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Does Exchange Rate Matter to Agricultural Bilateral Trade Between the United States and Canada?

Mina Kim, Guedae Cho, and Won W. Koo

Center for Agricultural Policy and Trade Studies
Department of Agribusiness and Applied Economics
North Dakota State University
Fargo, North Dakota 58105-5636

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Abstract

This study examines the effects of the U.S.-Canada exchange rate on bilateral trade of agricultural goods between the two countries and on U.S. farm income. Special attention is given to agricultural trade between the two countries under the Canada – United States Free Trade Agreement (CUSTA). This study utilizes two time series models: the vector error correction model (VECM) and the vector moving average model (VMA) with quarterly time series data from 1983 to 2000. This study found that exchange rates have a significant impact on U.S. agricultural trade with Canada and that the exchange rate between the two currencies is weakly exogenous in the U.S. agricultural sector, indicating that it is not influenced by U.S. agricultural trade with Canada and U.S. farm income.

Keywords: cointegration, VECM, VMA, exchange rate impacts, weak exogeneity, over-identification, short- and long-run impulse response

Highlights

This study explores the question of how significantly the exchange rates interact with U.S. – Canada bilateral trade and U.S. farm income and evaluates both short- and long-run responses of U.S. agricultural income to changes in bilateral trade and the exchange rate under the Canada – United States Free Trade Agreement (CUSTA).

The study utilizes two time series models: the vector error correction model (VECM) and the vector moving average model (VMA). Quarterly time series data from 1983:IV to 2000:I are used. Variables utilized in this study are the U.S. – Canada exchange rate, U.S. exports to Canada, U.S. imports from Canada, U.S. agricultural prices, and U.S. agricultural income.

It is found that the U.S. – Canada exchange rate has a significant impact on bilateral trade of agricultural products between the two countries. Both U.S. exports to Canada and imports from Canada are significantly affected in the short-run by changes in the exchange rate. In the long-run, however, the impact of the exchange rate on U.S. exports diminishes, while that on U.S. imports remains significant, resulting in a U.S. trade deficit with Canada. This result indicates that the exchange rate asymmetrically affects U.S. trade with Canada.

The exchange rate and U.S. imports from Canada are significant factors causing farm income to change in both the short- and long-run. Exports to Canada also affect U.S. farm income in the short-run but do not have the same impact in the long-run.

The exchange rate is found to be weakly exogenous, implying that it pushes the model away from the long-run steady state position but is not moved by other variables in return. This is mainly because the agricultural economy is less than 3% of the U.S. economy.

CUSTA is found to more favorably impact U.S. imports than exports. In addition, CUSTA contributes to an increase in U.S. farm income, but the size is minimal.

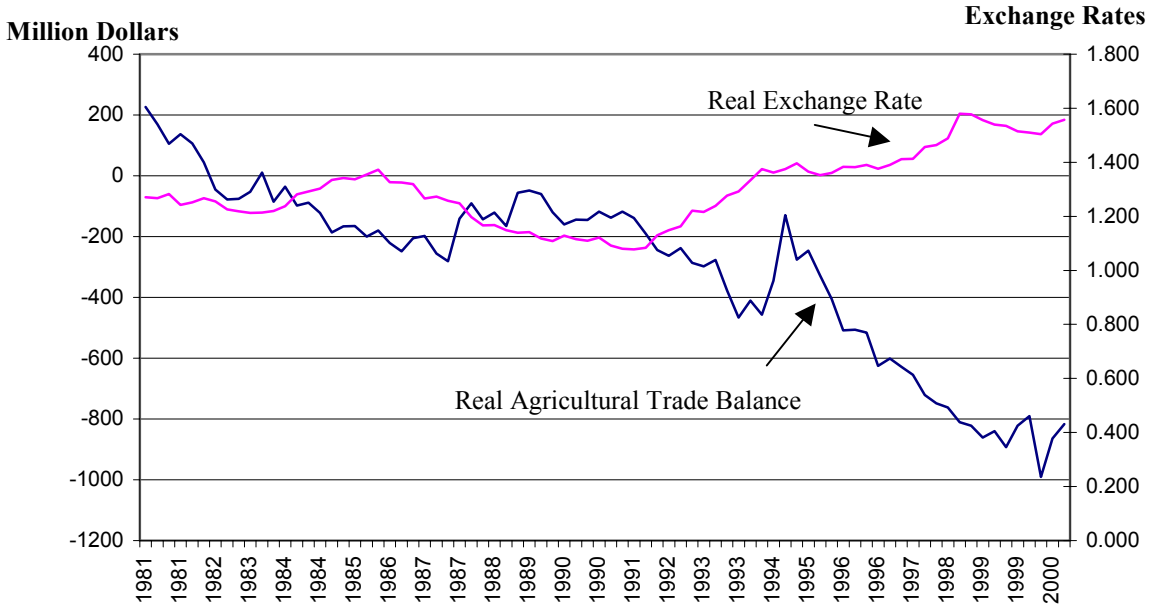
Does Exchange Rate Matter to Agricultural Bilateral Trade Between the United States and Canada?

Mina Kim, Guedae Cho, and Won W. Koo*

I. Introduction

The Canada-United States Free Trade Agreement (CUSTA) has had a profound impact on U.S. agricultural trade with Canada. However, concerns over the bilateral trade of agricultural products between the two countries have emerged, due mainly to the rapid increase in the U.S. agricultural trade deficit with Canada. In the first quarter of 1981, the U.S. agricultural trade balance with Canada was a $226.53 million surplus, but it became a trade deficit beginning in the third quarter of 1982 (Figure 1).[1] The U.S. agricultural trade deficit with Canada gradually increased from $45.57 million in the third quarter of 1982 to $165.00 million in the fourth quarter of 1988. For the post-CUSTA period (1989 - 2000), the U.S. agricultural trade deficit increased dramatically by 1371% and reached a level of $816.88 million by the fourth quarter of 2000.[2]

Figure 1. Agricultural Trade Balance and Exchange Rate



* Assistant Research Professors, and Professor and Director in the Center for Agricultural Policy and Trade Studies, North Dakota State University, Fargo.

[1] Trade balance is defined as the difference between export and import.

[2] Trade balances are seasonally adjusted real values based on 1996 levels.

Between the pre- and post-CUSTA periods, the value of U.S. dollar against the Canadian dollar has changed substantially. Between 1981 and 1988 (the pre-CUSTA period), the real U.S. dollar depreciated 9.6% relative to the Canadian dollar. However, the U.S. dollar appreciated by 36.74% during the post-CUSTA period (1989-2000 in this study). The U.S. dollar appreciation relative to the Canadian dollar makes Canada's products cheaper in the U.S. market, leading to increases in demand for Canadian goods. However, it discourages foreign import demand for U.S. products. In terms of the U.S. agricultural economy during the last two decades, U.S. net farm income followed a path similar to the movements in the U.S. agricultural trade balance with Canada; it rose by 2.35% during the pre-CUSTA period, but declined by 27.55% during the post-CUSTA period[3].

This study explores how significantly the exchange rates interact with U.S. – Canada bilateral trade and U.S. farm income. By examining the degree of involvement among these variables, we can evaluate the impacts of the exchange rate on bilateral trade and the U.S. agricultural income.

Changes in the exchange rate may not be the greatest contributing factor leading to the increased demand for U.S. imports and the decreases in U.S. exports of agricultural products. However, changes in the exchange rate are generally believed to have a considerable impact on international trade. Orden (1999) argues the importance of exchange rate impacts on international trade by stating that exchange rate fluctuations in excess of 40% could cause significant realignment in relative prices that would necessitate several years of economic adjustment.

Although many studies focus on identifying the impact of exchange rate changes on the agricultural sector (Bessler and Babula, 1987; Bradshaw and Orden, 1990; Orden, 1999), little research has been directed toward analyzing the role of the U.S.-Canada exchange rate in bilateral trade between the two countries. Since exchange rates are time-dependent and subject to shocks from other variables, they are expected to interact (behave both exogenously and endogenously) with other variables. However, the exchange rate may behave solely exogenously in the agricultural sector because the size of the U.S. agricultural sector is relatively small compared to the entire economy.

This study also evaluates both short- and long-run responses of U.S. agricultural income to changes in bilateral trade and the exchange rate under CUSTA and examines the implications for the U.S. agricultural sector. It is hypothesized that the U.S. – Canada exchange rate is a significant factor affecting the U.S. agricultural trade balance with Canada and U.S. farm income.

This study uses an enhanced vector error correction model (VECM) analysis with dummy variables and vector moving average representation (VMAR). These methods enable us to verify and confirm that the U.S.-Canada exchange rate is exogenous rather than endogenous in the U.S. agricultural sector, meaning that the exchange rate is more likely to trigger other variables to

[3] The growth rates are calculated based on the data provided by the U.S. Department of Agriculture.

deviate from their long-run steady state position. This study also analyzes an exogenous shock, such as the impact of CUSTA, which is treated as a dummy variable. In addition, the time series models allow us to differentiate short- and long-run impulse responses in the U.S. agricultural economy to a shock given to the exchange rate. These methods helped identify significant, though small, responses.

The paper is organized in five sections. Section II develops time series models that are used for the analysis. The data and important preliminary estimation results are presented in Section III, followed by the empirical results, demonstrating the impact of U.S. – Canada exchange rate shocks on the U.S. agricultural economy in Section IV. Finally, a summary of the principal findings and conclusions of the research is included in Section V.

II. Development of Time Series Models

Variables are cointegrated if they have a long-run steady state relationship (Engel and Granger, 1987). In the short-run, variables may drift apart from one another, but economic forces will bring them back to the long-run equilibrium state. The enhanced VECM is utilized to analyze the long-run relations (long-run steady states) among the exchange rate, the bilateral trade, and the U.S. agricultural economy, which are in the process of adjusting toward an equilibrium when they are pushed away from an equilibrium. The model evaluates the impacts of the exchange rate and CUSTA on the U.S. agricultural sector (Granger-causality relationship). This analysis enables us to distinguish those variables, which are more likely to be forced to deviate from the long-run steady states from those that are more likely to push the others to depart but not be pushed away themselves. The pushing forces causing the model to deviate from the equilibrium are called the common stochastic trends and can be captured through the VMAR.

In addition, we employ the VMAR to assess the long-run impulse response of individual variables to shocks in other individual variables (causality analysis in the long-run) and to confirm the role of the exchange rate in the agricultural sector.[4]

[4] The long-run responses are different from the short-run adjustment to the long-run relation generated in the VECM in terms of the identification of the source of shocks. The long-run response of an individual variable is an average response to certain shocks in a long sample period, so that the source of shock is identified. Meanwhile, the short-run adjustment of individual variables to the long-run equilibrium concerns the speed of adjustment of individual variables when a shock is given, but the shock is collaborated by the rest of variables.

II.1. Vector Error Correction Model (VECM)

To evaluate interdependency among the variables, we use the VECM. The model starts with the vector autoregressive (VAR) model.

Consider a vector, Z_t, consisting of N nonstationary variables of interest, defined by a general polynomial distributed lag process as

$$Z_t = A_1 Z_{t-1} + \cdots + A_k Z_{t-k} + \mu + \Psi D_t + \varepsilon_t, \tag{1}$$

where $t = 1, \cdots, T$, k is a maximum lag length of Z, and ε_t is an independently and identically distributed N dimensional vector with zero mean and variance-covariance matrix, Ω. Z_t is a $p \times 1$ vector of stochastic variables where p is the number of variables: U.S. exports to Canada, U.S. imports from Canada, the exchange rate, U.S. agricultural price, and U.S. agricultural income. D_t is a vector of nonstochastic variables, a CUSTA dummy variable in this study. This type of VAR model has been advocated most notably by Sims (1980) as a way to estimate dynamic relationships among jointly endogenous variables without imposing strong a priori restrictions. The purpose of the cointegration analysis is to distinguish between the long-run steady state positions and the Granger-type causality relationship. Model (1) can be reformulated into a VECM as follows:

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \cdots + \Gamma_{k-1} \Delta Z_{t-k+1} + \Pi Z_{t-k} + \mu + \Psi D_t + \varepsilon_t, \tag{2}$$

where $\Gamma_i = -\left(I - \sum_{i=1}^{k-1} \pi_i \right)$, $\Pi = -\left(I - \sum_{i=1}^{k} A_i \right)$, and I is a $N \times N$ identity matrix. The VECM contains information on both the short-run and long-run adjustments to changes in Z_t via the estimates of Γ_i and Π, respectively. The number of distinct cointegrating vectors (r) that exist among the variables of Z is given by the rank of Π. The hypothesis of cointegration is formulated as a reduced rank of Π to identify the relationship among the variables and is defined as two $p \times r$ matrices, α and β, such that:

$$H_o(r) : \Pi = \alpha\beta', \tag{3}$$

where α represents the speed of adjustment to equilibrium, while β is a matrix of long-run coefficients. The rank of Π is the number of cointegrating relationships among variables, indicating that, although Z_t is nonstationary, the linear combinations of $\beta' Z_t$ are stationary, and hence the rows of β form r distinct cointegrating vectors. Then, Model (2) becomes

$$\Delta Z_t = \sum_{i=1}^{k-1} \Gamma_i \Delta Z_{t-i} + \alpha \left(\sum_{i=1}^{r} \hat{\beta}_i Z_{t-1} \right) + \varepsilon_t. \tag{4}$$

An over-identification problem arises with more than two cointegrating vectors ($r \geq 2$) because any linear combination of, for example, two-cointegration relations, can preserve the

stationarity property (Juselius and MacDonald, 2000 a b). To resolve the over-identification problem, we impose restrictions on each of the cointegrating relations so that we can identify a unique long-run structure. Structural restrictions on each of the cointegrating vectors are given as follows:

$$\beta = \{h_1\varphi_1, \cdots, h_r\varphi_r\},$$

where h_i is a $p \times s_i$ matrix, φ_I is a $s_i \times 1$ vector of unknown parameters (unjustified cointegration coefficients), and s must be smaller than p. If there are two-cointegration relations, then we need to use $\beta = \{h_1\varphi_1, h_2\varphi_2\}$, which specifies a proportionality restriction to induce a unique elasticity in the long-run relations. More details are described in Johansen and Juselius (1994) and Harris (1995).

II.2. Vector Moving Average Representation (VMAR)

In the VAR model (2), ΔZ_t can be decomposed into two parts: the conditional expectation (predictable), $E_{t-1}\{\Delta Z_t | \Delta Z_{t-1}, \beta' Z_{t-1}\}$, and the error term (unpredictable), ε_t, given the information available at t-1. This section analyzes the unpredictable shock, ε_t, to variables, which causes the model to depart from the equilibrium, and the long-run impact of these "unanticipated shocks" on the model.

The VMA is the dual representation of the VAR model in terms of $\alpha_\perp$ and $\beta_\perp$, which are orthogonal to α and β. The VMA model can be obtained by inverting the VAR model as follows:

$$Z_t = C\sum_{i=1}^{t}\varepsilon_i + C^*(L)(\varepsilon_t + \mu) + B, \tag{5}$$

where $C^*(L)$ is an infinite polynomial in the lag operator L, and B is a function of the initial values. $C = \beta_\perp(\alpha_\perp'\Gamma\beta_\perp)^{-1}\alpha_\perp'$ is a long-run impact matrix and has reduced rank $(p-r)$, and $\alpha_\perp$ and $\beta_\perp$ are $p \times (p-r)$ matrices orthogonal to α and β. The matrix C can be decomposed (similar to $\Pi = \alpha\beta'$ in (3)) into two $p \times (p-r)$ matrices:

$$C = \tilde{\beta}_\perp \alpha_\perp' \tag{6}$$

where $\tilde{\beta}_\perp = \beta_\perp(\alpha_\perp'\Gamma\beta_\perp)^{-1}$. $\alpha_\perp'\sum\varepsilon_i$ in the first part of (5) determines the $(p-r)$ common stochastic trends which influence the variable Z_t with the weights $\tilde{\beta}_\perp$. It is possible to calculate the impulse responses of a shock to one variable and observe how they are transmitted within the model over time based on (5).

III. Data and Econometric Procedure

To evaluate the impacts of the value of the U.S. dollar against the Canadian dollar on U.S. trade flows and the domestic agricultural economy, five variables are selected and tested for their relevance to the cointegration model (Table 4 provides the test result explained in a later section). The variables considered in this study are the U.S.-Canada exchange rate, U.S. exports to Canada, U.S. imports from Canada, domestic prices, and national income. It is hypothesized that there are dynamic interactions among the variables. The data are quarterly aggregated measurements of U.S.-Canada trade and the U.S. domestic economy. The data span the fourth quarter of 1983 through the first quarter of 2000, leading to 69 observations for each variable.

The U.S.-Canada real exchange rate (e_t) is obtained from the Economic Research Service (ERS) in the United States Department of Agriculture (USDA). U.S. agricultural exports to Canada and agricultural imports from Canada in U.S. dollar terms are obtained from the ERS and the CANSIM database from Statistics Canada. The price index received by farmers (p_t) as a proxy for domestic price, published by the USDA, was used. Agricultural real GDP, the income variable, is provided by the Bureau of Economic Analysis (BEA) in the U.S. Department of Commerce (USDC). To convert nominal values of the variables into real terms, the GDP deflator is used, which is provided by the BEA.

U.S. domestic agricultural prices and national farm income are selected to analyze the impact of exchange rates on the U.S. agricultural sector. The price variable is included to examine how significantly prices adjust to the impact of the exchange rate (pass-through process) and vice versa, which has been discussed in various studies (Krugman, 1987; Gagnon and Knetter, 1995; Ran and Balvers, 2000). Farm income may be significantly affected by changes in the volume and direction of agricultural trade between the two countries resulting from changes in U.S.-Canada exchange rates. The variables take the logarithm form and are converted into seasonally adjusted real terms with 1996 as the base year.

III.1. Unit Root Tests

Table 1 provides a summary of the unit root test results for the variables. The Augmented Dickey-Fuller test (ADF), the Philips-Perron test (PP) with intercept and trend, and the LR test are conducted.[5] Nonstationarity is the null hypothesis of the ADF and PP tests, and stationarity is the null hypothesis of the LR test. None of variables are stationary, indicating these variables are not mean reverting. Akaike Information Criteria (AIC) and the Schwartz Information Criteria (SIC) are used to determine lag lengths for the unit root test.

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[5] See Johansen and Juselius (1992), Juselius and MacDonald (2000 a b) and Kim and Koo (2002) for the LR test of Unit Root.

Table 1. Unit Root Tests of the Selected Variables

	PP Test	LR test χ^2
	Level $I(0)$	Level $I(0)$
x_t	2.32	22.49
m_t	3.79	22.84
e_t	1.26	20.94
p_t	1.95	3.63
y_t	2.04	12.47

The results of PP unit root test with an intercept and a trend are presented for brevity. Critical value with an intercept and trend is 4.68 at a 95% significance level. For LR test, the critical value at a 95% significance level, χ^2 =7.81.

III.2. Johansen Test

The Johansen cointegration test is conducted to investigate if certain interactions exist among the variables, and the results are reported in Table 2.

Table 2. Johansen Test

	Agricultural Sector		
r	Eigenvalues	Maximum Eigenvalue Test	Trace Test
0	0.4818	**48.65**	**101.17**
1	0.2753	**27.83**	**58.52**
2	0.2231	18.68	28.69
3	0.1264	10.00	10.02
4	0.0002	0.01	0.01

The critical values are provided by Johansen and Juselius (1990).

The maximum eigenvalue and the trace tests are conducted to determine the number of cointegrating relationships among the variables.[6] The null hypothesis is that the number of cointegrating vectors, $\Pi = \alpha\beta'$ in Equation (3), is equal to r for the maximum eigenvalue test, and the number of cointegrating vectors is less than or equal to r for the trace test, where r is a cointegration rank. Both tests suggest two cointegration ranks at the 95 % significance level. Such relations are called long-run equilibria, in which the variables are attracted and converge in the long-run (Granger, 1986). Lag length of four periods in the VAR model are determined by using AIC and SIC, and by following a procedure identifying the shortest lag which eliminates the temporal correlation in residuals as measured by the Box-Ljung Q statistic (Johansen and Juselius, 1990; Franses and Kofman, 1991).

[6] For more details about these tests, see Harris (1995).

III.3. Misspecification Test

Table 3 presents the results of both multivariate and univariate misspecification tests to check the statistical adequacy of the VECM (2). The multivariate LM tests for first order residual autocorrelation are not significant. As presented in Table 3, χ^2 is less than the critical value and the *p*-value equals 0.17, and thus the null hypothesis of no autocorrelation is not rejected. Multivariate normality is, however, clearly violated according to the LM test (*p*-value = 0.02). Since cointegration estimators are more sensitive to deviations from normality due to skewness than to kurtosis, univariate skewness and kurtosis are tested (Juselius and MacDonald, 2000 a). Standard deviations for skewness and kurtosis are 0.2723 and 0.5318, respectively. The ratios of the skewness and kurtosis to their standard deviation are used to construct normality tests of significance based on the Student's *t*-statistic. The ratio for skewness ranges from –1.3900 to 0.9254, which is less than two tailed *t*-critical values at a 95% significance level.

Table 3. Misspecification Tests

Multivariate Tests					
Residual Autocorrelation		$\chi^2(19) = 15.22$	$p-value = 0.17$		
Normality: LM		$\chi^2(1) = 21.52$	$p-value = 0.02$		
Univariate Tests					
	x_t	m_t	e_t	p_t	y_t
Skewness	0.252	0.197	-0.049	0.099	-0.379
Kortosis	3.129	3.049	3.433	5.466	4.039
ARCH(6)	9.370	4.221	2.193	2.119	4.161
R^2	0.453	0.350	0.456	0.374	0.671

Numbers in parentheses are the degree of freedom of χ^2.

However, the ratio for kurtosis extends from 5.7334 to 10.2783, exceeding two tailed *t*-critical values at a 95% significance level. Nonnormality is essentially due to excess kurtosis, and hence not a serious factor in the estimation results.

Both fourth- and sixth-order autoregressive conditional heteroskedasticity tests are conducted, and the null hypothesis of heteroskedasticity is rejected for all the equations. Therefore, no crucial problem caused by heteroskedasticity is expected.

III.4. Long-Run Weak Exclusion Test and Suitability of the VAR model

Long-run weak exclusion of the variables is tested to examine whether any variable can be excluded from the cointegrating space (Johansen and Juselius 1992; Juselius and MacDonald 2000 a), and the test results are presented in Table 4.

Table 4. Test of Long-Run Exclusion and Weak Exogeneity

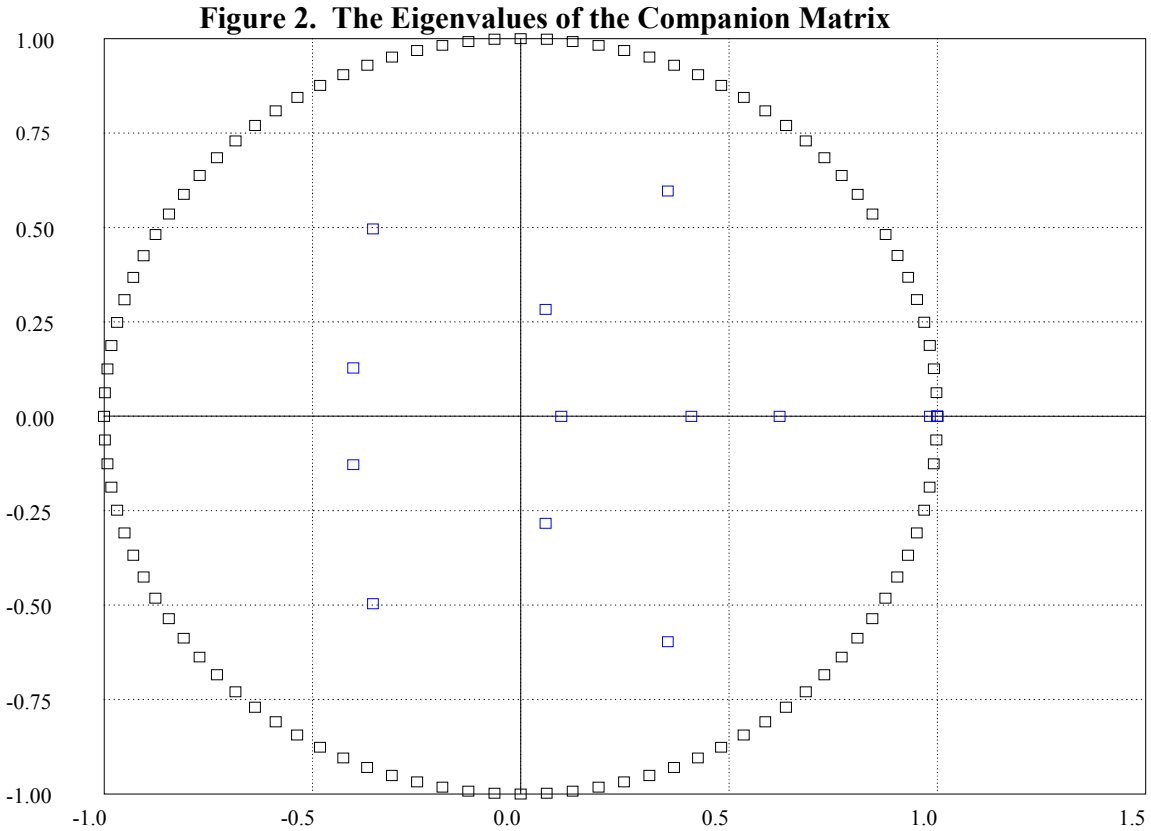
	x_t	m_t	e_t	p_t	y_t	Critical Values
Long-Run Exclusion	10.34	21.14	6.98	8.37	8.98	$\chi^2(2) = 5.99$
Weak Exogeneity	7.63	9.17	**3.40**	**5.25**	8.25	$\chi^2(2) = 5.99$

v denotes the degree of freedom.

The null hypothesis states that the variable, Z_i, does not enter the cointegrating space, where $i = 1, \cdots, p$, by setting up as a zero row in β, i.e. $H_0^{\beta} : \beta_{ij} = 0$, and $j = 1, \cdots, r$. The results of the likelihood ratio test are greater than the χ^2 critical value, and hence the null hypothesis is rejected, indicating that all the variables are statistically relevant to the cointegrating space.

Figure 2 presents the estimated eigenvalues of the companion matrix, which are the reciprocal values of the roots and should be inside of the unit circle or equal to unity under the assumption of the cointegrated VAR model (1) if the cointegrated model is appropriately specified (Johansen and Juselius, 1992). All of the estimated eigenvalues are inside the unit circle, and the two of largest roots are quite close to unity. This implies that the cointegrated VAR model (1) using the variables is robust.

Figure 2. The Eigenvalues of the Companion Matrix



III.5. Test of Long-Run Exogeneity

The test of long-run weak exogeneity of the individual variables in the model investigates the absence of long-run levels of feed-back because of exogenity (Johansen and Juselius, 1992; Juselius and MacDonald, 2000a b). In other words, a weakly exogenous variable is a driving variable in the model, which pushes the models away from adjusting to long-run equilibrium errors but is not pushed by the other variables in the model. The long-run weak exogeneity is formulated as a zero row of α, and is hypothesized $H_{\alpha}^{i} : \alpha_{ij} = 0$, where $j = 1, \cdots, r$, implying the variable Z_i, where $i = 1, \cdots, p$, does not adjust to the equilibrium errors $\beta_i Z_t$, where $i = 1, \cdots, r$.

The test results are presented in Table 4. The results indicate that the exchange rates and the price are weakly exogenous at the 95% significance level, indicating that these variables influence the long-run movements of the other variables, but are not driven by other variables in return. This finding partly confirms the result found in Kim and Koo (2002). The prior study concluded that the trade weighted real exchange rate is weakly exogenous in the U.S. agricultural sector, whereas it acts both endogenously and exogenously in the U.S. industrial economy.

IV. Empirical Results

IV.1. Cointegrating Relationships

Two cointegrating relationships are found by the Johansen test. As mentioned earlier in Section II.1, there is an over-identification problem that arises because of the stationarity caused by the linear combination of the two cointegrating relations. To resolve the problem, we impose restrictions on the cointegrating spaces, β. The hypotheses of joint stationary relationships are constructed to generate a cointegrating space structure.[7] The hypothesis is

$$\mathrm{H}_1 : \ \beta = \{h_1\varphi_1, h_2\varphi_2\} \tag{7}$$

where the design matrices are defined as

$$h_1 = \begin{bmatrix} 1 & 0 & 0 \\ -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \ h_2 = \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}.$$

[7] Individual stationary relationships are recovered by the hypothesis tests, which have the form of $\beta = \{H\phi_1, \varphi_1\}$ for each sector, and the results are abbreviated because there is no direct relation to this study. Refer to Johansen and Juselius (1992, 1994) and Juselius and MacDonald (2000 a b).

The likelihood ratio statistic for testing the over-identifying restrictions, asymptotically χ^2 with 8 degree of freedom, is 4.27 with *p*-values of 0.25.

Table 5 reports the long-run speed adjustment (α) and the long-run coefficients (β).[8] Two stationary relations are confirmed by the estimated α coefficients. The first relation is significant in the exports (x_t), imports (m_t), and income (y_t) equations, whereas the second relation is significant in the imports (m_t) and income (y_t) equations. The findings indicate that the three variables (exports, imports, and income) are correcting the equilibrium error in the economy, implying that joint deviations by the three variables from the steady state position due to a certain shock on the U.S. agricultural sector gradually disappear, and the sector eventually goes back to the equilibria.

Table 5. Structural Representation of the Cointegrating Space

Eigenvectors β			Weights, α		
Variables	$\hat{\beta}_1$	$\hat{\beta}_2$	Equations	$\hat{\alpha}_1$	$\hat{\alpha}_2$
x_t	1.000	-0.438 (0.002)	Δx_t	**0.217** **(3.309)**	0.116 (1.156)
m_t	-1.000	0.000	Δm_t	**0.149** **(2.612)**	**0.164** **(2.282)**
e_t	0.255 (0.911)	0.742 (0.146)	Δe_t	-0.016 (-0.636)	0.088 (0.322)
p_t	0.719 (0.235)	0.000	Δp_t	-0.019 (-0.455)	-0.253 (-1.987)
y_t	-0.926 (0.099)	1.000	Δy_t	**-0.412** **(-3.509)**	**0.249** **(3.381)**
Constant	0.003	0.001			

The numbers in parentheses are standard errors for β, and *t*-static values for others.

Meanwhile, the remaining two variables, the exchange rate and price, do not adjust to both cointegration relations, indicating that they are joint weakly exogenous. A joint test of the weak exogeneity of the two variables generates a $\chi^2(4)$ statistic of 5.73 with an associated *p*-value of 0.22. Hence, permanent shocks to these two variables seem to have a long-run impact on U.S. exports, U.S. imports and income, but the two variables are not pushed by the other variables.

Cointegrating relationships among the variables are explained by the long-run coefficients, βs, in Table 5. The first error correction model, $ecm1$ ($\hat{\beta}_1$), representing the U.S.

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[8] The long-run speed adjustment (α) measures how fast the model goes back to the long-run equilibrium, while the long-run coefficients (β) imply the weights of the variables making the long-run equilibrium.

agricultural trade balance (U.S. exports to Canada – U.S. imports from Canada) relation, is written as

$$ecm1:\ x_t - m_t = -0.255e_t - 0.719p_t + 0.926y_t - 0.003 + error\ . \qquad (8)$$

The interpretation is that the U.S. agricultural trade balance ($x_t - m_t$) with Canada is related to the rest of the variables: the exchange rate, U.S. agricultural price, and U.S. agricultural income. Short-run adjustment to *ecm*1 occurs primarily through the trade balance signifying its importance for the U.S. agricultural economy. The *ecm*1 in equation (8) indicates that U.S. agricultural trade balance increases (U.S. exports increase and imports decrease) as the U.S. dollar depreciates, U.S. agricultural price decreases, and U.S. agricultural income increases.

The second model, *ecm*2 ($\hat{\beta}_2$), representing the U.S. agricultural income relation, is

$$ecm2:\ y_t = 0.438x_t - 0.742e_t - 0.001 + error. \qquad (9)$$

This relationship shows that U.S. agricultural income is related to both U.S. agricultural exports to Canada and the exchange rate. The short-run adjustment to *ecm*2 occurs primarily through the U.S. agricultural income, symptomatic of its importance for the U.S. agricultural economy.

IV.2. Short-Run Dynamics

Two short-run behaviors are analyzed in this section: (1) the short-run response of the selected variables (Granger-type causality); and (2) the short-run adjustment to long-run steady states (the cointegrating relations). Using the identified cointegration relations presented in Table 5, the short-run VAR in error correction model (4) is estimated. Since the exchange rate is found to be weakly exogenous but more significant than the price, the model is re-estimated conditional on exchange rate. By removing insignificant coefficients of the variables based on a likelihood ratio test, a parsimonious model is estimated by using full-information maximum likelihood estimation (FIML) (Harris, 1995), and the results are reported in Table 6.[9]

The coefficient Γ_i in Model (4) denotes the direct short-run responses of dependent variables. The results show that there are significant short-run interactions among the exchange rate, U.S. – Canada bilateral trade, and the U.S. agricultural economy, which can be decomposed into five impacts: exchange rate impact, trade impact, price impact, income effect, and CUSTA impact.

First, in terms of the exchange rate impact, changes in the exchange rates (e_{t-1} and e_{t-2}) have a prevailing effect on both U.S.-Canada trade and U.S. agricultural income, as shown in Table 6. U.S. exports are immediately reduced by 0.108% in *t*-1 and 0.164% in *t*-2 with a 1% increase in the exchange rate, whereas U.S. imports from Canada increase by 0.235% and 0.195%, respectively. Also, there is a negative impact of the U.S.-Canada exchange rate on U.S. agricultural income, but the size of the effect is marginal: 1% appreciation in the

[9] Refer to Harris (1995) for more details about the procedure.

Table 6. Short-Run Adjustment Model

	Δx_{t-1}	Δm_{t-1}	Δm_{t-2}	Δm_{t-3}	Δe_{t-1}	Δe_{t-2}	Δp_{t-2}	Δp_{t-3}	Δy_{t-2}	Δy_{t-3}	CUSTA	*ecm*1	*ecm*2
Δx_t	0	0	0	0	**-0.108 (-3.111)**	**-0.164 (-2.510)**	0	0	**-0.021 (-2.357)**	**-0.002 (-2.043)**	**0.005 (3.736)**	**0.260 (3.682)**	**0.184 (2.932)**
Δm_t	0	0	0	0	**0.235 (2.226)**	**0.195 (2.674)**	**0.119 (2.316)**	**0.013 (2.213)**	**0.030 (2.727)**	**0.020 (2.398)**	**0.014 (3.153)**	**0.148 (2.332)**	**0.144 (2.542)**
Δp_t	0	0	0	0	0	0	0	0	**0.123 (2.977)**	**0.025 (2.412)**	0	0	**0.098 (2.273)**
Δy_t	**0.455 (2.290)**	**-0.154 (-2.153)**	**-0.110 (-2.236)**	**-0.054 (-2.365)**	**-0.011 (-2.028)**	**-0.004 (-2.563)**	**0.290 (2.143)**	**0.062 (2.080)**	0	0	**0.003 (2.101)**	**0.471 (3.926)**	0

Values in parentheses are *t*-statistics.

U.S. dollar at *t*-1 and *t*-2 causes 0.011% and 0.004% decreases in agricultural income, respectively.

Second, bilateral trade has a significant impact on U.S. agricultural income even though the size of the effect is small. A 1% increase in U.S. exports to Canada causes a 0.455% increase in income, while income declines by 0.1% over three time periods due to a 1% increase in U.S. imports from Canada.

As the U.S. dollar appreciates relative to the Canadian dollar, Canadian purchasing power of U.S. products decreases, and American purchasing power of Canada's product increases. Hence, U.S. exports to Canada decrease while U.S. imports from Canada increase, which affects U.S. agricultural income. However, the size of the impact on agricultural income is minimal mainly because the value of U.S. – Canada bilateral agricultural trade is small relative to the size of the overall U.S. agricultural economy.

Third, agricultural price positively affects both U.S. – Canada trade and U.S. agricultural income. As U.S. agricultural products become expensive relative to Canadian agricultural goods, imports from Canada increase. One percent increase in U.S. agricultural price causes U.S. agricultural income to increase by 0.290% and 0.062% over *t*-2 and *t*-3.

With regard to the income effect, both bilateral trade (exports and imports) and price respond to changes in U.S. agricultural income. However, the size of income effect is fairly small because overall U.S. agricultural GDP represents "income gained from the bilateral trade." Specifically, agricultural income is found to be the only variable affecting U.S. agricultural price. Changes in agricultural income affect aggregate demand for goods, which, in turn, influences domestic agricultural price. Other variables do not influence agricultural price mainly because of the weak exogeneity of the price. Since U.S. farm prices are used to represent the price determined by the U.S. – Canada bilateral trade, the price would seem to impinge other variables to depart from the equilibrium rather than be influenced by the bilateral trade.

Lastly, the U.S.-Canada free trade agreement has significant influence on both U.S. agricultural trade with Canada and U.S. agricultural income. The size of the CUSTA impacts on U.S. imports from Canada is bigger than the size of the same impact on U.S. exports to Canada, indicating that the trade agreement performs more favorably to U.S. imports than exports. CUSTA also contributes to an increase in U.S. agricultural income, but its size is not substantial.

The coefficients of both *ecm*1 and *ecm*2 in Table 6 represent the short-run adjustment speed of the dependent variables to the long-run equilibrium position. Both U.S. exports and imports react to both *ecm* terms. U.S. exports adjust to the long-run equilibria by 26.0% (*ecm*1) and 18.4% (*ecm*2), implying it takes more than three quarters (1/0.260 = 3.85 quarters) and more than five quarters (1/0.184 = 5.43 quarters), respectively, to eliminate the disequilibria. U.S. imports adjust 14.8% to the first equilibrium (*ecm*1) and 14.4% to the second equilibrium (*ecm*2) in one quarter, implying that approximately seven quarters are required to return to both equilibria. When a shock is given to the agricultural bilateral trade, it takes more than a year for both U.S. exports and imports to recover to the long-run equilibrium positions.

U.S. agricultural price and income react to *ecm*2 and *ecm*1, respectively (Table 6). U.S. price adjusts to the second *ecm* term (*ecm*2), which represents the U.S. income relation shown in Equation (9), while U.S. income adjusts to the first term (*ecm*1), the U.S. trade balance relation shown in Equation (8). U.S. price adjusts slowly, 9.8% in one quarter, to the long-run U.S. income relation equilibrium. In the meantime, U.S. income adjusts quickly by 47.1% in one quarter to the long-run U.S. trade balance relation. These findings indicate that interaction of the variables with U.S. agricultural income is more active than the variables' interaction with agricultural price.

IV.3. Common Stochastic Trend and Long-Run Impacts of Shocks using VMAR

The results of the common stochastic trends and the long-run impulse response of the variables are discussed in this section and are reported in Table 7.

Common stochastic trends are dual representation of the cointegrating relationship. Since two cointegrating relationships are found in VECM, there are three common stochastic trends which act as forces driving the variables jointly from the equilibria. The common stochastic trends are obtained from the VMAR.

Table 7: Common Stochastic Trends and Impulse Response

	Common Stochastic Trends			Impulse Response				
				Shock				
	$\alpha_{\perp.1}$	$\alpha_{\perp.2}$	$\alpha_{\perp.3}$	x_t	m_t	e_t	p_t	y_t
x_t	0.188	0.001	-0.674	**0.290** **(3.746)**	0.068 (0.576)	-0.471 (-1.203)	-0.121 (-0.686)	**-0.082** **(-2.359)**
m_t	0.364	0.390	-0.283	0.051 (0.628)	**0.369** **(2.963)**	**0.535** **(2.302)**	0.319 (1.723)	**0.084** **(2.321)**
e_t	**1.000**	**1.000**	**0.879**	0.181 (1.344)	0.188 (0.913)	**1.956** **(2.872)**	0.364 (1.188)	-0.027 (-0.442)
p_t	**0.901**	0.231	**1.000**	-0.066 (-0.428)	-0.271 (-1.153)	-1.447 (-1.869)	**0.744** **(2.135)**	-0.103 (-1.506)
y_t	0.158	0.001	-0.120	-0.165 (-0.567)	**-0.873** **(-2.951)**	**-1.549** **(-2.727)**	0.820 (1.533)	**0.392** **(3.004)**

Figures in parentheses are asymptotic *t*-values. Note that no standard errors for the coefficients of $\alpha_{\perp}$ are generated and the coefficients in bold face are only indicative.

Values of the exchange rates and the U.S. agricultural price in each trend are close to one, indicating that they are driving forces (Table 7). The cumulative shocks to the exchange rates (or simply the exchange rate shocks) dominate all of the common stochastic trends, $a_{\perp,1}, a_{\perp,2}$, and $a_{\perp,3}$. In the meantime, the first and third common trends ($a_{\perp,1}$ and $a_{\perp,3}$) are related to shocks to U.S. agricultural price. The results suggest that joint deviation of the variables is mainly driven by the exchange rate and the agricultural price, which is consistent with the results of the long-run weak exogeneity test using VECM.

The results of the long-run impulse response function (C) for a unitary change of $\hat{\varepsilon}_t$ (shock) are reported in the right panel of Table 7. The result should be differentiated from the results of the short-run adjustment (α) to the long-run equilibrium presented in Table 6. The interpretation of long-run impulse response is similar to the short-run response, Γ_i in Table 6. The significance of each entry C_{ij} indicates that the shock, $\hat{\varepsilon}_t$, to one variable, Z_i, exhibits a permanent effect on the other variable, Z_j. The results of long-run impulse response reinforce the results of the short-run response. Significant interaction among bilateral trade, exchange rate, and the U.S. agricultural income is found in the long-run. The interaction fragments into three impacts: exchange rate impact, trade impact, and income impact.[10]

The exchange rate has permanent impacts on U.S. imports and on U.S. agricultural income. For a 1% shock of U.S. dollar appreciation relative to the Canadian dollar, U.S. imports increase by 0.535% and U.S. income decreases by 1.549% (Table 7). Because of the interdependency among major economies, changes in the U.S. dollar value against the Canadian dollar may affect other currencies in the same direction, resulting in the significant changes in U.S. agricultural income.

With regard to the impact of bilateral trade on the U.S. agricultural income, U.S. imports from Canada are a significant factor causing income to change. A 1% shock in U.S. imports causes U.S. agricultural income to decrease by 0.873% over the sample period. On the other hand, U.S. agricultural income has long-run impacts on U.S. – Canada bilateral trade. U.S. exports decrease by 0.082% and U.S. imports increase by 0.084% when the income grows by 1%.

The U.S.-Canada exchange rate is weakly exogenous in the U.S. agricultural economy, indicating that it affects another variable (income) but is not pushed by other variables. Another weakly exogenous variable, U.S. agricultural price would seem to affect both U.S. imports from Canada and U.S. agricultural income, but neither relationship is significant at a 5% significance level. Thus, the price neither has significant long-run impacts on any of the variables at a 5% significance level nor is it affected by any of the variables in the long-run, indicating it is solely adjusting in the system.

V. Conclusion

This study examines the effects of the U.S.-Canada exchange rate on bilateral trade of agricultural goods and on the U.S. farm income. Special attention is given to agricultural trade between the two countries under CUSTA. This study utilizes two time series models: the vector error correction model (VECM) and vector moving average model (VMA) with quarterly time series data from 1983:IV to 2000:I.

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[10] CUSTA dummy variables are excluded because of statistical difficulty in VMAR.

It is found that the U.S. – Canada exchange rate has significant impacts on bilateral trade of agricultural products between the two countries. Both U.S. exports to Canada and imports from Canada are significantly affected in the short-run by changes in the exchange rate. In the long-run, however, the impacts of the exchange rate on U.S. exports diminish, while those on U.S. imports are significant, leading to the U.S. trade deficit with Canada. This result indicates that exchange rate affects asymmetrically U.S. trade with Canada; U.S. imports from Canada are more influenced by the exchange rate changes than are U.S. exports.

The exchange rate and U.S. imports from Canada are significant factors causing the farm income to change in both the short- and long-run. U.S. exports to Canada also affect the U.S. farm income in the short-run but not in the long-run.

The exchange rate is found to be weakly exogenous, implying that it influences the model to drift away from the long-run steady state position but is not moved by other variables. This is mainly because the agricultural economy is less than 3% of the U.S. economy.

CUSTA impacts are found to be more favorable to U.S. imports than exports. In addition, CUSTA contributes to an increase in U.S. farm income, but the size is minimal.

Since the interest of this study is limited to the impact of the U.S. – Canada exchange rate on the U.S. agricultural economy, the response of the Canadian agricultural economy to the exchange rate shock is not analyzed. Further research might analyze the exchange rate impact on the Canadian agricultural economy and compare relative benefits from the free trade agreement for the United States and Canada.

Reference:

Bessler, D. A., and R. A. Babula. "Forecasting Wheat Exports: Do Exchange Rates Matter?" *J. Bus. Econ. Statist.* 5(1987): 397-406.

Bradshaw, R., and D. Orden. "Granger Causality from the Exchange Rate to Agricultural Prices and Export Sales." *Wes. J. Agr. Econ.* 15(1990): 100-110.

Engel, R. F., and C. W. J. Granger. "Cointegration and Error Correction: Representation, Estimation and Testing." *Econometrica* 55(1987): 251-276.

Franses, P., and P. Kofman. "An Empirical Test for Parities between Metal Prices at the LME." *Journal of Futures Markets* 11(1991): 729-736.

Gagnon, J., and M. Knetter. "Markup Adjustment and Exchange Rate Fluctuations: Evidence from Panel Data on Automobile Exports." *Journal of International Money and Finance* 14(1995): 289-310.

Granger, C. W. J. "Developments in the Study of Cointegrated Economic Variables." *Oxford Bulletin of Economics and Statistics* 48(1986): 213-228.

Harris, R. *Using Cointegration Analysis in Econometric Modeling*. New York: Prentice Hall, 1995.

Johansen, S., and K. Juselius. "Identification of the Long-run and the Short-run Structure: An Application to the ISLM Model." *Journal of Econometrics* 63(1994): 7-36.

Johansen, S., and K. Juselius. "Maximum Likelihood Estimation and Inference on Cointegration With Applications to the Demand for Money." *Oxford Bulletin of Economics and Statistics* 52(1990): 169-210.

Johansen, S., and K. Juselius. "Testing Structural Hypotheses in a Multivariate Cointegration Analysis of the PPP and the UIP for UK." *Journal of Econometrics* 53(1992): 211-244.

Juselius, K., and R. MacDonald. "Interest Rate and Price Linkages between the USA and Japan: Evidence from the Post-Bretton Woods Period." *Unpublished Manuscript*,(2000b).

Juselius, K., and R. MacDonald. "International Parities between Germany and the United States: A Joint Modeling Approach." *Unpublished paper*,(2000a).

Kim, M., and W. Koo. "How Differently Agricultural and Industrial Sectors Respond to Exchange Rate Fluctuation?" Agribusiness and Applied Economics Report No. 482. North Dakota State University, 2002.

Krugman, P. "Pricing to Market When the Exchange Rate Changes." *Real Financial Linkages among Open Economies*. Edited by S. Arndt, and J. Richardson. Cambridge, MA: MIT Press, 1987.

Orden, D. "Exchange Rate Effects on Agricultural Trade and Trade Relations." *Policy Harmonization and Adjustment in the North American Agricultural and Food Industry (Proceedings of the Fifth Agricultural and Food Policy Systems Information Workshop.* Winnipeg, MB: Friesen Printers, 1999.

Ran, J., and R. Balvers. "Exchange Rate Shocks and the Speed of Trade Price Adjustment." *Southern Economic Journal* 67(2000): 200-211.

Sims, C. "Macroeconomics and Reality." *Econometrica* 48(1980): 1-49.