How Differently 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 the 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 the industrial sector. This study fulfills a fundamental question about the role of exchange rate between 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.

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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. Relative appreciation of U.S. dollar to the currencies of U.S. trade competitors is considered problematic, making U.S. producers less competitive in world market. The exchange rate economics has been the focus of many studies over the last two decades, and the results are inconclusive. In many studies, exchange rates are given to be exogenous (Frankel and Wei, 1993; Rogoff, 1996; Goldberg and Knetter, 1997; Klaassen, 1999). Dellariccia (1999), however, calls into question about the exogeneity of exchange rates because central banks could systematically try to stabilize the exchange rate with their most important trade partners. Several studies pay attention to the 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).

Making a decision on either endogeneity or exogeneity is dependent on the purpose of studies. However, one should consider that the decision must also rely on economic conditions such as an economic activity and characteristics of exchange rates. Exchange rates are time dependent and more or less continuously subject to shocks from other variables as well as shock to other variables. Their dynamic interaction with other variables becomes more complicated as an economic activity becomes more intricate. For example, the exchange rates might more dynamically interact with the U.S. industrial sector than the U.S. agriculture because of higher intricacy of economic activities in the industrial sector than the agricultural sector. This indicates that exchange rates may act exogenously only in the agricultural sector while performing more endogenously in the industrial sector than exogenously. A study may generate biased results if the fore-mentioned conditions are not considered.

Because of different degree of economic activities, the exchange rate impacts on trade may vary between sectors, indicating the involvement of exchange rates may be different. This is especially true for the agricultural sector versus the industrial sector because the economic scale of agricultural sector is relative small (less than three percent) compared to the industrial sector in the U.S. economy. The agricultural economy has grown 0.1% annually, whereas the industrial economy has grown more than 4.0% per year over the period from 1990 to 2000 (Lum and Moyer, 2001). For this period, both the U.S. agricultural and industrial trade weighted exchange rates have appreciated relative to other currencies more than 6.5% and 5.9% in real terms, respectively. U.S. dollar appreciation increases its purchasing power of foreign products, whereas decreases demand for U.S. products in foreign countries. The U.S. dollar appreciation may be one of the most contributing factors for the decline in the agricultural trade surplus by 16.4% and the increase in the industrial trade deficit by more than 143.8% for the same period, indicating possible loss of U.S. competitiveness. A few studies compare exchange rate impacts among sectors but are based on the assumption of exchange rate exogeneity (Maskus, 1986; Klein, 1990).

This study divides the U.S. economy into the agricultural and industrial sectors and explores, without specifying the rigid assumption of either exogeneity or endogeneity of exchange rates, the degree of the involvement of exchange rates in U.S. trade and the U.S. economy and their interdependency. The degree to which variables are linked, sharing both contemporaneous and noncontemporaneous information mutually, and the consistency of such linkages can provide useful information relevant to macroeconomic policy analysis.

More specifically, this study (1) examines how significantly the value of the U.S. dollar measured against foreign currencies influences the U.S. trade balance and the U.S. domestic economy; (2) identifies the different role of exchange rates in each sector, either endogenous or exogenous; and (3) compares how differently the agricultural and the industrial sectors respond to changes in the U.S. dollar value. 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 enhanced vector error correction model (VECM) to avoid over identification problems occurred in cointegrating space and vector moving average representation (VMAR) to analyze various impacts in the long-run. These methods enable us to analyze and confirm the different functions of exchange rates between the agricultural and industrial sector.

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, a summary of the principal findings and conclusions are discussed in Section V.

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 back to the long-run equilibrium state. It is well known that vector autoregressive (VAR) analysis can be used to analyze cointegrating relationship among the variables. However, an over-identification problem occurs if more than two cointegrating relationships exist, indicating no unique solution exists in cointegrating space. Hence, the enhanced vector error correction model (VECM) is utilized to resolve the over-identification problem in cointegration analysis.[1] This analysis 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 push the others to depart but not pushed away. The pushing forces causing the model to deviate from the equilibrium are called the common stochastic trends and can be captured through the vector moving average representation (VMAR), which is a dual representation of vector autoregressive model. There is another advantage of using VMAR. We can isolate the long-run impulse response of individual variable to a certain shock. Most of studies end up with the Granger-type causal relationship analysis, focusing short-run responses to certain shock. However, it is also important to learn the long-run responses of individual variables to the shocks of other individual variables.[2] Enhanced VECM and VMAR are discussed to assess the cointegrating relation and confirm the function of the exchange rate.

II.1. Vector Error Correction Model (VECM)

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

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

$$Z_t = A_1 Z_{t-1} + \cdots + A_k Z_{t-k} + \mu_t + \varepsilon_t \qquad (1)$$

where $t = 1, \cdots, T$, k is a maximum lag length of Z, and ε_t is an independently and identically distributed N dimensional vector with zero mean and variance-covariance matrix, Ω. μ is a constant. Z_t is a $p \times 1$ vector of stochastic variables: U.S. trade balance, exchange rates, price, income, and interest rate, where p is the number of variables (p = 5). 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. We can reformulate equation (1) into a vector error correction model (VECM) as follows:

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

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, which is defined as two of $p \times r$ matrices, α and β, such that:

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

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

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

However, equation (4) may generate non-unique solution when there exist more than two cointegrating vectors ($r \geq 2$) because any linear combination of more than two cointegrating relations preserves the stationarity property (Juselius and MacDonald, 2000a; 2000b). To resolve the over-identification problem, we have to impose restrictions on each of cointegrating relations, so that we can identify unique long-run structure. Structural restrictions on each of the cointegrating vectors are given as follows:

$$\beta = \{h_1\varphi_1, \cdots, h_r\varphi_r\} \tag{5}$$

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 $\beta = \{h_1\varphi_1, h_2\varphi_2\}$ which specifies proportionality restriction to induce a unique elasticity in the long-run relations. More details are described in Johansen and Juselius (1994) and Harris (1995).

II.2. Vector Moving Average Representation (VMAR)

The VMAR model can be obtained by inverting the VAR model as follows:

$$Z_t = C\sum_{i=1}^{t}\varepsilon_i + C^*(L)(\varepsilon_t + \mu) + B \tag{6}$$

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

$$C = \tilde{\beta}_\perp\alpha'_\perp \tag{7}$$

where $\tilde{\beta}_\perp = \beta_\perp(\alpha'_\perp\Gamma\beta_\perp)^{-1}$. $\alpha'_\perp\sum\varepsilon_i$ in the first part of equation (5) determines the $(p-r)$ common stochastic trends which influence the variable Z_t with the weights $\tilde{\beta}_\perp$. It is possible to calculate the impulse responses of a shock to one variable and how they are transmitted over time within the model based on equation (6).

III. Data and Econometric Procedure

III.1. Choice of Variables

The choice of variables is directed to account for the key features in relationships between U.S. international trade and the U.S. domestic economy. Z_t in equations (4) and (6) is composed of five variables: 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 U.S. dollar value 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 are quarterly aggregated measurements spanning the fourth quarter of 1987 through the first quarter of 2000, leading to 50 observations for each variable. All variables are real terms with 1996 as a base year and are converted to logarithms. The U.S. economy is divided into the agricultural sector and the industrial sector for a comparison under an assumption that the two sectors may react differently to changes in the exchange rate.

Agricultural 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.[3] To convert nominal exports and imports into real trade flow, GDP deflator is used, which 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 (pf_t) and the producer price index (ppi_t) are used for the agricultural and industrial sector, respectively. They do not contain value-added costs such as transportation costs. Agricultural and industrial price data are provided from the ERS in USDA and the Bureau of Labor Statistics (BLS) in the U.S.Department of Labor (USDL), respectively.

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 USDA and divided by the GDP deflator to convert into real terms. U.S. real disposable income is provided by the Bureau of Economic Analysis (BEA) in USDC.

Interest rates are included as proximity of government monetary policy. Treasury bills, which are short-term interest rate (in real term), are selected among several because of two reasons: (1) they are important determinants of the prices of critical inputs and widely recognized as representative of broad economic condition (i_t for both sectors); (2) short-term real rates relative to one in other countries are believed to affect exchange rates, while long-term real interest rates affect saving and business investment.

III 2. Empirical Econometric Procedure[4]

The econometric procedure is based on the 'general-to-specific' approach discussed in Hendry and Mizon (1993), which is a procedure moving from an unrestricted model to a restricted model to have economically meaningful coefficients.

All parameters $\{\Gamma_i, \alpha, \beta, \mu, \Omega\}$ in equation (4) are unrestricted and maximum likelihood estimates can be obtained by OLS. However, equation (4) is heavily over-parameterized, therefore over-identified, indicating that it is a convenient way of describing the covariances of the data rather than a meaningful economic model. To decipher the problem, we impose some restrictions on equation (4) such as zero parameter restrictions, reduced rank restrictions, and others as suggested in Hendry and Mizon (1993) and Juselius and MacDonald (2000a). Thus, we can arrive at more parsimonious model with economically interpretable coefficients.

Unit Root and Johansen Tests

According to the Philips-Perron test, we reject the null hypothesis of unit root in both agricultural and industrial trade balance, $(ab_t \text{ and } ib_t)$, implying stationary $I(0)$, whereas other variables become $I(1)$ at a 95% significance level.[5]

Both the maximum eigenvalue and the trace tests on equation (3) suggest two cointegration ranks for the agricultural sector and three cointegration ranks for the industrial sector at a 95 % significance level. Lag lengths of four and six periods in the VAR model (1) 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).

Misspecification Test

Both multivariate and univariate misspecification tests are conducted to check the statistical adequacy of the VAR model (2). No significant first order autocorrelation problem is detected according to the multivariate LM test for both sectors. Since multivariate normality is violated for the agricultural sector and cointegration estimators are more sensitive to skewness than to kurtosis, univariate skewness and kurtosis for the agricultural sector are tested (Juselius and MacDonald, 2000b). Nonnormality is essentially due to excess kurtosis in net farm income and interest rate equations (5.046 and 5.305, respectively, which are significantly greater than three), and hence is not a serious factor in the estimation results.

The null hypothesis of heteroskedasticity is rejected for all the equations in both sectors except for the agricultural trade balance. No crucial problem is expected because cointegration estimates are not very sensitive to an ARCH effect (Rahbek, et al., 1999).

Long-Run Weak Exclusion Test (Suitability of the VAR model) [6]

Long-run weak exclusion is tested to examine the relevance of the selected variables to the model (Johansen and Juselius, 1992; Juselius and MacDonald, 2000b). The null hypothesis is that the variable, Z_i, does not enter the cointegrating space, where $i = 1, \cdots, p$, by setting up $H_0^{\beta} : \beta_{ij} = 0$, and $j = 1, \cdots, r$. The results are greater than the critical values of $\chi^2(2)$ and $\chi^2(3)$ for the agricultural and industrial sectors, respectively, and hence the null hypothesis is rejected for both sectors. This indicates that all the variables are statistically relevant and none of the variables should be excluded for both sectors.

Test of Long-Run Exogeneity

The long-run weak exogeneity is tested to investigate the absence of long-run levels feed-back from endogenous variables (Johansen and Juselius, 1992, Juselius and MacDonald, 2000b). It is hypothesized $H_{\alpha}^{i}: \alpha_{ij} = 0$, where $j = 1, \cdots, r$, implying the variable Z_i, where $i = 1, \cdots, p$, does not adjust to the equilibrium errors, $\beta_i Z_t$, where $i = 1, \cdots, r$. Three variables are found weakly exogenous: agricultural weighted exchange rates and net farm income in the agricultural sector; and interest rates in the industrial sector (Table 1), implying that these variables influence the long-run movements of the other variables in each sector, but are not driven by other variables.

Interestingly, the exchange rate is weakly exogenous in the agricultural sector, while it is not in the industrial sector. This is mainly because the size of the agricultural sector is relatively small compared to the U.S. economy, and hence the impact of agricultural economy on the exchange rate is trivial.

Another discrepancy is the role of interest rate. A large portion of agricultural products is used as inputs that are more interacted with short-term real rate than long-term rate, whereas a large portion of industrial product is used as outputs that are more interdependent with long-term rate. Thus short-term rates are relatively more influenced by the agricultural sector.

IV. Empirical Results

Two and three stationary relationships are found in each sector based on the Johansen test results. Because of over-identification problem, some restrictions are put on cointegrating space. To generate economically interpretable coefficients in cointegrating space structure, the hypotheses of joint stationary relationships are constructed.[7] The hypotheses are

$$\mathrm{H}_0^a: \ \beta = \{h_1\varphi_1, h_2\varphi_2\} \tag{8}$$

$$\mathrm{H}_0^i: \ \beta = \{h_3\varphi_3, h_4\varphi_4, h_5\varphi_5\} \tag{9}$$

where H_0^a and H_0^i are for the agricultural and industrial sectors, respectively, and the design matrices are defined as follows

$$h_1 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \ h_2 = \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}, h_3 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 1 & 0 \\ 0 & -1 \\ -1 & 0 \end{bmatrix}, \ h_4 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 0 & -1 \\ 0 & 0 \\ -1 & 0 \end{bmatrix}, \ h_5 = \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 1 \\ -1 & 0 \\ 0 & 0 \end{bmatrix}.$$ [8]

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 2 reports the long-run speed adjustment (α) and the long-run coefficients (β)[9]. For the agricultural sector, two stationary relations are confirmed by the estimated α coefficients in panel A of Table 2. The price (pf_t) and interest rate (i_t) equations are significant in both relations, while the agricultural trade balance (ab_t) is significant in the second relation.[10] These variables are equilibrium error correcting 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.

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 1. 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 agricultural price, and 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.[11]

$$ecm1:\ ab_t = -0.098ae_t - 0.001pf_t - 0.045i_t - 0.002\,. \quad (10)$$

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

$$ecm2:\ pf_t = -1.554ae_t - 0.001i_t - 0.003 \quad (11)$$

Short-run adjustments to *ecm*1 and *ecm*2 occur primarily through the trade balance and price, respectively, indicating the importance of these variables in 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 2. Interestingly, the industrial weighted exchange rate (ie_t) adjusts to all the steady-state relations, which reflects distinct role of the exchange rate in an industrial sector. That is, the exchange rate is more likely endogenous in the industrial sector, while it is exogenous in the agricultural sector. Results are 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 price (ppi_t) and the exchange rate (ie_t) .

The interest rate does not adjust to the cointegrating relation in the industrial sector, which is consistent with the result of weak exogeneity test in panel B of Table 1. Error correcting relations are as follows:

$$ecm1:\ ppi_t = 0.341ib_t - 0.090ie_t - i_t + 0.241dy_t - 0.004 \quad (12)$$

$$ecm2:\ (ie_t - i_t) = 0.345ib_t - 0.118\,ppi_t - 0.004 \qquad (13)$$

$$ecm3:\ ib_t = 0.575ie_t + ppi_t + 0.575dy_t - 0.003i_t - 0.005\,. \qquad (14)$$

The *ecm*1 and *ecm*3 describe that U.S. industrial price and trade balance for the respective models would be satisfied with as a stationary relation if a linear combination of the rest of variables in each model is 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 is 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 2, 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 3.1 and 3.2.[12]

For the agricultural sector (Table 3.1), 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, $ae_{t\text{-}1}$, and $ae_{t\text{-}2}$) generate significant detrimental effect on both agricultural trade balance (surplus) and agricultural income. Agricultural trade balance is immediately reduced by 1.944% due to 1% increase in exchange rate (ae_t). The exchange rate impact remains over two quarters, and ab_t declines by 1.164% and 0.765% due to 1% increase in the exchange rate at *t*-1 and *t*-2, respectively. Also, One percent 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 that to those in prices.

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

The coefficients of *ecm* (α) in Table 3.1 represent 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 to the long-run equilibrium position. The absolute values of both *ecm* coefficients for the interest rate are slightly larger than one, indicating the interest rate is unstable in the agricultural sector. The short-term interest rate does not fully react to changes in the agricultural sector. Agricultural income never adjusted shortly 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 3.2 presents the estimated coefficients for the industrial sector. Exchange rates significantly affect the industrial trade balance and industrial price, and are also affected by the variables (industrial trade balance and prices) as well as interest rates. One percent increase in exchange rate instantaneously influences the industrial trade balance (deficit) by 2.770%. Also, it has 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% to the one percent 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. Note that only one direction of causality is found between the agricultural trade balance and exchange rate, but simultaneous causality is found between the industrial trade balance and exchange rate. 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 than the exchange rate to the trade balance shock over three quarters.

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 gives detrimental effect on price over one lagged period. In the discussion of positive interest rate effects on exchange rates (0.211% at *t*-2 and 0.103% at *t*-3), the link between interest rate and price should be explained because both of them are found to affect the exchange rate via monetary policy. In general, changes in price are often associated with subsequent inflation, finally leading to changes in the real interest rate, which affects industrial prices. However, since the interest rate is found weakly exogenous in the industrial sector, the short-run impact of interest rate on the price is analyzed.[13] One percent positive shocks to the interest rate at *t*-2 and *t*-3 causes the price to decline 0.072% and 0.051% at *t*, respectively. However, more importantly in the long-run, the impacts of the interest rate on the price are found to be positive in the industrial sector, as shown in the next section.[14]

Significant relationship is found 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, one percent increase in the price at *t*-1 influences the trade deficit to increase by 0.971% at *t*, while one percent increase in income at *t*-1 increases U.S. imports at *t*, so that the trade deficit increases by 0.873%.

In terms of short-run adjustment to the long-run steady-states (α in Table 3.2), faster adjustment is found in the industrial sector than the agricultural sector. The industrial trade balance adjust 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 exchange rate on the industrial trade are larger with 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. 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 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 to all three cointegrating relations, but most strongly to *ecm*1, unlike the agricultural exchange rate which reveals weakly exogeneity. It takes about two to five quarters for the industrial exchange rate to go back 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.

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

Three common stochastic trends are found for the agricultural sector and two for the industrial sector. The results are reported in panel A and B of Table 4, respectively. 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 1. Meanwhile, both of the common stochastic trends for the industrial sector are composed of accumulated shocks to the interest rate.

These results confirm that exchange rate performs differently between the agricultural sector and the industrial sector. Exchange rate is more likely exogenous in the agricultural sector, so that exchange rate affects the agricultural economy but is not significantly affected by the agricultural economy. However, exchange rates function is more likely endogenous for the industrial sector, indicating that exchange rates are not only affected by industrial economy but also affect the industrial economy.

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 4. The significance of each entry C_{ij} indicates that the shock 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 3.1 and 3.2.

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, agricultural trade balance (surplus) falls by about two percent (-1.997%) on average to an one percent 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 impact in agricultural exports is larger than that in industrial exports. Agricultural price is also more susceptible to an one percent shock of exchange rate than industrial domestic price (-

0.925% and –0.474%, respectively). Thus, changes in the agricultural exchange rate cause the agricultural sector to move, so that increase in the exchange rate instigates less trade surplus, lowers prices received by farmers, and hence causes less farm income (-1.564% for agricultural income).

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

Rising inflation often leads to a higher interest rate, and 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" as indicated in (Juselius and MacDonald, 2000a). Note that 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 impacts of exchange rates on the U.S. international trade and domestic economy using quarterly data and the role of exchange rate in the agricultural and industrial sectors. Three main questions addressed in this study are (1) how significantly the U.S. trade and U.S. domestic economy interact with exchange rate, (2) how differently the two sectors respond to a shock in exchange rate, and (3) how differently the exchange rate performs in each sector, exogenously, endogenously, or both. To answer these questions, enhanced vector error correction model (VECM) and vector moving average representation (VMAR) are adopted.

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

However, the sensitivity of the two sectors to the exchange rate impacts is different. The effect of an exchange rate shock on the agricultural sector is larger than the industrial sector. This is mainly because of the different attributes of the two sectors. In general, the 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 output produced from the raw materials decrease, which nullify the initial price effect. 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 in the agricultural sector. This implies that, unlike the industrial sector, imported raw material does not nullify the initial effects of exchange rate appreciation in the agricultural sector.

This study fulfills a fundamental question about the role of exchange rate between the two sectors and confirms the significance of the exchange rate role. The exchange rate is exogenous in the agricultural sector, while being endogenous in the industrial sector. This is mainly because the agricultural economy is less than three percent of the size of the industrial economy, so that exchange rate is more likely to be affected by the industrial sector rather than the agricultural sector.

Table 1. Test of Long-Run Weak Exogeneity

Agricultural Sector	ab_t	ae_t	pf_t	nfi_t	i_t	$\chi^2(v)$
	25.14	**2.23**	11.05	**2.15**	9.59	$\chi^2(2) = 5.99$
Industrial Sector	ib_t	ie_t	ppi_t	dy_t	i_t	$\chi^2(v)$
	14.40	11.96	22.83	20.74	**5.38**	$\chi^2(3) = 7.81$

v denotes the degree of freedom.

Table 2. Structural Representation of the Cointegrating Space

Panel A: Agricultural Sector

Eigenvectors (β)			Weights (α)		
Variables	$\hat{\beta}_1$	$\hat{\beta}_2$	Equations	$\hat{\alpha}_1$	$\hat{\alpha}_2$
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	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	Equations	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$
ib_t	-0.341 (0.016)	-0.345 (0.012)	1.000 (0.000)	$\Delta\ ib_t$	**-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.

Table 3.1: Short-Run Adjustment Model: Agricultural Sector

ΔZ_t \ ΔZ_{t-i}	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 3.2: Short-Run Adjustment Model: Industrial Sector

ΔZ_t	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

ΔZ_t	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

Table 4: 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.

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[1] The term "enhanced" is used to differentiate the over-identification problem from typical VAR analyses in which no restriction is given to the cointegrating space when there are more than two relationships.

[2] The long-run responses are different from the short-run adjustment to the long-run relation generated in the vector error correction model in terms of the identification of the source of shocks. The long-run response of individual variable is to 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 shock is given but the shock is collaborated by the rest of variables.

[3] 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 period.

[4] Results are abbreviated because of simplicity and are available from authors on request.

[5] 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. Because of the low power of Dickey-Fuller type tests to distinguish slow mean reverting and series form nonstationary series, we also conduct the LR test (Johansen and Juselius, 1992, Juselius and MacDonald, 2000b). LR (χ^2) test indicates that the null hypothesis of stationarity should be rejected for all the variables and the variables become $I(1)$.

We can proceed further cointegrating relation because cointegrating analysis requires that only two of the variables are $I(1)$ (Hendry and Juselius, 1999), implying that stationarity of those variables does not affect the cointegration estimation.

[6] Also, we examine the eigenvalues of the companion matrix for each sector. The companion matrix is given by

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

where A_i is defined previously in (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). 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 the unity, indicating appropriate VAR model set up.

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

[8] Refer to Johansen and Juselius (1994), Johansen and Juselius (1992), Juselius and MacDonald (2000b) for more details about setting restrictions on the cointegrating space.

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

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

[11] 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).

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

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

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