



*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

*No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.*

## **Identifying Macroeconomic Linkages to U.S. Agricultural Trade Balance**

**Jungho Baek**  
**Research Assistant Professor**  
**Department of Agribusiness and Applied Economics**  
**North Dakota State University**  
**Email: [jungho.baek@ndsu.edu](mailto:jungho.baek@ndsu.edu)**  
**Phone: (701) 231-7451**  
**Fax: (701) 231-7400**

**Won W. Koo**  
**Professor**  
**Department of Agribusiness and Applied Economics**  
**North Dakota State University**  
**Email: [wkoo@ndsu.edu](mailto:wkoo@ndsu.edu)**  
**Phone: (701) 231-7448**  
**Fax: (701) 231-7400**

*Selected Paper prepared for presentation at the American Agricultural Economics  
Association Annual Meeting, Long Beach, California, July 23-26, 2006*

*Copyright 2006 by Jungho Baek and Won Koo. All rights reserved. Readers may make  
verbatim copies of this document for non-commercial purposes by any means, provided  
that this copyright notice appears on all such copies.*

## **Identifying Macroeconomic Linkages to U.S. Agricultural Trade Balance**

**Abstract:** This study explores the short-run and long-run relationships between the U.S. agricultural trade balance and domestic macroeconomic aggregates and agricultural variables. We use cointegration analysis and a vector error-correction model with quarterly data for 1981-2003. The results show that, in the long-run, the exchange rate, agricultural price, and disposable income are weakly exogenous in the U.S. agricultural sector and have significant effects on the trade balance. The combined short-run dynamic effects of the exchange rate, agricultural price and production, and disposable income jointly explain changes in the trade balance.

**Key Words:** Agricultural trade balance, cointegration analysis, exchange rate, vector error-correction model

## **Introduction**

The United States has been a net exporter of agricultural products for several decades. During the first half of the 1990s, for example, U.S. agricultural exports increased by more than \$20 billion, from \$39 billion in 1990 to \$60 billion in 1996. In contrast, U.S. agricultural imports were fairly stable during the same period, ranging from \$23 billion in 1990 to \$33 billion in 1996. As a result, the agricultural trade surplus reached a record high of \$27 billion in 1996, a 62% increase over the trade surplus in 1990. However, since 1996, this trend has reversed as a result of the rapid growth of U.S. agricultural imports relative to exports. Over the last eight years, for example, U.S. agricultural imports have increased by approximately 50%, from \$36 billion in 1997 to \$54 billion in 2004. Meanwhile, U.S. agricultural exports have fluctuated from a low of \$48 billion in 1999 to a high of \$61 billion in 2004. Accordingly, the agricultural trade surplus has shrunk to \$7 billion in 2004, down 74.1% from 1996 (Figure 1). The U.S. Department of Agriculture (USDA) recently predicted that if these trends continue, the current trade surplus will turn into a deficit by 2010.

The U.S. agricultural trade balance is mainly determined by macroeconomic factors such as exchange rates, prices, national income, and/or personal disposable income. For example, the strong U.S. dollar drives up the relative prices of U.S. agricultural goods and dampens U.S. exports, which results in an increase of the trade deficit. Or, an increase in U.S. income boosts the American purchasing power and leads to an increase of U.S. agricultural imports, thereby decreasing the trade surplus. It is thus important to understand the dynamic interrelationship between macroeconomic factors

and the U.S. agricultural trade balance. The waning U.S. agricultural trade surplus offers an excellent opportunity to explore this relationship.

It has become a standard practice in international economics to analyze the relationships between macroeconomic variables and a country's balance of trade (Bahmani-Oskooee 1985; Bahmani-Oskooee and Ratha 2004; Backus, Kehoe, and Kydland 1994; Boyd, Caporale, and Ron 2001). Within the agricultural trade literature, however, studies have concentrated mostly on the relationships between macroeconomic variables (i.e., money supply and exchange rates) and U.S. agricultural exports and/or prices (Chambers 1981 and 1984; Chambers and Just 1981; Gardner 1981; Batten and Belongia 1986; Bessler and Babula 1987; Bradshaw and Orden 1990; Orden 1999). Limited efforts have been made to directly identify the relationships between macroeconomic variables and the U.S. agricultural trade balance. More recently, Kim, Cho, and Koo (2004) use the vector error-correction model to examine the effect of changes in the exchange rate, income, and price on the U.S. agricultural trade deficit with Canada. They conclude that the exchange rate has a significant impact on the agricultural bilateral trade between the U.S. and Canada.

The objective of this study is to examine the dynamic interaction between the U.S. agricultural trade balance and macroeconomic variables. The empirical focus is on identifying the short-run and long-run relationships between the aggregate U.S. agricultural trade balance and U.S. macroeconomic aggregates and agricultural variables using cointegration analysis and a vector error-correction (VEC) model. This approach is used for three reasons. First, the time-series model is a convenient tool to characterize dynamic interactions when variables used in the model are non-stationary and

cointegrated. Second, the cointegration test is used to find the long-run equilibrium relationships among variables. More specifically, if a linear combination of non-stationary series is stationary, the series are said to be cointegrated and tend to move together in the long-run. The concept of cointegration is thus identical to the existence of a long-run equilibrium to which an economic system converges over time (Harris and Sollis 2003). Finally, the VEC model provides information on the short-run dynamic adjustment to changes in the variables within the model. More specifically, the VEC model uses the cointegrating or long-run relationship as a restriction to provide flexible short-run dynamics. These dynamic interactions can provide an explanation for fluctuations in the U.S. agricultural trade balance. This timely analysis will shed new light on dynamic interrelationships between economic forces and the U.S. agricultural trade balance, which will contribute to the literature of international agricultural trade.

The remainder of the paper is organized as follows. First, we briefly discuss the macro-trade model for the U.S. agricultural sector. Next, we develop the time-series model that is used for the analysis. Then, we present our data and empirical procedure, followed by the empirical results. Finally, we make some concluding remarks.

### **A macro-trade model for the U.S. agricultural sector**

To construct the macro-trade model, we first define the trade balance for agricultural goods as follows:

$$(1) \quad TB = P_x X - P_m M$$

where  $TB$  is the trade balance,  $P_x$  ( $P_m$ ) is the domestic price of exports (imports), and  $X$  ( $M$ ) is the volume of exports (imports). Changes in macroeconomic factors affect the

trade balance through changes in export and import volumes. For this reason, we modify the agricultural trade model developed by Chambers (1981) to represent the interaction between U.S. agricultural exports and imports and domestic macroeconomic factors. U.S. exports of agricultural goods are represented by export price ( $P_x$ ), agricultural production ( $AP$ ), and exchange rate ( $EX$ ). U.S. imports of agricultural goods are a function of import price ( $P_m$ ), agricultural production ( $AP$ ), disposable income ( $DI$ ), and exchange rate ( $EX$ ).

$$(2) \quad X = f_1(P_x, AP, EX)$$

$$\frac{\partial X}{\partial P_x} > 0; \frac{\partial X}{\partial AP} > 0; \frac{\partial X}{\partial EX} < 0$$

$$(3) \quad M = f_2(P_m, AP, DI, EX)$$

$$\frac{\partial M}{\partial P_m} < 0; \frac{\partial M}{\partial AP} < 0; \frac{\partial M}{\partial DI} > 0; \frac{\partial M}{\partial EX} > 0$$

Exports (imports) of agricultural goods are expected to increase (decrease) as export (import) prices increase. An increase in domestic production results in a rise (decrease) in agricultural exports (imports). Depreciation of the U.S. dollar causes an increase (decrease) in exports (imports) of agricultural goods through a decline (rise) in export (import) prices. Finally, an increase in domestic income results in an increase of agricultural imports.

Assuming that in the absence of transportation costs the law of one price holds in equilibrium, which implies  $P_x = P_m = P$ , we substitute equations (2) and (3) into equation (1), which yields the following relationship:

$$(4) \quad TB = g(P, AP, DI, EX)$$

This equation is used to assess the dynamic interaction between the U.S. agricultural trade balance and domestic macroeconomic aggregates and agricultural variables.

### Development of time-series models

To estimate the long-run relationships among variables in equation (4), we use the Johansen maximum likelihood estimation procedure. Following Johansen, the cointegrated vector auto-regression (VAR) model can be defined as follows:

$$(5) \quad \Delta X_t = \alpha + \Gamma_1 \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \varepsilon_t$$

where  $X_t$  is a  $(1 \times 5)$  vector of endogenous variable (i.e.,  $X_t = [TB_t, P_t, EX_t, AP_t, DI_t]$ );

$\Delta$  is the difference operator,  $\Gamma_1, \dots, \Gamma_{k-1}$  are the coefficient matrices of short-term dynamics, and  $\Pi = -(I - \Pi_1 + \dots + \Pi_k)$  are the matrix of long-run coefficients;  $\alpha$  is a vector of constant; and  $\varepsilon_t$  is white noise. Granger's representation theorem asserts that if the coefficient matrix  $\Pi$  has reduced rank  $r < 5$ , then there exist  $(5 \times r)$  matrices of  $\alpha$  and  $\beta$ , each with rank  $r$  such that  $\Pi = \alpha\beta'$  and  $\beta' X_{t-k}$  is stationary (Engle and Granger 1987). Here,  $r$  is the number of cointegrating relations,  $\alpha$  represents the speed of adjustment to equilibrium, and  $\beta'$  is a matrix of long-run coefficients. For five endogenous non-stationary variables, there can be zero to four linearly independent cointegrating relations in the system. The number of cointegration vectors, the rank of  $\Pi$ , in the model is determined by the likelihood ratio test (Johansen 1995).

If all variables in a vector of stochastic process  $X_t$  are cointegrated, an error-correction representation captures the short-run dynamics while restricting the long-run behavior of variables to converge to their cointegrating relationships (Engler and Granger



1987). This is accomplished by estimating an error-correction model in which residuals from the equilibrium cointegrating regression are used as an error-correcting regressor. For this purpose, equation (5) can be reformulated as a short-run dynamic model as follows:

$$(6) \quad \Delta X_t = \alpha + \Gamma_1 \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-k+1} + \alpha(\beta' X_{t-1}) + \varepsilon_t$$

where  $\beta' X_{t-1}$  is a measure of the error or deviation from the equilibrium, which is stationary since the series are cointegrated. Since variables are cointegrated, the VEC model incorporates both short-run and long-run effects. That is, if the long-run equilibrium holds,  $\beta' X_{t-1} = 0$ . During periods of disequilibrium, on the other hand, this term is non-zero and measures the distance of the system from equilibrium during time  $t$ . Thus, an estimate of  $\alpha$  provides information on the speed-of-adjustment, which implies how the variable  $X_t$  changes in response to disequilibrium.

## **Data and econometric procedure**

### *Data*

Because the aim of this study is an investigation of the linkages between the U.S. agricultural trade balance ( $TB_t$ ) and domestic macroeconomic aggregates and agricultural variables, market variables which are thought to be of central importance in influencing the trade balance are selected. These include exchange rate ( $EX_t$ ), U.S. disposable income ( $DI_t$ ), U.S. agricultural price ( $P_t$ ), and U.S. agricultural production ( $AP_t$ ). The data contains 92 quarterly observations for 1981-2003. All variables are in natural logarithms.

The U.S. agricultural trade balance is obtained from the Economic Research Service (ERS) in the U.S. Department of Agriculture (USDA). The exchange rate is a trade-weighted exchange rate index for agricultural trade and is taken from the ERS in the USDA. The personal disposable income is obtained from the Bureau of Economic Analysis (BEA) in the U.S. Department of Commerce (USDC). The wholesale price index for agricultural products is used as a proxy for domestic agricultural price and is provided by the BEA in the USDC. Finally, the U.S. agricultural gross domestic product is used as a proxy for aggregate U.S. agricultural production and is obtained from the BEA in the USDC. The GDP deflator obtained from the BEA is used to derive real disposable income, price, and agricultural GDP (1996=100).

Agricultural trade balance is generally measured as the difference between the U.S. dollar values of agricultural exports (X) and agricultural imports (M). In this study, however, we measure trade balance as the ratio of the exports value to the import value ( $X/M$ ). One of the major reasons for using the ratio is that it is not sensitive to the units of measurement, particularly when it is in a logarithmic form and can be interpreted as the real trade balance (Boyd, Caporale, and Ron 2001). The ratio also can narrow the range of the variable to make it less susceptible to outlying or extreme observations (Wooldridge 2000). In addition, since the trade-weighted exchange rate index represents the dollar value against currencies of all trading countries, an increase (decrease) in the exchange rate index indicates an appreciation (depreciation) of the U.S. dollar.

#### *Econometric Procedure*

The first requirement for the cointegration test is that the selected variables must be non-stationary. The existence of a unit root is thus determined using the augmented Dickey-Fuller (ADF) test (Dickey and Fuller 1979). The results show that the levels of all the variables are non-stationary, while the first differences are stationary (Table 1), indicating that the five variables are non-stationary  $I(1)$  processes. The ADF test statistics are estimated from a model that includes a constant and a trend variable. Akaike Information Criteria (AIC) is used to determine lag lengths for the unit root test.

In addition, before applying the cointegration test, it is necessary to determine the lag length for the VAR model since the Johansen procedure is sensitive to changes in lag structure (Maddala and Kim 1998). The lag length ( $k$ ) for the model is selected based on the likelihood ratio (LR) tests. This method compares the models of different lag lengths to see if there is a significant difference in results (Doornik and Hendry 1994). The sequential pairwise equivalence of models with one through three lags is rejected at the 5% significance level. However, the hypothesis that there is no significant difference between a four- and a five- lag model cannot be rejected. Thus, four lags ( $k=4$ ) are used for our cointegration analysis.

Diagnostic tests on the residuals of each equation and corresponding vector test statistics support the VAR model with four lags as a sufficient description of the data (Table 2). Specifically, serial correlation of the residuals is examined using the  $F$ -form of the Lagrange Multiplier (LM) test, which is valid for systems with lagged dependent variables. The null hypothesis of no serial correlation cannot be rejected at the 5% significance level. Heteroskedasticity is tested using the  $F$ -form of the LM test. The null hypothesis of no heteroskedasticity cannot be rejected at the 5% significance level.

Normality of the residuals is tested with the Doornik-Hansen test. The null hypothesis of normality is rejected for the residuals of domestic price, production, and exchange rate equations and the system at the 5% significance level. However, non-normality of residuals does not bias the results of the cointegration estimation (Gonzalo 1994).

The Johansen cointegration procedure is applied to determine the number of cointegrating vectors. The results show that the trace tests reject the hypothesis of no cointegrating vector ( $r=0$ ), but fail to reject the null of one cointegrating vector ( $r=1$ ) at the 5% significance level (Table 3). This result suggests that there is a stable, long-run equilibrium relationship among the five variables. Test results are presented with an unrestricted constant, allowing for a linear trend and seasonality in the data.

After identifying one cointegrating vector ( $r=1$ ), a parameter in speed-of-adjustment ( $\alpha$ ) is restricted to zero to identify long-run weak exogeneity (Johansen and Juselius 1990). The results show that the exchange rate, disposable income, and domestic price are weakly exogenous at the 5% significance level. In addition, the joint test of the weak exogeneity shows that these three variables are jointly weakly exogenous ( $\chi^2(3) = 5.65$ ,  $p$ -value=0.13). The finding indicates that these three variables are the driving variables in the system and influence the long-run movements of the other variables, but are not affected by the other variables (U.S. agricultural trade balance and agricultural production) in the model (Table 4).

Using the relevant long-run coefficients ( $\beta_1$ ) and normalizing the coefficient of trade balance, the long-run equilibrium relationship among the variables is as follows:

$$(7) \quad TB = -1.24EX + 0.26AP - 0.25P - 0.40DI$$

The corresponding weight matrix is  $-0.63TB - 0.41AP - 0.08EX - 0.09P - 0.02DI$  . These values indicate the speed of adjustment ( $\alpha$ ) of each variable to any shock in the long-run equilibrium.

### **Empirical results**

Equation (7) can be considered a long-run trade balance equation in accordance with Krueger (1983). The result shows that the U.S. agricultural trade balance has a negative long-run relationship with exchange rates. This suggests that an appreciation of the U.S. dollar causes a decrease in U.S. exports and an increase in U.S. imports through the decreased price competitiveness of U.S. goods, thereby decreasing the trade surplus. A positive long-run relationship between the trade balance and aggregate agricultural GDP suggests that an increase in U.S. agricultural production results in an increase in exportable products and import substitutes and improves the trade surplus. A negative long-run relationship between the trade balance and domestic price implies that an increase in the U.S. price causes a decrease in exports and an increase in imports, diminishing the agricultural trade surplus. Finally, the trade balance has a negative long-run relationship with disposable income, indicating that an increase of disposable income leads to a rise in U.S. agricultural imports through the increased purchasing power of U.S. consumers, thereby decreasing the trade surplus.

In order to examine the short-run adjustment to long-run steady states, as well as the short-run dynamics between the trade balance and other macroeconomic variables, the VEC model is estimated with the identified cointegration relationship in equation (7). The procedure used to find this representation follows a general-to-specific approach

(Hendry 1995). Specifically, since the exchange rate, domestic price, and disposable income are found to be jointly weakly exogenous to the system, the VEC model is first estimated conditional on the three variables. By eliminating all the insignificant variables based on an  $F$ -test, the parsimonious VEC (PVEC) model is then estimated using the full-information maximum likelihood estimation (FIML) (Harris and Sollis 2003). The number of lags included in the PVEC model is the same as in the cointegration test. The multivariate diagnostic tests on the estimated model as a system indicate no serious problems with serial correlation, heteroskedasticity, and normality (Table 5). Hence, the model specification does not violate any of the standard assumptions.

The results show that the error-correction terms for trade balance and agricultural production are negatively significant at the 5% level (Table 5). The negatively significant coefficients of the error-correction term ensure the short-run adjustment speed of the dependent variables to the long-run equilibrium. For example, trade balance adjusts 71% to the long-run equilibrium in one quarter. This implies that it takes less than two quarters ( $1/0.71=1.4$  quarters) to correct long-run disequilibria. In addition, real agricultural GDP adjusts 37% to the long-run equilibrium in one quarter, indicating that it takes approximately three quarters to adjust to correct long-run disequilibria.

The coefficients of the lagged variables in the model show the short-run dynamics of the dependent variables (Table 5). Specifically, the trade balance is negatively correlated with lagged trade balance, domestic price and exchange rate, while it is positively correlated with agricultural production. Notice that variables related to the U.S. macroeconomic aggregates such as exchange rate and disposable income are more important than agricultural variables in determining the trade balance in the short-run.

For example, as the exchange rate and disposable income increase by 1%, the trade surplus deteriorates by 0.97% and 1.90%, respectively. On the other hand, the trade surplus decreases by only 0.25% given a 1% increase in the domestic price. In addition, the agricultural production is positively correlated with trade balance and domestic price, but negatively correlated with exchange rate. Finally, the results indicate that there is a significant short-run dynamic effect between trade balance and agricultural production; that is, trade balance is significantly affected by lagged changes in agricultural production, which is also influenced by the lagged changes in trade balance.

Our results indicate that the most significant factor affecting U.S. agricultural trade balance in both the short-run and long-run is the strength of the economy. This is because data on exchange rate and disposable income are generally convenient tools for measuring the strength of the U.S. economy. For example, a stronger economy causes the U.S. dollar to appreciate, effectively driving up U.S. export prices, which leads to a decline in U.S. agricultural exports, resulting in deterioration of the agricultural trade balance. Similarly, an increase in disposable income stimulates U.S. agricultural imports and diminishes the agricultural trade surplus. The findings thus provide some clues for understanding the declining U.S. agricultural trade surplus since the mid-1990s. That is, the strong dollar and rising income due to the remarkable economic expansion in the late 1990s could be a major reason for U.S. agricultural exports to grow slower than U.S. agricultural imports.

## **Summary and conclusions**

This study analyzes the short-run and long-run relationships between U.S. agricultural trade balance, exchange rate, U.S. agricultural price, agricultural production, and disposable income using cointegration analysis and a VEC model. The Johansen's maximum likelihood procedure indicates that there is one stable long-run equilibrium relationship between the trade balance and the selected variables. The cointegrating vector involves the U.S. trade balance and agricultural production, as variables endogenous to the system. The weak exogeneity tests show that exchange rate, agricultural price, and disposable income are jointly weakly exogenous in the U.S. agricultural trade. This implies that these three variables play key roles in determining the long-run movement of U.S. agricultural trade balance and agricultural production, but they are not affected by the other variables. In other words, U.S. agricultural trade balance and production are the adjusting parts, while exchange rate, disposable income, and price are the determining parts of the long-run relationship.

The negatively significant coefficients of the error-correction terms for U.S. trade balance and agricultural production in the VEC model validates the existence of an equilibrium relationship among the variables, which further suggests that these two variables are endogenous to the system. The VEC model shows that the combined short-run dynamic effect of the lagged trade balance, the lagged domestic price, agricultural production, exchange rate, and disposable income jointly explain changes in the U.S. agricultural trade. In addition, the changes in agricultural production are determined jointly by the trade balance, domestic price, and exchange rate in the short-run.



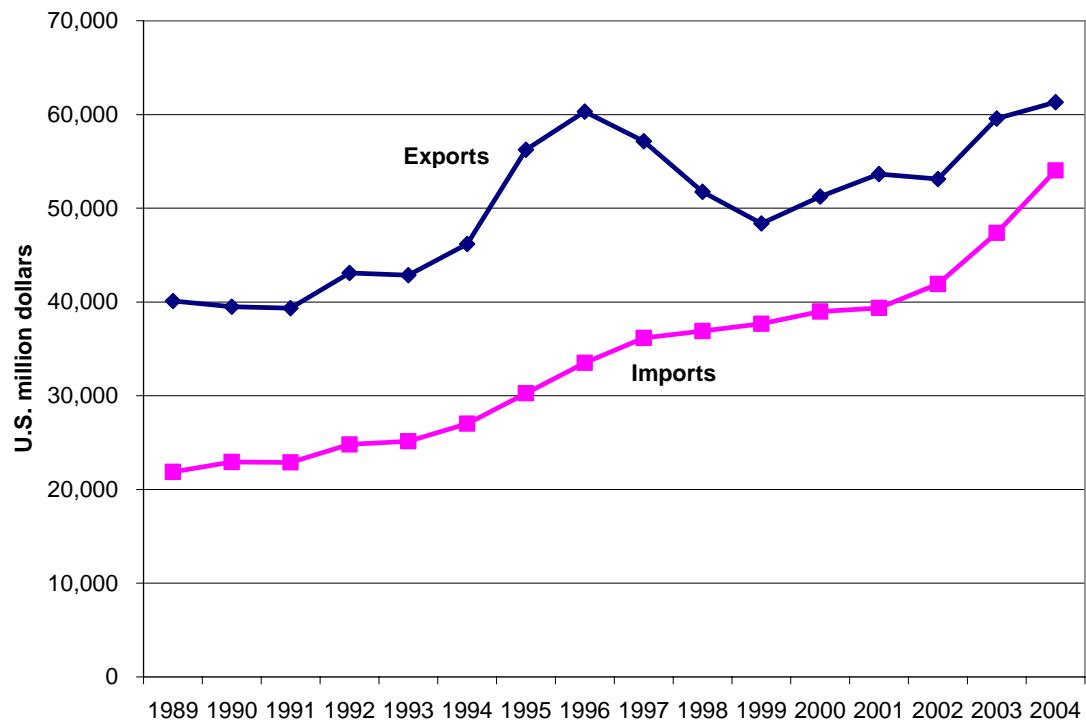


Figure 1. U.S. agricultural exports and imports<sup>a</sup>

<sup>a</sup>Data Source: Economic Research Services (ERS) in the U.S. Department of Agriculture (USDA).

Table 1. Results of Augmented Dickey-Fuller (ADF) unit root test<sup>a</sup>

Variable	Level	First difference	Lag
$TB_t$	-1.81	-8.15*	2
$P_t$	-2.62	-4.03*	2
$EX_t$	-2.61	-3.40*	3
$AP_t$	-3.29	-6.22*	6
$DI_t$	-3.13	-4.73*	2

<sup>a</sup> $TB_t$ ,  $P_t$ ,  $EX_t$ ,  $AP_t$ , and  $DI_t$  represent U.S. agricultural trade balance, U.S. agricultural price, exchange rate, U.S. agricultural production, and U.S. disposable income, respectively. \* denotes rejection of the null hypotheses of a unit root (ADF test) at the 5% level. The 5% critical value for the ADF, including a constant and a trend, is -3.46.

Table 2. Misspecification tests for residuals from Johansen cointegration estimation<sup>a</sup>

	Serial Correlation	Heteroskedasticity	Normality
	$F_{AR}(3,60)$	$F_{ARCH}(4,55)$	$\chi^2(2)$
$\Delta TB_t$	1.48 [0.23]	0.85 [0.50]	0.45 [0.80]
$\Delta P_t$	0.22 [0.88]	0.25 [0.91]	19.34 [0.00]*
$\Delta EX_t$	2.01 [0.12]	0.62 [0.65]	6.74 [0.04]*
$\Delta AP_t$	0.71 [0.55]	0.73 [0.58]	6.26 [0.04]*
$\Delta DI_t$	0.85 [0.47]	0.43 [0.79]	4.86 [0.09]
System	1.24 [0.12]	-	37.64 [0.00]*

<sup>a</sup> $TB_t$ ,  $P_t$ ,  $EX_t$ ,  $AP_t$ , and  $DI_t$  represent U.S. agricultural trade balance, U.S. agricultural price, exchange rate, U.S. agricultural production, and U.S. disposable income, respectively.  $\Delta$  denotes the first differences of the variables. \* indicates that the null hypothesis is rejected at the 5% significance level. Serial correlation of the residuals of individual equations and a whole system was examined using the  $F$ -form of the Lagrange-Multiplier (LM) test, which is valid for systems with lagged independent variables. Heteroskedasticity was tested using the  $F$ -form of the LM test. Normality of the residuals was tested with the Doornik-Hansen test (Doornik and Hendry 1994).

Table 3. Results of Johansen co-integration rank tests<sup>a</sup>

Null hypothesis	Eigenvalue	Trace statistics	5% critical value
$H_0: r = 0$	0.479	109.58*	87.31
$H_0: r \leq 1$	0.241	53.56	62.99
$H_0: r \leq 2$	0.158	29.80	42.44
$H_0: r \leq 3$	0.106	14.97	25.32
$H_0: r \leq 4$	0.059	5.31	12.25

<sup>a</sup>\* denotes rejection of the hypothesis at the 5% significance level.

Table 4. Results of weak exogeneity tests<sup>a</sup>

Variable	Weak exogeneity $H_0 : \alpha_i = 0$
$TB_t$	15.93 [0.00]*
$P_t$	2.79 [0.10]
$EX_t$	2.35 [0.15]
$AP_t$	8.99 [0.00]*
$DI_t$	1.58 [0.21]

<sup>a</sup> $TB_t$ ,  $P_t$ ,  $EX_t$ ,  $AP_t$ , and  $DI_t$  represent U.S. agricultural trade balance, U.S. agricultural price, exchange rate, U.S. agricultural production, and U.S. disposable income, respectively. LR test statistic is based on the  $\chi^2$  distribution, and parentheses are  $p$ -values. \* denotes significance at the 5% level.

Table 5. Results of parsimonious VEC (PVEC) models<sup>a</sup>

Variable	$\Delta TB_t$		$\Delta AP_t$	
	Coefficient	t-values	Coefficient	t-values
$\Delta TB_{t-1}$	-0.35	-3.82*		
$\Delta TB_{t-2}$	-0.39	-4.32*		
$\Delta TB_{t-4}$			0.32	2.62*
$\Delta P_{t-3}$	-0.25	-2.03*	0.51	2.61*
$\Delta EX_t$	-0.97	-3.56*		
$\Delta EX_{t-2}$			-0.99	-2.65*
$\Delta AP_{t-1}$	0.53	5.44*		
$\Delta AP_{t-2}$	0.30	3.61*		
$\Delta AP_{t-3}$	0.35	4.34*		
$\Delta AP_{t-4}$	0.16	2.08*		
$\Delta DI_{t-1}$	-1.90	-2.39*		
Constant	7.01	7.00*	3.69	4.63*
Error-correction	-0.71	-7.00*	-0.37	-4.63*
Multivariate Test	$F_{AR}(20,128)=1.16 [0.30]$ , $F_{ARCH}(144,72)=0.64[0.98]$ , $\chi^2(4)=8.84 [0.07]$			

<sup>a</sup>\* indicates significance at the 5% level. Parentheses in multivariate diagnostic tests are  $p$ -values.

## REFERENCES

- Backus, D.K., P.J. Kehoe and F.E. Kydland. 1994.** Dynamics of the trade balance and the terms of trade: the J-curve? *American Economic Review* 84(1): 84-103.
- Bahmani-Oskooee, M. 1985.** Devaluation and the J-curve: some evidence from LDCs. *Review of Economics and Statistics* 67(3): 500-504.
- Bahmani-Oskooee, M. and A. Ratha. 2004.** Dynamics of the U.S. trade with developing countries. *Journal of Developing Areas* 37(2): 1-11.
- Batten, D.S. and M.T. Belongia. 1986.** Monetary policy, real exchange rates, and U.S. agricultural exports? *American Journal of Agricultural Economics* 68(2): 422-427.
- Bessler, D.A. and R.A. Babula. 1987.** Forecasting wheat exports: do exchange rates matter? *Journal of Business, Economics and Statistics* 5: 397-406.
- Boyd, D., G.M. Caporale and S. Ron. 2001.** Real exchange rate effects on the balance of trade: cointegration and the Marshall-Lerner condition. *International Journal of Finance and Economics* 6 (3): 187-200.
- Bradshaw, R. and D. Orden. 1990.** Granger causality from the exchange rate to agricultural prices and export sales. *Western Journal of Agricultural Economics* 15 (1): 100-110.
- Chambers, R.G. 1984.** Agricultural and financial market interdependence in the short-run. *American Journal of Agricultural Economics* 66(1): 12-24.
- Chambers, R.G. 1981.** Interrelationships between monetary instruments and agricultural commodity trade. *American Journal of Agricultural Economics* 63(5): 934-941.

- Chambers, R.G. and R.E. Just. 1981.** Effects of exchange rate changes of U.S. agriculture: a dynamic analysis. *American Journal of Agricultural Economics* 63(1): 33-46.
- Dickey, D.A. and W.A. Fuller. 1979.** Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association* 74: 427-431.
- Doornik, J. and D. Hendry. 1994.** Interactive econometric modeling of dynamic System (PcFiml 8.0). London: International Thomson Publishing.
- Engle, R. and C.W.J. Granger. 1987.** Cointegration and error-correction: representation, estimation and testing. *Econometrica* 55: 251-276.
- Gardner, B. 1981.** On the power of macroeconomic linkages to explain events in U.S. agriculture. *American Journal of Agricultural Economics* 63 (5): 872-878.
- Gonzalo, J. 1994.** Five alternative methods of estimating long-run equilibrium relationships. *Journal of Econometrics* 60: 203-233.
- Harris, R. and R. Sollis. 2003.** Applied time series modeling and forecasting. Chichester, W. Sussex: John Wiley and Sons.
- Hendry, D. 1995.** Dynamic econometrics. Oxford: Oxford University Press.
- Johansen, S. 1995.** Likelihood-based inference in cointegrated vector autoregressive models. Oxford: Oxford University Press.
- Johansen, S. and K. Juselius. 1990.** Maximum likelihood estimation and inference on cointegration — with application to the demand for money. *Oxford Bulletin of Economics and Statistics* 52(2): 169-210.



**Kim, M., G.D. Cho and W.W. Koo. 2004.** Does the exchange rate matter to agricultural bilateral trade between Canada and the U.S.? *Canadian Journal of Agricultural Economics* 52: 127-145.

**Krueger, A.D. 1983.** Exchange rate determination. Cambridge: Cambridge University Press.

**Maddala, G.S. and I.M. Kim. 1998.** Unit roots, cointegration, and structural change. Cambridge: Cambridge University Press.

**Orden, D. 1999.** Exchange rate effects on agricultural trade and trade relations. The Fifth Agricultural and Food Policy Systems Information Workshop, Acapulco, Mexico.

**Wooldridge, J.M. 2000.** Introductory econometrics: a modern approach. Mason, Ohio: South-Western College Publishing.