriculture.

Using partial equilibrium trade theory, we obtain the equilibrium price of U.S. agricultural products in an open economic scenario. The equilibrium price is a function of five factors which represent the new market circumstance created by NAFTA. We could, on a microeconomic level, mathematically isolate the effect on U.S. agriculture of structural adjustment from the effect of tariff elimination and income growth. In so doing, one finding of this study is that if agricultural product *j* is a normal good in country *i* (while an inferior good in country *k*), market integration leads country *i* to produce more of

agricultural product *j* because the price of agricultural product *j* increases more in country *i* than before market integration took place. In contrast, country *k* produces less of agricultural product *j* because the price of agricultural product *j* decreases more in country *k* than prior to market integration. Therefore, market integration may accelerate specialization in the agricultural sector of each country through consumer preferences in addition to the impact of resource endowments.

To empirically demonstrate these theoretical constructs, we applied the theoretical model to the U.S. corn industry. In doing so, we limited the number of participants to *US*, *MC*, and another major importer (*JK*). Using the restricted statistical model, we estimated benchmark values and 95% confidence intervals for the parameters of the three participants. The results showed that the U.S. corn price is influenced not only by changes in the import tariff and income levels, but also by shifts in and changes in the slope of both the demand and supply curves. The empirical result showed that there is a limitation to the extent to which the United States would specialize in corn production as a sole function of consumer preference because, as shown by the empirical result, the income response to corn consumption in both the U.S. and *MC* markets decreased. Finally, to supplement the limitation of statistical estimation for model parameters, we recalculated U.S. corn prices through *Monte Carlo* simulations. Five thousand random parameter draws were generated using two-sided power probability distributions over the respective ranges of the model parameters. The drawn parameters were then used to recalculate the U.S. corn price. All procedures of simulation are conducted in MATLAB Version 7.8.0(R2009a). This result is consistent with those obtained at benchmark values except that the prices obtained by *Monte Carlo* simulation are slightly higher than those obtained at benchmark values.

Footnotes

1. We classified the world market of agricultural product *j* like this because partial equilibrium theory shows that large and small country effects are different and the United States was a net exporter of corn while Mexico and Canada were net importers of corn during this study's sample period.

2. As shown in previous econometric analyses, it is better to use sample and non-sample information in constructing a statistical model which provides lower unexplained sum of squares by reducing the degrees of freedom. However, there is a risk in obtaining biased estimators if this restriction is not compatible with the sample data.

3. During that period of time, most Asian economies, including Japan and Korea, suffered from economic recession resulting in a decrease in the value of their currencies. We used U.S. dollar values for aggregate national income for each of the economies included in this study.

4. See Vedenov and Wetzstein, p.208

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APPENDIX 1. Excess Supply, Excess Demand, and Weighted Price

1.1 Excess Supply of Large Exporters Group

$$^{MC}ES_K^j = \sum_{k=1}^{K} {}^{MC}\beta_k^j \times ES_k^j$$

$$^{L}ES_K^j = \sum_{k=1}^{K}\sum_{l=1}^{L} {}^{l}\beta_k^j \times ES_k^j$$

$$^{S}ES_K^j = \left(\sum_{k=1}^{K} 1 - \sum_{k=1}^{K} {}^{MC}\beta_k^j - \sum_{k=1}^{K}\sum_{l=1}^{L} {}^{l}\beta_k^j\right) \times ES_k^j \quad ES_k^j = \left(a_k^j + d_k^j\right)P_k^j - b_k^j Y_k - \left(c_k^j + e_k^j\right)$$

$$ES_K^j = {}^{MC}ES_K^j + {}^{L}ES_K^j + {}^{S}ES_K^j = \sum_{k=1}^{K}\left(a_k^j + d_k^j\right)P_k^j - b_k^j Y_k - \left(c_k^j + e_k^j\right)$$

1.2 Excess Supply of Small Exporters Group

$$^{MC}ES_N^j = \sum_{n=1}^{N} {}^{MC}\beta_n^j \times ES_n^j$$

$$^{L}ES_N^j = \sum_{n=1}^{N}\sum_{l=1}^{L} {}^{l}\beta_n^j \times ES_n^j$$

$$^{S}ES_N^j = \left(\sum_{k=1}^{K} 1 - \sum_{n=1}^{N} {}^{MC}\beta_n^j - \sum_{n=1}^{N}\sum_{l=1}^{L} {}^{l}\beta_n^j\right) \times ES_n^i$$

$$ES_n^j = \left(a_n^j + d_n^j\right)P_n^j - b_n^j Y_n - \left(c_n^j + e_n^j\right)$$

$$ES_N^j = {}^{MC}ES_N^j + {}^{L}ES_N^j + {}^{S}ES_N^j = \sum_{n=1}^{N}\left(a_n^j + d_n^j\right)P_n^j - b_n^j Y_n - \left(c_n^j + e_n^j\right)$$

1.3 Excess Demand of Large Importers Group

$$^{US}ED_L^j = \sum_{l=1}^{L} {}^{US}\alpha_l^j \times ED_l^j$$

$$^{K}ED_L^j = \sum_{l=1}^{L}\sum_{k=1}^{K} {}^{k}\alpha_l^j \times ED_l^j$$

$$^{N}ED_L^j = \left(\sum_{l=1}^{L} 1 - \sum_{l=1}^{L} {}^{US}\alpha_l^j - \sum_{l=1}^{L}\sum_{k=1}^{K} {}^{k}\alpha_l^j\right) \times ED_l^i$$

$$ED_l^j = -\left(a_l^j + d_l^j\right)P_l^j + b_l^j Y_l + \left(c_l^j + e_l^j\right)$$

$$ED_L^j = {}^{US}ED_L^j + {}^{K}ED_L^j + {}^{N}ED_L^j = \sum_{l=1}^{L} -\left(a_l^j + d_l^j\right)P_l^j + b_l^j Y_l + \left(c_l^j + e_l^j\right)$$

1.4 Excess Demand of Small Importers Group

$${}^{US}ED_S^j = \sum_{s=1}^{S} {}^{US}\alpha_s^j \times ED_s^j$$

$${}^{K}ED_S^j = \sum_{s=1}^{S}\sum_{k=1}^{K} {}^{k}\alpha_s^j \times ED_s^j$$

$${}^{N}ED_S^j = \left(\sum_{s=1}^{S} 1 - \sum_{l=1}^{L} {}^{US}\alpha_s^j - \sum_{s=1}^{S}\sum_{k=1}^{K} {}^{k}\alpha_s^j\right) \times ED_s^j$$

$$ED_s^j = -\left(a_s^j + d_s^j\right)P_s^j + b_s^j Y_s + \left(c_s^j + e_s^j\right)$$

$$ED_S^j = {}^{US}ED_S^j + {}^{K}ED_S^j + {}^{N}ED_S^j = \sum_{s=1}^{S} -\left(a_s^j + d_s^j\right)P_s^j + b_s^j Y_s + \left(c_s^j + e_s^j\right)$$

1.5 Price in Large Importer's Market, *l*.

$$P_l^j = {}^{US}\alpha_l^j P_{US}^j (1 + {}^{US}t_l^j) + \sum_{k=1}^{K} {}^{k}\alpha_l^j P_k^j (1 + {}^{k}t_l^j) + (1 - {}^{US}\alpha_l^j - \sum_{k=1}^{K} {}^{k}\alpha_l^j)\sum_{n=1}^{N} P_n^j (1 + {}^{n}t_l^j)$$

1.6 Price in Small Importer's Market, *s*.

$$P_s^j = {}^{US}\alpha_s^j P_{US}^j (1 + {}^{US}t_s^j) + \sum_{k=1}^{K} {}^{k}\alpha_s^j P_k^j (1 + {}^{k}t_s^j) + (1 - {}^{US}\alpha_s^j - \sum_{k=1}^{K} {}^{k}\alpha_s^j)\sum_{n=1}^{N} P_n^j (1 + {}^{n}t_s^j)$$

APPENDIX 2. Specific Functional Forms of Impact Factors in Equation (15)

$$A(\cdot)=\begin{bmatrix}\left(a_{US}^{j}+d_{US}^{j}\right)+\left(a_{MC}^{j}+d_{MC}^{j}\right)^{US}\alpha_{MC}^{j}(1+{}^{US}t_{MC}^{j})+\sum_{l=1}^{L}\left(a_{l}^{j}+d_{l}^{j}\right)^{US}\alpha_{l}^{j}(1+{}^{US}t_{l}^{j})\\ +\sum_{s=1}^{S}\left(a_{s}^{j}+d_{s}^{j}\right)^{US}\alpha_{s}^{j}(1+{}^{US}t_{s}^{j})\\ +\left(\varphi_{US}^{j}-\xi_{US}^{j}\right)D+\left(\varphi_{MC}^{j}-\xi_{MC}^{j}\right)D^{US}\alpha_{MC}^{j}(1+{}^{US}t_{MC}^{j})\end{bmatrix}$$

$$K(\cdot)=\begin{bmatrix}-\left(a_{MC}^{j}+d_{MC}^{j}\right)\sum_{k=1}^{K}{}^{k}\alpha_{MC}^{j}P_{k}^{j}(1+{}^{k}t_{MC}^{j})+\sum_{l=1}^{L}-\left(a_{l}^{j}+d_{l}^{j}\right)\sum_{k=1}^{K}{}^{k}\alpha_{l}^{j}P_{k}^{j}(1+{}^{k}t_{l}^{j})\\ +\sum_{s=1}^{S}-\left(a_{s}^{j}+d_{s}^{j}\right)\sum_{k=1}^{K}{}^{k}\alpha_{s}^{j}P_{k}^{j}(1+{}^{k}t_{s}^{j})-\sum_{k=1}^{K}\left(a_{k}^{j}+d_{k}^{j}\right)P_{k}^{j}\end{bmatrix}$$

$$N(\cdot)=-\begin{bmatrix}-\sum_{n=1}^{N}\left(a_{n}^{j}+d_{n}^{j}\right)P_{n}^{j}\\ -\left(a_{MC}^{j}+d_{MC}^{j}\right)(1-{}^{US}\alpha_{MC}^{j}-\sum_{k=1}^{K}{}^{k}\alpha_{MC}^{j})\sum_{n=1}^{N}P_{n}^{j}(1+{}^{n}t_{MC}^{j})\\ +\sum_{l=1}^{L}-\left(a_{l}^{j}+d_{l}^{j}\right)(1-{}^{US}\alpha_{l}^{j}-\sum_{k=1}^{K}{}^{k}\alpha_{l}^{j})\sum_{n=1}^{N}P_{n}^{j}(1+{}^{n}t_{l}^{j})\\ +\sum_{s=1}^{S}-\left(a_{s}^{j}+d_{s}^{j}\right)(1-{}^{US}\alpha_{s}^{j}-\sum_{k=1}^{K}{}^{k}\alpha_{s}^{j})\sum_{n=1}^{N}P_{n}^{j}(1+{}^{n}t_{s}^{j})\end{bmatrix}$$

$$G(\cdot)=b_{US}^{j}Y_{US}+b_{MC}^{j}Y_{MC}+\sum_{l=1}^{L}b_{l}^{j}Y_{l}+\sum_{s=1}^{S}b_{s}^{j}Y_{s}-\sum_{k=1}^{K}b_{k}^{j}Y_{k}-\sum_{n=1}^{N}b_{n}^{j}Y_{n}$$

$$C=\left(c_{US}^{j}+e_{US}^{j}\right)+\left(c_{MC}^{j}+e_{MC}^{j}\right)+\sum_{l=1}^{L}\left(c_{l}^{j}+e_{l}^{j}\right)+\sum_{s=1}^{S}\left(c_{s}^{j}+e_{s}^{j}\right)-\sum_{k=1}^{K}\left(c_{k}^{j}+e_{k}^{j}\right)-\sum_{n=1}^{N}\left(c_{n}^{j}+e_{n}^{j}\right)$$

$$S(\cdot)=\begin{bmatrix}-\left(\varphi_{MC}^{j}-\xi_{MC}^{j}\right)D\sum_{k=1}^{K}{}^{k}\alpha_{MC}^{j}P_{k}^{j}(1+{}^{k}t_{MC}^{j})\\ -\left(\varphi_{MC}^{j}-\xi_{MC}^{j}\right)D(1-{}^{US}\alpha_{MC}^{j}-\sum_{k=1}^{K}{}^{k}\alpha_{MC}^{j})\sum_{n=1}^{N}P_{n}^{j}(1+{}^{n}t_{MC}^{j})\\ +\zeta_{US}^{j}Y_{US}D+\zeta_{MC}^{j}Y_{MC}D\\ -\left(\phi_{US}^{j}-\varsigma_{US}^{j}\right)D-\left(\phi_{MC}^{j}-\varsigma_{MC}^{j}\right)D\end{bmatrix}$$