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How Differently Do the Agricultural and Industrial Sectors Respond to Exchange Rate Fluctuation?

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Abstract

This study divides the U.S. economy into the agricultural and industrial sectors and compares the degree of involvement of exchange rates in each sector without specifying the rigid assumption of either exogeneity or endogeneity of exchange rates. Both short- and long-run impacts of shocks in the exchange rate are found to be significant. However, the effect of an exchange rate shock on the agricultural sector is larger than that on the industrial sector. This study examines a fundamental question about the role of the exchange rate in the two sectors. The exchange rate is exogenous in the agricultural sector, while being endogenous in the industrial sector.

Keywords: role of exchange rates, endogeneity, exogeneity, over-identification, short- and long-run impulse response.

Highlights

This study empirically examines the impact of exchange rates on U.S. international trade and the domestic economy using quarterly data and the role of the exchange rate in the agricultural and industrial sectors. Three main questions addressed in this study are (1) how significantly U.S. trade and the domestic economy interact with the exchange rate, (2) how differently the two sectors respond to a shock in the exchange rate, and (3) how differently the exchange rate performs in each sector, whether exogenously, endogenously, or both. To answer these questions, an enhanced vector error correction model (VECM) and a vector moving average representation (VMAR) are utilized.

It is found that U.S. international trade and the domestic economy are strongly interconnected in both the agricultural and industrial sectors, but interaction is more vigorous in the industrial sector than in the agricultural sector. Also, the exchange rate is found to have a pervasive effect on U.S. trade and the economy in both sectors. Both the short- and long-run impacts of exchange rate shocks are found to be significant on both sectors' income and price levels.

However, the sensitivity of the two sectors to the exchange rate shocks differs: the effect on the agricultural sector is larger than that on the industrial sector. This is mainly because of the different attributes of the two sectors. In general, U.S. industry trades both consumer goods and raw materials. When the U.S. dollar appreciates relative to foreign currencies, imported raw materials become cheaper and production costs of an output produced from the raw materials decrease, which nullify the initial price effect. However, the agricultural sector suffers a comparative disadvantage when the U.S. dollar appreciates because imported inputs are processed for domestic consumption rather than for export products. This implies that, unlike the industrial sector, imported raw material does not nullify the initial effects of exchange rate appreciation for the agricultural sector.

This study examines a fundamental question about the role of exchange rates in the two sectors and confirms the significance of the exchange rate role. The exchange rate is exogenous in the agricultural sector, implying exchange rate pushes other variables in the system to deviate from an equilibrium. By contrast, it is found that the exchange rate is more likely endogenous in the industrial sector, indicating the exchange rate is influenced by other variables in the system. This contrast can be explained mainly by a difference in size: the agricultural economy is less than 3% the size of the industrial economy, so that the exchange rate is more likely to be affected by other factors in the industrial sector than it would be in the agricultural sector. Thus, these two sectors should be treated differently when developing and analyzing trade policies related to exchange rates.

How Differently Do the Agricultural and Industrial Sectors Respond to Exchange Rate Fluctuation?

MinKyoung Kim and Won W. Koo*

I. Introduction

Although the 1990s have been a relatively stable period in foreign exchange markets, continuous U.S. dollar appreciation raises concerns over the competitiveness of U.S. international trade. The literature on exchange rate economics over the last two decades is vast. Many studies have analyzed the impact of exchange rates on U.S. international trade by assuming their exogeneity in various macroeconomic models (Frankel and Wei, 1993; Rogoff, 1996; Goldberg and Knetter, 1997; Klaassen, 1999). Dellariccia (1999) argued that exchange rates should not be treated as exogenous variables because central banks could systematically try to stabilize the exchange rate for their most important trade partners. In the meantime, several studies focused on endogeneity of exchange rates and examined their determinants using monetary and liquidity models (MacDonald and Taylor, 1994; Grilli and Roubini, 1993; Eichenbaum and Evans, 1995).

Since exchange rates and other macroeconomic variables are time-dependent and each of the variables is, more or less continuously, subject to shocks from other variables, they may exhibit either endogenous, exogenous, or both characteristics. A study may generate biased results if the dynamic and simultaneous properties of the variables are not considered. Therefore, this study analyzes the interaction between exchange rates and important macroeconomic variables without specifying the rigid assumption of either exogeneity or endogeneity of exchange rates, which enables us to understand the degree of the involvement of exchange rates in U.S. trade and the domestic economy, as well as the role of exchange rates in international trade. The degree to which variables are linked, mutually sharing both contemporaneous and noncontemporaneous information, and the consistency of such linkages can provide useful information relevant to macroeconomic policy analysis.

Most studies do not differentiate between economic sectors when examining the importance of exchange rates. The impact of exchange rates on trade may vary between sectors, especially agricultural versus industrial sectors, because of difference in economic scale (the size of the agricultural sector is less than 5% that of the industrial sector) and characteristics of products (agricultural products are relatively homogeneous and non-durable). The agricultural economy has grown 0.1% annually, in contrast to more than 4.0% annual growth in the industrial economy, from 1990 to 2000 (Lum and Moyer, 2001). During this period, both the U.S. agricultural and industrial trade weighted exchange rates appreciated relative to other currencies by more than 6.5% and 5.9%, respectively, in real terms. U.S. dollar appreciation increases American purchasing power of foreign products, resulting in an increased demand for foreign

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products in the United States, but a decrease in demand for U.S. products abroad. This may be one of the contributing factors to the 16.4% decline in the agricultural trade surplus and the increase in the industrial trade deficit of more than 143.8% for the same period. A few studies do compare exchange rate impacts among sectors but are based on the assumption of exchange rate exogeneity (Maskus, 1986; Klein, 1990). Conversely, this study analyzes and compares the impacts of exchange rates between the agricultural and industrial sectors, without preconditions regarding the exogeneity or endogeneity of the variables.

The main purpose of this study is to examine the impacts of exchange rates on the U.S. economy. More specifically, this study empirically examines (1) how significantly the value of the U.S. dollar measured against foreign currencies impacts the U.S. trade balance and the domestic economy; (2) how differently the agricultural and the industrial sectors respond to changes in the U.S. dollar value; and (3) how differently the exchange rate behaves in each sector. It is hypothesized that the exchange rate plays a significant role in U.S. trade flows of agricultural and industrial goods, which may affect the U.S. domestic economy.

This study uses the enhanced vector error correction model (VECM) to avoid over-identification problems occurring in cointegrating space. Also, a relatively new method, vector moving average representation (VMAR), is used to analyze the role of each variable in cointegrating space. These methods enable us to analyze and confirm the different functions of exchange rates between the U.S. agricultural and industrial sectors and allow us to differentiate short- and long-run impulse responses of the two sectors to certain shocks.

The paper is organized into five sections. The next section develops time series models that are used for the analysis. The data and estimation procedures are explained in Section III, followed by the results of exchange rate impacts on the U.S. economy in Section IV. Finally, we include a summary in Section V in which the principal findings and conclusions are discussed.

II. Development of Time Series Models

According to Engel and Granger (1987), variables are cointegrated if they have a long-run steady state relationship. In the short-run, variables may drift apart from one another, but economic forces will bring them back to the long-run equilibrium state. An over-identification problem occurs when there are more than two cointegrating relationship among variables. Hence, the enhanced VECM is utilized to avoid the over-identification problem in cointegration analysis. This model enables us to verify the role of variables by distinguishing between the variables that are more likely to be forced to deviate from the long run steady states and the variables that are more likely to influence the others to deviate 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, which is a dual representation of the vector autoregressive model. Also, there is an advantage to using VMAR in that we can isolate the long-run impulse response of an individual variable to a certain shock. Most of studies select the Granger-type causal relationship analysis, focusing on short-run responses to certain shock. However, it is also important to discover the long-run responses of individual variables to the shocks from other variables.[1] Thus, we employ the VMAR to assess the long-run impulse response (causality analysis in the long-run) and to confirm the role of exchange rate in the agricultural sector.

II.1. Vector Error Correction Model (VECM)

To evaluate interdependency among the variables, we use the VECM. The model starts by using 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 such as

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

where $t = 1, \cdots, T$, *k* is the 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 (U.S. exports to Canada, U.S. imports from Canada, the exchange rate, U.S. agricultural price, and U.S. agricultural income), where *p* is the number of variables. D_t is a vector of nonstochastic variables; in this study it is a CUSTA dummy variable. 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:

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

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. VECM contains information on both the short-run and long-run adjustments to changes in Z_t via the estimates of $\hat{\Gamma}_i$ and $\hat{\Pi}$, 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 and is defined as two $p \times r$ matrices, α and β, such that:

$$H_o(r) : \Pi = \alpha\beta', \qquad (3)$$

where α represents the speed of adjustment to equilibrium, and β is a matrix of long-run coefficients. The rank of Π is the number of cointegrating relationship among variables,

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[1]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 to the shock given to the other individual variables, so that the source of shock is identified, whereas the short-run adjustment of individual variables to the long-run equilibrium is about the speed of adjustment of individual variables when a shock is given, but the shock is collaborated by the rest of variables.

indicating that, although Z_t is nonstationary, the linear combinations of $\beta' Z_t$ are indeed stationary. Hence, the rows of β form r distinct cointegrating vectors. If this is the case, Model (2) becomes

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

An identification problem arises with more than two cointegrating vectors ($r \geq 2$), called over-identification, because any linear combination of, for example, two-cointegration relations, preserves the stationarity property (Juselius and MacDonald, 2000 a; Juselius and MacDonald, 2000 b). To resolve the over-identification problem, we have to impose restrictions on each of cointegrating relations, so that we can identify the 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, and s must be smaller than p.

If there are two-cointegration relations, then we need to utilize $\beta = \{H_1\varphi_1, H_2\varphi_2\}$, which specifies a proportionality restriction to induce a unique elasticity in the long-run relations. More details are provided 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 given the information available at t-1: 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. This section analyzes the unpredictable shock, ε_t, to a variable, 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:

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

where $C^*(L)$ is an infinite polynomial in the lag operator L and B is a function of the initial values. $C = \beta_\perp \left(\alpha_\perp' \Gamma \beta_\perp\right)^{-1} \alpha_\perp'$ 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 Equation (3)) into two $p\times(p-r)$ matrices:

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

where $\tilde{\beta}_\perp = \beta_\perp \left(\alpha'_\perp \Gamma \beta_\perp\right)^{-1}$. $\alpha'_\perp \sum \varepsilon_i$ in the first part of Model (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 resulting from a shock to one variable and how they are transmitted over time within the model based on Model (5).

III. Data and Econometric Procedure

This study is based on a time series analysis to evaluate the impact of U.S. dollar values against foreign currencies on U.S. trade balances and other major variables representing the U.S. domestic economy. The U.S. economy is divided into the agricultural and the industrial sectors under an assumption that the two sectors may react differently to changes in the exchange rate.

The variables considered in this study are the U.S. trade weighted dollar values against foreign currencies, U.S. trade balances, domestic prices, national income, and interest rates. It is hypothesized that there are dynamic interactions among the variables. The U.S. domestic prices and national income are selected to analyze the impacts of exchange rates on the U.S. economy. The price variable is included to examine how significantly prices adjust to the impact of exchange rate changes (pass-through process), which has been discussed in various studies (Krugman, 1987; Gagnon and Knetter, 1995; Ran and Balvers, 2000), and vice versa. The value of the U.S. dollar measured against foreign currencies affects the U.S. trade flow and domestic prices; these variables simultaneously influence U.S. dollar values against foreign currencies. Because changes in price are often associated with subsequent inflation rates, it is interesting to know how closely interest rates are linked with domestic prices.

The data consist of quarterly aggregated measurements spanning the fourth quarter of 1987 through the first quarter of 2000, leading to 50 observations for each variable. The U.S. economy is divided into the agricultural sector and the industrial sector in order to compare the separate impacts of exchange rates on each sector. Five different variables are utilized for each sector. Thus, Z_t in each sector includes (1) trade weighted U.S. dollar value relative to the rest of world, (2) trade balance, (3) domestic price aggregated for the sector, (4) national income, and (5) interest rate. Agricultural trade weighted exchange rates and industrial trade weighted exchange rates (ae_t and ie_t) are used in the respective sectors. The real weighted exchange rates are provided by the Economic Research Service (ERS) in the U.S. Department of Agriculture (USDA). Trade balance variables are defined as the difference between export and import values: agricultural trade balance (surplus) and industrial balance (deficit), represented as ab_t and ib_t, are used for respective sectors. The United States has experienced decreases in the trade surplus in the agricultural sector and increases in the trade deficit in the industrial sector over the sample period. To convert nominal exports and imports into real trade flow, a GDP deflator is used. This deflator is provided by the Bureau of Economic Analysis (BEA) in the U.S. Department of Commerce (USDC).

As a proxy for domestic price, prices received by farmers are used for the agricultural sector (pf_t). The producer price index is used for the industrial sector (ppi_t), which does not contain value-added costs such as transportation costs. Price data are provided by ERS in USDA and the Bureau of Labor Statistics (BLS) in the U.S.Department of Labor (USDL).

For the income variable, net farm income and disposable income are used to represent purchasing power in the agricultural and industrial sectors (nfi_t and dy_t), respectively. Net farm income is provided by the ERS in the USDA and divided by the GDP deflator to convert into real terms. U.S. real disposable income is provided by the BEA in the USDC.

Agricultural prices are largely determined by changes in demand and supply. A rise in aggregate demand is reflected earlier in agricultural prices, which is the commonly used rationale for treating agricultural prices as leading indicators of inflation. Hints of rising inflation often lead to higher nominal interest rates, which have a correlation with real interest rates. Treasury bills are selected because they are important determinants of the prices of critical inputs in general, and widely recognized as representative of the broad economic condition (i_t for both sectors). The selected variables are converted into real terms using 1996 as a base year and converted to logarithms.

III.1. Unit Root Tests

Table 1 provides the summary of the unit root test results for the variables. In addition to the Augmented Dickey-Fuller test (ADF), the Philips-Perron test (PP) with intercept and trend is conducted to avoid possible problems caused by heteroskedasticity in the variables. We fail to reject the null hypothesis of the unit roots for both agricultural and industrial trade balances $(ab_t \text{ and } ib_t)$, implying they are stationary $I(0)$, whereas other variables are $I(1)$ at a 95% significance level. The variables used in the model should be chosen not because of their time-series properties but because of their economic relevance. Since cointegrating analysis requires that only two of the variables are $I(1)$ (Hendry and Juselius, 1999), stationarity of the variables does not affect the cointegration estimation. Lag lengths for the unit root test are determined by both the Akaike Information Criteria (AIC) and the Schwartz Information Criteria (SIC).

Table 1. Unit Root Tests of the Selected Variables

	PP Test		LR(χ^2) Test
	Level $I(0)$	First Difference $I(1)$	Level $I(0)$
Agricultural Sector			
ab_t	**5.5533**	-	24.62
ae_t	2.7433	**21.3260**	25.21
pf_t	2.6845	**11.4170**	22.22
nfi_t	2.9223	**7.7121**	22.74
i_t	0.5326	**6.0868**	17.85
Industrial Sector			
ib_t	**6.3507**	-	27.63
ie_t	2.6444	**19.2743**	27.39
ppi_t	4.9518	**-**	17.90
dy_t	1.3322	**8.1273**	24.28
i_t	0.5326	**6.0868**	22.34

The results of PP unit root test with an intercept and a trend are presented for brevity. Significant test results are given in bold face. Critical value with an intercept and trend is 4.68 at 95% significance level.

In addition to ADF and PP tests for unit roots, the stationarity test in the cointegrating space is conducted based on a LR (χ^2) test due to the low power of distinguishing mean reverting and stationarity (Johansen and Juselius, 1992; Juselius and MacDonald, 2000). The χ^2 test generates results similar to the ADF and PP unit root tests except for ab_t and ib_t. It is hard to compare the two tests directly, but it gives an idea of how sensitive the variables are to various unit root tests. Stationarity acts as the null hypothesis of the Johansen and Juselius stationarity test, while nonstationarity is the null hypothesis of ADF and PP tests. For the cointegration ranks, $r = 2$ in the agricultural sector and $r = 3$ in the industrial sector, the variables are not considered stationary over the sample period, whereas trade balances for both sectors are found stationary by the ADF and PP tests.

III.2. Long-Run Weak Exclusion Test and Suitability of the VAR model

Long-run weak exclusion is tested to examine the relevance of the selected variables to the model. The results are presented in Table 2. The test of long-run exclusion investigates whether any variable can be excluded from the cointegrating space, implying that the variable does not have any long-run relationship with the other variables (Johansen and Juselius, 1992; Juselius and MacDonald, 2000). 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 null hypothesis is rejected, indicating that all the variables are statistically relevant and none of the variables can be excluded for both sectors.

Table 2. Long-Run Exclusion Test

Long-Run Exclusion						
Agricultural Sector	ab_t	ae_t	pf_t	nfi_t	i_t	Critical Value
	13.02	17.79	13.09	6.35	14.81	$\chi^2(3) = 7.81$
Industrial Sector	ib_t	ie_t	ppi_t	dy_t	i_t	Critical Value
	44.82	36.55	40.86	37.74	78.95	

Numbers in parentheses are the degree of freedom of $\chi 2$.

Figures 1 and 2 present the eigenvalues of the companion matrix for each sector, where the matrix is given by

$$A = \begin{bmatrix} A_1 & A_2 & \cdots & A_{k-1} & A_k \\ I_p & 0 & \cdots & 0 & 0 \\ 0 & I_p & \cdots & 0 & 0 \\ \vdots & & \ddots & & \vdots \\ 0 & 0 & \cdots & I_p & 0 \end{bmatrix} \qquad (7)$$

where A_i is defined previously in Model (1) and I_p is the p-dimensional identity matrix. The estimated eigenvalues of A 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 for both sectors are inside of the unit circle, and the two and three largest roots for the respective sectors are quite close to unity, as shown in Figures 1 and 2. Hence, the cointegrated VAR model (1) using the variables can be said to be quite suitable.

Figure 1. Agricultural Sector

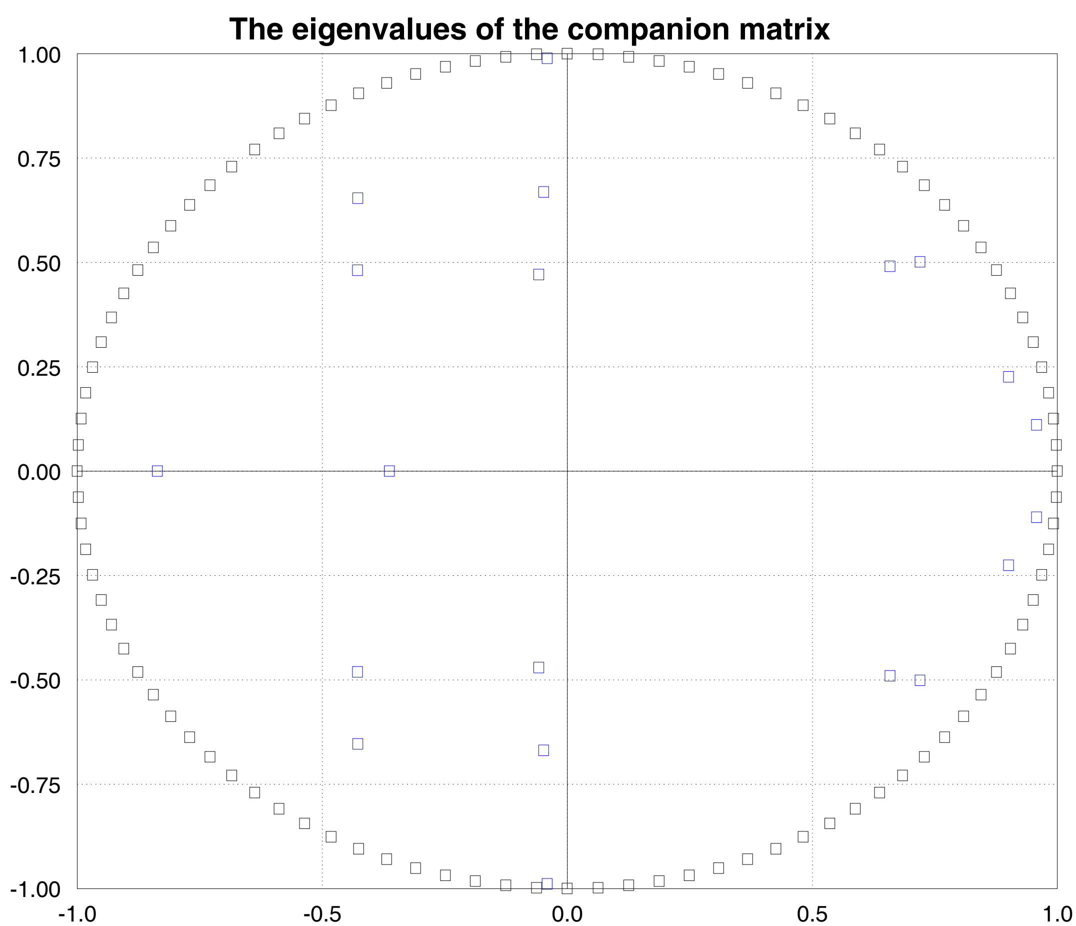
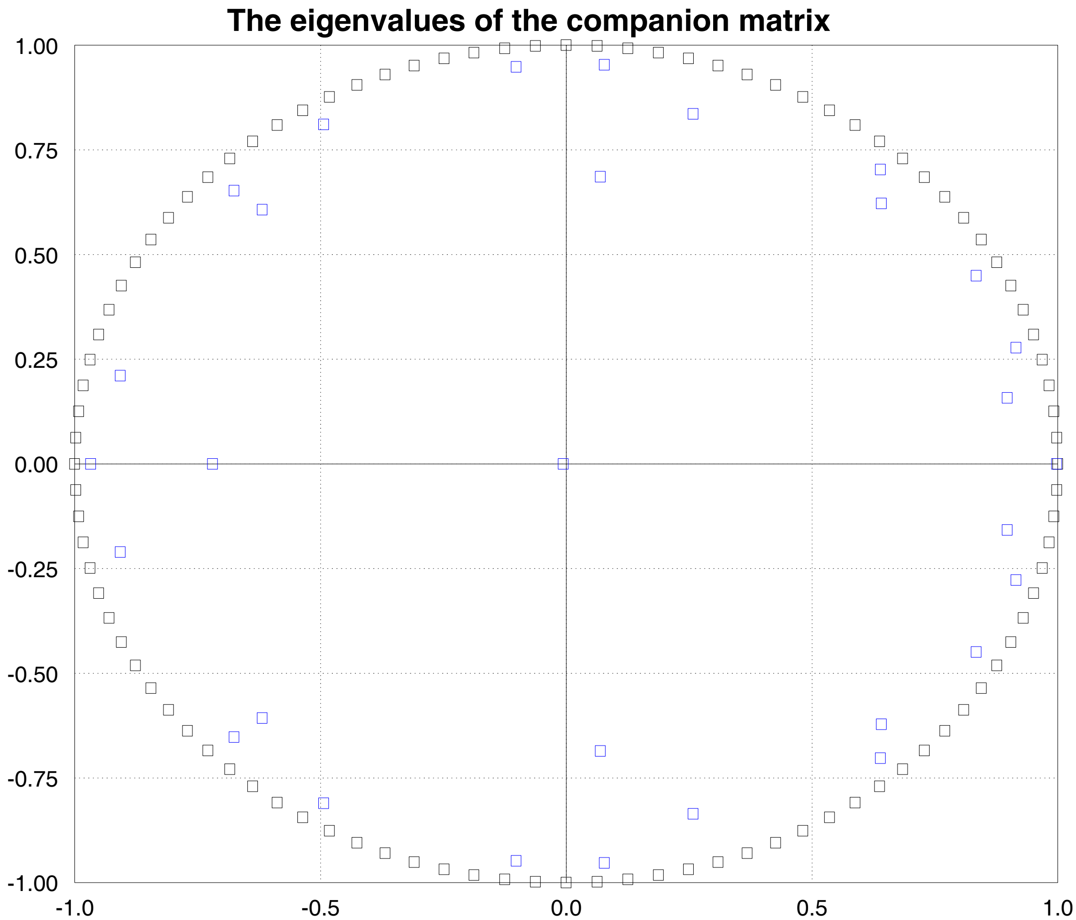


Figure 2. Industrial Sector



III.3. Johansen Test

The results of Johansen test are reported in Table 3. 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 that the number of cointegrating vectors is less than or equal to *r* for the trace test, where *r* is a cointegration rank. Both the maximum eigenvalue and the trace tests suggest two cointegration ranks for the agricultural sector and three cointegration ranks for the industrial sector at a 95% significance level. Such relations are called long-run equilibria, in which the variables are attracted to converge in the long-run (Granger, 1986). Lag lengths of four and six periods in the VAR model are determined for the agricultural and industrial sectors, respectively, 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).

Table 3. Johansen Test

	Agricultural Sector			Industrial Sector		
r	Eigenvalues	Maximum Eigenvalue Test	Trace Test	Eigenvalues	Maximum Eigenvalue Test	Trace Test
0	0.5756	**39.43**	**93.65**	0.9107	**106.27**	**205.78**
1	0.4808	**30.16**	**54.22**	0.6960	**52.39**	**99.51**
2	0.2591	13.80	24.07	0.4903	**29.65**	**47.11**
3	0.1562	7.81	10.27	0.3218	17.09	17.46
4	0.0520	2.46	2.46	0.0084	0.37	0.37

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

III.4. Misspecification Test

Table 4 presents the results of both multivariate and univariate misspecification tests to check the statistical adequacy of the VAR model (2). The multivariate LM tests for first order residual autocorrelation are not significant for either the agricultural or industrial sectors. Multivariate normality is, however, clearly violated for the agricultural sector, whereas it cannot be rejected for the industrial sector. Since cointegration estimators are more sensitive to deviations from normality due to skewness than to kurtosis, univariate skewness and kurtosis for the agricultural sector are tested (Juselius and MacDonald, 2000). Standard deviations for skewness and kurtosis are 0.3578 and 0.6876 for the agricultural sector and 0.3657 and 0.7017 for the industrial sector, 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. Nonnormality is essentially due to excess kurtosis in net farm income and interest rate equations, and hence not a serious factor in the estimation results.

Table 4. Misspecification Tests

Panel A: Agricultural Sector					
Multivariate Tests					
Residual Autocorrelation Normality: LM	$p-value=0.02$				
Univariate Tests					
	ab_t	ae_t	pf_t	nfi_t	i_t
Skewness	0.245	-0.113	-0.040	0.695	-0.528
Kortosis	3.611	3.176	2.303	**5.046**	**5.305**
ARCH(4)	**18.303**	3.472	5.113	6.538	1.936
R^2	0.850	0.428	0.535	0.473	0.598

Panel B: Industrial Sector					
Multivariate Tests					
Residual Autocorrelation Normality: LM	$p-value=0.63$				
Univariate Tests					
	ib_t	ie_t	ppi_t	dy_t	i_t
Skewness	-0.139	0.003	0.091	0.420	-0.394
Kortosis	2.709	2.514	2.960	2.857	2.674
ARCH(6)	5.246	5.372	6.219	3.702	6.029
R^2	0.900	0.687	0.775	0.789	0.831

Fourth and sixth order autoregressive conditional heteroskedasticity tests are conducted for the agricultural sector and the industrial sector, respectively, and the null hypothesis of heteroskedasticity is rejected for all the equations in both sectors, except the agricultural trade balance (Table 4). No crucial problem is expected because cointegration estimates are not very sensitive to an ARCH effect (Rahbek, et al., 1999).

The R^2s , which measure the improvement in explanatory power relative to the random walk hypothesis (i.e., $\Delta Z_t = \varepsilon_t$), indicate that a large proportion of variations in the dependent variable in each equation can be explained by independent variables in the equation for both sectors. Specifically, variations in trade balance equations for both sectors are explained better than those in other equations, whereas variations in exchange rate equations for both sectors are not well-explained relative to those in other equations.

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 feed-back (Johansen and Juselius, 1992; Juselius and MacDonald, 2000). In other words, a weakly exogenous variable is a driving force 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 as $H_\alpha^i : \alpha_{ij} = 0$, 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 5. The results indicate that agricultural weighted exchange rates and net farm income are weakly exogenous in the agricultural sector, while interest rates appear to be weakly exogenous in the industrial sector. Hence, these variables influence the long-run movements of the other variables in each sector, but are not driven by other variables in return.

Table 5. Test of Long-Run Weak Exogeneity

Agricultural Sector	ab_t	ae_t	pf_t	nfi_t	i_t	$\chi^2(3)=7.81$
	25.14	**2.23**	11.05	**2.15**	9.59	
Industrial Sector	ib_t	ie_t	ppi_t	dy_t	i_t	
	14.40	11.96	22.83	20.74	**5.38**	

v denotes the degree of freedom.

The exchange rate is the moving force of the model in the agricultural sector, but it is influenced by other variables in the industrial sector. Moreover, interest rate is not a driving factor in the agricultural sector, whereas it pushes the model from equilibrium in the industrial sector.

IV. Empirical Results

Based on the Johansen test results, two and three stationary relationships are found in each sector. Because of an over-identification problem, some restrictions are put on cointegrating space. To generate economically interpretable coefficients in the cointegrating space structure, the hypotheses of joint stationary relationships are constructed.[2] The hypotheses are

$$\mathrm{H}_a: \ \beta = \{h_1\varphi_1, h_2\varphi_2\} \tag{8}$$

$$\mathrm{H}_i: \ \beta = \{h_3\varphi_3, h_4\varphi_4, h_5\varphi_5\}, \tag{9}$$

where H_a and H_i are hypotheses for the agricultural and industrial sectors, respectively, and the design matrices are defined as

$$h_3 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 1 & 0 \\ 0 & -1 \\ -1 & 0 \end{bmatrix}, \ h_4 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 0 & -1 \\ 0 & 0 \\ -1 & 0 \end{bmatrix}, \ h_5 = \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 1 \\ -1 & 0 \\ 0 & 0 \end{bmatrix} \ h_1 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \ h_2 = \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 0 \\ 0 & 0 \end{bmatrix},$$

(Johansen and Juselius, 1994; Johansen and Juselius, 1992; Juselius and MacDonald, 2000b).

The likelihood ratio statistics for testing the overidentifying restrictions, asymptotically χ^2 with 8 and 12 degree of freedom for each sector, are 1.03 and 3.84, respectively. Both structures are clearly accepted with *p*-values of 0.42 and 0.75, respectively.

IV.1. Cointegrating Relationship

Table 6 reports the long-run speed adjustment (α) and the long-run coefficients (β)[3]. For the agricultural sector, two stationary relations are confirmed by the estimated α coefficients in panel A of Table 6. The price (pf_t) and interest rate (i_t) equations are significant in both

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[2]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 of no direct relation to this study. Refer to Johansen and Juselius (1992, 1994) and Juselius and MacDonald (2000b).

[3]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.

Table 6. Structural Representation of the Cointegrating Space

Panel A: Agricultural Sector					
Eigenvectors (β)			Weights (α)		
Variables			Equations		
ab_t	1.000	0.000 (0.000)	ab_t	-3.528 (-1.725)	**-2.884 (-2.987)**
ae_t	0.098 (0.009)	1.554 (0.095)	ae_t	0.001 (0.050)	0.001 (0.023)
pf_t	0.001	1.000	pf_t	**0.661 (2.526)**	**-0.442 (-3.579)**
nfi_t	0.000	0.000	nfi_t	0.000 (0.000)	0.000 (0.000)
i_t	0.045 (0.007)	0.001	i_t	**-2.756 (-3.671)**	**1.052 (2.967)**
Constant	0.002	0.003			

Panel B: Industrial Sector							
Eigenvectors (β)				Weights (α)			
Variables				Equations			
$\boldsymbol{ib_t}$	**-0.341 (0.016)**	**-0.345 (0.012)**	**1.000 (0.000)**	$\Delta\, \boldsymbol{ib_t}$	**-0.713 (-2.238)**	0.476 (1.521)	-0.135 (-1.542)
ie_t	0.090	1.000	-0.575 (0.071)	$\Delta\, ie_t$	**0.294 (3.258)**	**-0.377 (-4.256)**	**0.053 (2.741)**
ppi_t	1.000	0.118 (0.012)	1.000	ppi_t	-0.098 (-1.792)	**0.137 (2.544)**	**0.061 (4.074)**
dy_t	-0.241 (0.016)	0.000	-0.575 (0.071)	dy_t	0.045 (1.486)	0.013 (0.427)	0.005 (0.585)
i_t	1.000	-1.000	0.003 (0.002)	i_t	0.002 (0.011)	0.000 (0.000)	0.003 (0.001)
Constant	0.004	0.004	0.005				

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

relations, while the agricultural trade balance (ab_t) is significant in the second relation.[4] These variables correct for equilibrium error in the agricultural sector, implying that joint deviations of the three variables from the steady state position due to a certain shock on the agricultural sector disappear, and the sector eventually goes back to the equilibria.

[4]The first relation in the price equation for the agricultural sector is hardly significant when a Dickey-Fuller distribution is used.

Meanwhile, agricultural weighted exchange rate and net farm income do not adjust to both cointegration relations, consistent with the weak exogeneity test result in Table 5. A joint test of the weak exogeneity of the two variables generates a $\chi^2(4)$ statistic of 5.43 with an associated *p*-value of 0.25. Hence, permanent shocks to these two variables seem to have a long-run impact on the agricultural trade balance, the price, and the interest rate, but the two variables are not pushed by them.

Cointegrating relationships are explained by the long-run coefficient (β). The first error correction model (*ecm*1) represents the U.S. agricultural trade balance, which is related to the exchange rate, price, and interest rate.[5]

$$ecm1: \; ab_t = -0.098ae_t - 0.001pf_t - 0.045i_t - 0.002 \,. \tag{10}$$

The second error correction model (*ecm*2) shows U.S. agricultural price as a function of the agricultural exchange rate and interest rate.

$$ecm2: \; pf_t = -1.554ae_t - 0.001i_t - 0.003 \tag{11}$$

Short-run adjustment to *ecm*1 and *ecm*2 occurs primarily through the trade balance and price, respectively, indicating the importance of these variables for the U.S. agricultural economy.

For the industrial sector, three stationary relations are supported by the estimated α coefficients as presented in panel B of Table 6. Interestingly, the industrial weighted exchange rate (ie_t) adjusts to all the steady-state relations, which reflects the distinct role of the exchange rate in the industrial sector. That is, the exchange rate is a driving force in the agricultural sector, pushing away the other variables from the steady-state relationship, whereas it is a derived factor in the industrial sector, deviating from and adjusting to the equilibrium position in the long-run. Results are found similar to those in the agricultural sector: industrial trade balance and price equations contribute to the steady-state position. Industrial trade balance (ib_t) adjusts to the first relation, but no longer adjusts to the second and third relations. The second and third relations are significant in the price (ppi_t) and the exchange rate (ie_t) equations.

The interest rate does not adjust to the cointegrating relation, which is consistent with weak exogeneity result in panel B of Table 5. Error correcting relations are as follows:

$$ecm1: \; ppi_t = 0.341ib_t - 0.090ie_t - i_t + 0.241dy_t - 0.004 \tag{12}$$

$$ecm2: \; (ie_t - i_t) = 0.345ib_t - 0.118ppi_t - 0.004 \tag{13}$$

$$ecm3: \; ib_t = 0.575ie_t + ppi_t + 0.575dy_t - 0.003i_t - 0.005 \,. \tag{14}$$

The *ecm*1 and *ecm*3 relations imply that U.S. industrial price and trade balance for the respective models would be satisfied with a stationary relation if a linear combination of the rest of the

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[5]Note that the estimates of the freely estimated β coefficients and their asymptotic *t*-values indicate that all of them are strongly significant and, hence, that the suggested structure is also empirically identified. Refer to Johansen and Juselius (1994).

variables in each model was stationary. Meanwhile, *ecm*2 represents the exchange rate and interest spread and suggests the spread would be stationary if a linear combination of the trade balance and price was stationary.

IV.2. Short-Run Dynamics

Two short-run behaviors are analyzed in this section: first, direct short-run effects which are decomposed into (1) the contemporaneous interaction among variables and (2) the temporary dynamic effects (the short-run adjustment to the lagged variables) and second the short-run adjustment to long-run steady-states (the cointegrating relations). Using the identified cointegration relations presented in Table 6, the short-run VAR in error correction model, a parsimonious representation of restricted model (4), is estimated. Since the agricultural weighted exchange rate and the interest rate are found to be weakly exogenous in the agricultural and the industrial sectors, respectively, the model in each sector is re-estimated conditional on these two variables. By removing insignificant coefficients of the variables based on a likelihood ratio test, the parsimonious models are estimated by using full-information maximum likelihood estimation (FIML), and the results are reported in Tables 7.1 and 7.2.[6]

For the agricultural sector (Table 7.1), the coefficient, Γ_i in the model (4), denotes the direct short-run responses of dependent variables to shocks in exchange rates, price, and trade balance. First, changes in the agricultural weighted exchange rate (ae_t, ae_{t-1}, and ae_{t-2}) generate significant detrimental effect on both agricultural trade balance (surplus) and agricultural income. Agricultural trade balance is immediately reduced by 1.944% due to a 1% increase in the exchange rate (ae_t). The exchange rate impact remains over two quarters, and ab_t declines by 1.164% and 0.765% due to a 1% increase in the exchange rate at t-1 and t-2, respectively. Also, 1% appreciation in the U.S. dollar at t-1 and t-2 causes 0.075% and 0.023% decreases in agricultural income, respectively.

Second, agricultural price positively affects agricultural income. In each lag, the income coefficient to a shock in the price is larger than for the exchange rate, implying the farm income reacts to shocks in exchange rates slower than to those in prices.

Third, agricultural trade generates an affirmative effect on the U.S. agricultural economy: 1% increases in the agricultural trade surplus in t and t-1 cause agricultural price and income to increase by 0.062% and 0.203%, respectively. These results indicate that, as the U.S. dollar value appreciates relative to foreign currencies, U.S. agricultural exports decrease and imports increase, causing immediate decreases in agricultural prices and income.

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

Table 7.1: Short-Run Adjustment Model: Agricultural Sector

	Γ_i							α	
	Δab_t	Δab_{t-1}	Δae_t	Δae_{t-1}	Δae_{t-2}	Δpf_{t-1}	Δpf_{t-2}	ecm_{t-1}	ecm_{t-2}
Δab_t	0	0	-1.944 (-5.341)	-1.164 (-2.535)	-0.765 (-2.677)	0	0	0	0.279 (2.900)
Δpf_t	0.062 (2.420)	0	0	0	0	0	0	0.250 (3.547)	-0.183 (-3.470)
Δnf_i	0	0.203 (3.200)	0	-0.075 (-3.216)	-0.023 (-2.910)	1.160 (2.764)	0.892 (2.231)	0	0
Δi_t	0	0.143 (2.880)	0	0	0	0		-1.047 (-3.834)	1.225 (3.202)

Values in parentheses are *t*-statistics.

Table 7.2: Short-Run Adjustment Model: Industrial Sector

	Γ_i										
	Δib_t	Δib_{t-1}	Δib_{t-2}	Δib_{t-3}	Δie_t	Δie_{t-1}	Δie_{t-2}	Δie_{t-3}	Δppi_{t-1}	Δppi_{t-2}	Δppi_{t-3}
Δib_t	0	0	0	0	2.770 (6.819)	1.876 (5.882)	1.769 (4.716)	1.008 (4.042)	0.971 (4.365)	0.599 (4.542)	0.265 (2.783)
Δie_t	-0.080 (-2.496)	-0.140 (-2.720)	-0.159 (-2.948)	-0.152 (-3.037)	0	0	0	0	0.691 (2.428)	0.088 (2.314)	0
Δppi_t	0	-0.082 (-2.822)	-0.077 (-2.822)	-0.067 (-2.384)		-0.153 (-2.593)	0	0	0	0	0
Δdy_t	-0.057 (-3.560)	-0.046 (-2.962)	-0.043 (-2.959)	-0.042 (-2.763)	0	0	0	0	0	0	0

	Γ_i					α		
	Δdy_{t-1}	Δdy_{t-2}	Δdy_{t-3}	Δi_{t-2}	Δi_{t-3}	$ecm1_{t-1}$	$ecm2_{t-2}$	$ecm3_{t-3}$
Δib_t	0.873 (2.593)	1.859 (3.881)	1.410 (4.633)	0.321 (2.706)	0.018 (5.316)	-0.393 (-5.823)	0	0
Δie_t	0	0	0	0.211 (4.670)	0.103 (2.319)	0.547 (3.289)	0.346 (2.909)	0.243 (2.391)
Δppi_t	-1.003 (-2.487)	-1.081 (-2.608)	0	-0.072 (-2.844)	-0.051 (-2.043)	0	0.286 (2.951)	0.198 (2.815)
Δdy_t	0	0	0	0	-0.051 (-3.779)	0	0	0

The coefficients of *ecm* (α) in Table 7.1 represents the short-run adjustment speed of the dependent variables to the long-run equilibrium position discussed in Section IV.1. For agricultural trade balance that only reacts to the second *ecm* term (*ecm*2), 27.9% of adjustment occurs in one quarter, implying it takes more than three quarters (1/0.279 = 3.58 quarters) to return to equilibrium. Meanwhile, the domestic price and interest rate adjust to both *ecm* terms. The price adjusts 25% to the first equilibrium and 18.3% to the second equilibrium in one quarter, implying that it needs around four to six quarters for the price to go back to both equilibria. When a shock is given to the agricultural price, it takes more than a year for the price to recover its long-run equilibrium position. The absolute values of both *ecm* coefficients for the interest rate are slightly larger than one, indicating that the interest rate is unstable in the agricultural sector. In other words, the short-term interest rate does not fully react to changes in the agricultural sector. Agricultural income never adjusted to the long-run steady-state position. It was driven by the shock in exchange rates in the short-run, showing 0.875% and 0.023% decreases in Γ_i but never adjusting to the long-run equilibrium.

Table 7.2 presents the estimated coefficients for the industrial sector. More dynamic interaction among the variables is evident with a longer lagged period effect than in the agricultural sector. First, exchange rates significantly affect the industrial trade balance and price, and are in return affected not only by the industrial trade balance but also by prices and interest rates. One percent increase in exchange rate instantaneously influences the industrial trade balance (deficit), immediately increasing it by 2.770%. Also, the increase has longer lagged effects on trade balance, but the effects decline gradually with exchange rate shocks in *t*-1, *t*-2 and *t*-3. In the meantime, the exchange rate immediately declines by 0.08% in reaction to the 1% increase in the trade deficit, indicating that the U.S. dollar depreciates by 0.08% as the value of U.S. imports increases by 1% relative to exports. The U.S. dollar depreciates more to previous shocks in the trade deficit and the effect remains over three quarters. The absolute values of the exchange rate coefficients in the industrial trade balance equation (2.770% ~ 1.008%) are larger than the trade balance coefficients in the exchange rate equation (0.080% ~ 0.152%), indicating a faster response of the industrial trade balance to the exchange rate shock and vice versa.

Second, another interaction is found among the exchange rate, price, and interest rate. The exchange rate reacts favorably to changes in the industrial price and interest rate over three quarters, whereas the U.S. dollar appreciation has a detrimental effect on price over one lagged period. In discussing the positive effects of the interest rate on exchange rates (0.211% at *t*-2 and 0.103% at *t*-3), the link between the interest rate and the price should be explained since both of them are found to affect the exchange rate via monetary policy. Changes in price are often associated with subsequent inflation, leading to changes in the real interest rate, which affects industrial prices. Since the interest rate is found to be weakly exogenous in the industrial sector, the short-run impact of interest rate on the price is analyzed.[7] One percent positive shocks to the interest rate at *t*-2 and *t*-3 cause the price to decline 0.072% and 0.051% at *t*, respectively.

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[7]Since the interest rate is found to be insignificant in the agricultural sector, it is removed in the short-run analysis following the procedure Harris (1995) suggested.

However, and more important in the long-run, the impact of the interest rate on the price is found to be positive in the industrial sector, as shown in the next section.[8]

Third, a significant relationship is found to exist between industrial trade and the U.S. domestic economy. The industrial trade balance (deficit) has an effect on the U.S. domestic economy, even though the size is minimal (all the coefficients of price and income are less than 0.1%). In the meantime, the U.S. economy (price, income, and interest rate) positively affects the industrial trade deficit. For example, a 1% increase in the price at t-1 influences the trade deficit to increase by 0.971% at t, while a 1% increase in income at t-1 increases U.S. imports at t, so that the trade deficit increases by 0.873%.

In terms of the short-run adjustment to the long-run steady states (α in Table 7.2), faster adjustment is found in the industrial sector than in the agricultural sector. The industrial trade balance reacts to *ecm*1, which represents the industrial price relation (Equation (12)), and adjusts 39.3% in a quarter, indicating it takes less than three quarters (1/0.393 = 2.544 quarters) to eliminate the previous period's disequilibrium. Note that it takes more than three quarters (3.58 quarters) for the agricultural trade balance to adjust to the long-run equilibrium. The size of the direct short-run impact of the exchange rate on industrial trade is larger with a longer lagged period (2.770% ~ 1.008%) than the impact on the agricultural trade balance (1.944% ~ 0.765%), mainly because industrial trade is more liberalized than agricultural trade. However, and more importantly, the speed of adjustment to the long-run equilibrium is faster in the industrial sector than in the agricultural sector. This implies that variables in the agricultural sector interact less than in the industrial sector, and the impact of a given shock is pervasive over time, so that agricultural trade does not recover to the equilibrium position as fast as industrial trade.

The industrial weighted real exchange rate adjusts all three cointegrating relations, but much stronger in relation to *ecm*1, unlike the agricultural exchange rate which reveals weak exogeneity. It takes about two to five quarters for the industrial exchange rate to recover to the respective equilibria.

The U.S. industrial domestic price adjusts to two long-run steady-state positions, taking three and five quarters, which is faster than the agricultural price (four to six quarters). This implies that when a shock is given to the prices in both sectors, the agricultural price has a longer length of deviation from the long-run equilibrium than industrial price does, so that agricultural price suffers more than industrial price. Interestingly, similar to agricultural income, industrial income does not adjust to the long-run equilibrium.

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[8]This is a frequent empirical finding, the so called "price puzzle" as described in Juselius, K., and R. MacDonald (2000a).

IV.3. Common Stochastic Trend and Long-Run Impacts of Shocks Using VMA Representation

Three common stochastic trends are discovered for the agricultural sector and two for the industrial sector. The results are reported in panels A and B of Table 8. For the agricultural sector, it appears that the first common trend, $\alpha'_{\perp 1}\sum \varepsilon_i$ in Model (7), is equal to the cumulative shocks to the agricultural price (or simply agricultural price shocks). The remaining second and third trends capture the impact of shocks to the agricultural real weighted exchange rate and the agricultural income. The results suggest that joint deviation of the variables in the agricultural sector is mainly driven by the exchange rate and the agricultural income, which is consistent with the results of the long-run weak exogeneity test in Table 5. Meanwhile, both of the common stochastic trends for the industrial sector are composed of accumulated shocks to the interest rate.

These results confirm that the exchange rate performs differently between the agricultural sector and the industrial sector. The exchange rate is more likely exogenous in the agricultural sector, affecting the agricultural economy but not significantly influenced by it in return. However, exchange rates simultaneously interact with other variables in the industrial sector, so that exchange rates are not only influenced by industrial economy but also affect it.

The results of the long-run impulse response function, *C*, for a unitary change of $\hat{\varepsilon}_t$ (shock) are reported in the right side of both panels in Table 8. 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. Cumulative shocks to the agricultural trade balance (surplus) have no long-run impact on any of the variables and solely adjust to the equilibrium, whereas shocks in the industrial trade balance (deficit) have a significant negative impact on the industrial weighted exchange rate over the long-run as found in the short-run period presented in Tables 7.1 and 7.2.

Exchange rates in both sectors are the strongest factors, having pervasive and permanent effects on almost all equations. In the long-run, the agricultural economy is more sensitive than the industrial sector to shock in exchange rates. For example, the agricultural trade balance (surplus) falls by about two percent (-1.997%) on average as the result of a 1% shock of exchange rate in the long-run, whereas industrial trade balance (deficit) reacts by 1.23%. That is, when the U.S. dollar appreciates against foreign currencies, U.S. exports decline more than imports, but the size of the impact in agricultural exports is larger than that in industrial exports. Agricultural price is also more susceptible to a 1% shock in the exchange rate than industrial domestic price (-0.925% and –0.474%, respectively). Thus, changes in the agricultural exchange rate cause the

Table 8: Common Stochastic Trends and Impulse Response

Panel A: Agricultural Sector

	Common Stochastic Trends			Impulse Response Shock				
	$\alpha_{\perp 1}$	$\alpha_{\perp 2}$	$\alpha_{\perp 3}$	ab_t	ae_t	pf_t	nfi_t	i_t
ab_t	-0.036	-0.089	0.102	-0.034 (-0.288)	**1.997** **(3.172)**	-1.043 (-0.619)	-0.415 (-1.214)	0.405 (0.672)
ae_t	-0.433	**0.967**	**1.000**	0.014 (1.050)	**0.671** **(3.211)**	-0.079 (-0.426)	0.020 (0.534)	-0.102 (-1.525)
pf_t	**1.000**	0.549	0.281	-0.020 (-0.948)	**-0.925** **(-2.676)**	0.305 (0.992)	-0.100 (-1.593)	0.201 (1.829)
nfi_t	-0.132	**1.000**	**-1.112**	-0.080 (-1.894)	**-1.564** **(-2.321)**	0.119 (0.198)	**0.545** **(4.478)**	0.186 (0.868)
i_t	0.351	-0.002	0.026	-0.262 (-1.814)	-1.849 (-0.798)	**0.883** **(2.365)**	0.442 (1.054)	**1.625** **(2.202)**

Panel B: Industrial Sector

	Common Stochastic Trends		Impulse Response Shock				
	$\alpha_{\perp 1}$	$\alpha_{\perp 2}$	ib_t	ie_t	ppi_t	dy_t	i_t
ib_t	**0.011**	**0.060**	**0.339** **(0.943)**	**-1.230** **(-2.405)**	-1.415 (-0.942)	6.653 (1.945)	-0.595 (-1.766)
ie_t	-0.548	0.655	**-0.018** **(-2.312)**	**0.810** **(2.234)**	-0.316 (-0.851)	1.548 (1.828)	**0.164** **(2.261)**
ppi_t	-0.437	0.003	-0.044 (-0.858)	**-0.474** **(-2.263)**	0.151 (0.704)	-0.799 (-1.633)	**0.108** **(2.248)**
dy_t	0.353	0.672	0.017 (1.035)	0.090 (1.360)	-0.113 (-1.657)	**0.416** **(2.685)**	0.011 (0.697)
i_t	**1.000**	**-1.000**	0.049 (0.985)	**0.433** **(2.143)**	**-0.223** **(-2.177)**	0.997 (1.913)	-0.067 (-1.449)

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

agricultural sector to move, so that increases in the exchange rate instigate a decrease in the trade surplus, lower prices received by farmers, and hence result in less farm income (-1.564% for agricultural income).

In the long-run, the agricultural exchange rate does not respond to a shock in any other variables. However, the industrial exchange rate is driven by international trade and the interest rate to deviate from the equilibrium. The industrial exchange rate depreciates as the U.S. trade deficit increases.

Prices in both sectors are found to have positive long-run impacts on the interest rate. On the other hand, the interest rate positively affects the industrial price by 0.108% in the long-run, unlike the results in the short-run analyses. This is a frequent empirical finding, so called "price puzzle" (Juselius and MacDonald, 2000a)). Note that the interest rate does not affect agricultural price, which was removed in the short-run analysis because of insignficancy. Also, shocks to the interest rate are found to have a permanent impact on the industrial exchange rate as well.

V. Conclusion

This study empirically examines the impact of exchange rates on U.S. international trade and the domestic economy and the role of the exchange rate in the agricultural and industrial sectors. Three main questions addressed in this study are (1) how significantly U.S. trade and the domestic economy interact with the exchange rate, (2) how differently the two sectors respond to a shock in the exchange rate, and (3) how differently the exchange rate performs in each sector, whether exogenously, endogenously, or both. To answer these questions, an enhanced vector error correction model (VECM) and a vector moving average representation (VMAR) are utilized.

It is found that U.S. international trade and the domestic economy are strongly interconnected in both the agricultural and industrial sectors, but interaction is more vigorous in the industrial sector than in the agricultural sector. Also, the exchange rate is found to have a pervasive effect on U.S. trade and the economy in both sectors. Both the short- and long-run impacts of exchange rate shocks are found to be significant on both sectors's income and price levels.

However, the sensitivity of the two sectors to the exchange rate impacts is different; the effect on the agricultural sector is larger than that on the industrial sector. This is mainly because of the different attributes of the two sectors. In general, U.S. industry trades both consumer goods and raw materials. When the U.S. dollar appreciates relative to foreign currencies, imported raw materials become cheaper and production costs of an output produced from the raw materials decrease. As a result, the industrial sector may be able to increase its export. In the meantime, a comparative disadvantage exists in the agricultural sector when the U.S. dollar appreciates because imported inputs are processed for domestic consumption rather than exports. This implies that, unlike the industrial sector, imported raw material does not nullify the initial effects of exchange rate appreciation in the agricultural sector. These findings reveal the important role of exchange rates in both the U.S. trade and the domestic economy for both sectors.

A discrepancy in the role of the exchange rate is found between the agricultural and the industrial sectors. The agricultural exchange rate drives the agricultural sector, while the other variables are more likely to be adjusting to the long-run equilibrium. However, the exchange rate has mutual relationships with other variables in the industrial sector. Specifically, the industrial exchange rate is the largest contributing factor forcing the industrial sector to deviate from the equilibrium, and it is also the most responsive variable to shocks in the industrial trade balance and interest rate. This is mainly because the agricultural economy is less than 5% of the size of the industrial economy, so that the exchange rate is more likely to be affected by the industrial sector than the agricultural sector.

In terms of a relationship between the exchange rate and the trade balance, a discrepancy is found between the two sectors. This is due to the fact that the exchange rate performs differently between the two sectors. Only one direction of causality is found between the agricultural trade balance and the exchange rate, but simultaneous causality is found between the industrial trade balance and exchange rate.

The findings in this study confirm the significance of the exchange rate within the two sectors. Because the exchange rate performs differently, and has different impacts, the two sectors should be differentiated in developing and analyzing trade policy related to exchange rates.

References

Dellariccia, G. "Exchange Rate Fluctuations and Trade Flows: Evidence from the European Union." *IMF Staff Papers* 46(1999).

Eichenbaum, M., and C. Evans. "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates." *Quarterly J. Econ.* 110(1995): 975-1009.

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

Frankel, J., and W. Wei. "Trade Blocs and Currency Blocs." *Working Paper No. 4335. National Bureau of Economic Research*,(1993).

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.

Goldberg, P., and M. Knetter. "Goods Prices and Exchange Rates: What Have We Learned?" *J. Econ. Lit.* 35(1997): 1243-1272.

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

Grilli, V., and N. Roubini. "Liquidity and Exchange Rates: Puzzling Evidence from the G-7 Countries." Mimeo. Department of Economics, Yale Univ., 1993.

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

Hendry, D., and K. Juselius. "Explaining Cointegration Analysis: Part I." *Unpublished paper*,(1999).

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*,(2000 a).

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

Klaassen, F. "Why Is It So Difficult to Find an Effect of Exchange Rate Risk on Trade?" *Unpublished working paper, CentER*,(1999).

Klein, M. "Sectoral Effects of Exchange Rate Volatility on United States Exports." *Journal of International Money and Finance* 9(1990): 299-308.

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.

Lum, S., and B. Moyer. "Gross Domestic Product by Industry." Bureau of Economic Analysis, USDC, 2001.

MacDonald, R., and M. Taylor. "The Monetary Model of the Exchange Rate: Long-run Relationships, Short-run Dynamics and How to Beat a Random Walk." *Journal of International Money and Finance* 13(1994): 276-290.

Maskus, K. "Exchange Rate Risk and US Trade: A Sectoral Analysis." *Federal Reserve Bank of Kansas Economic Review* 3(1986): 16-28.

Rahbek, A., H. C. Kongsted, and C. Jørgensen. "Trend Stationarity in the I(2) Cointegration Model." *Journal of Econometrics* 90(1999): 265-289.

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

Rogoff, K. "The Purchsing Power Parity Puzzle." *Journal of Economic Literature* 34(1996): 647-668.

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