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On the Dynamic Relationship between U.S. Farm Income and Macroeconomic Variables

Jungho Baek and Won W. Koo

This study examines the short- and long-run effects of changes in macroeconomic variables—agricultural commodity prices, interest rates and exchange rates—on the U.S. farm income. For this purpose, we adopt an autoregressive distributed lag (ARDL) approach to cointegration with quarterly data for 1989–2008. Results show that the exchange rate plays a crucial role in determining the long-run behavior of U.S. farm income, but has little effect in the short-run. We also find that the commodity price and interest rate have been significant determinants of U.S. farm income in both the short- and long-run over the past two decades.

Key Words: autoregressive distributed lag model, commodity price, exchange rate, farm income, interest rate, long-run, short-run

JEL Classifications: C22, E23, Q11

U.S. net farm income has been fairly stable in the 1990s and early 2000s. Between 1991 and 2002, for example, the average annual net farm income in the U.S. was \$48.3 billion (Figure 1). Since 2003, however, this income outlook has changed dramatically as the U.S. farm sector has witnessed a considerable surge of annual net farm income. Over the 2003–2007 period, for example, the average annual net farm income was \$74.2 billion, an approximately 47% increase from the average of the 1991–2002 period. The U.S. Department of Agriculture (USDA) predicts that U.S. net farm income is to reach a record high of \$95.7 billion in 2008, a 10.3% increase over 2007.

Macroeconomic variables (e.g., exchange rates and interest rates) have long been considered to be important factors affecting the U.S. farm economy. For example, a weakened U.S. dollar (or dollar depreciation) tends to increase U.S. agricultural exports through a decrease in U.S. agricultural prices, thereby enhancing U.S. farm income. Similarly, lower interest rates in the United States result in higher farm income as the decline in interest rates lowers production costs for farmers without necessarily compensating with a decrease in the price of their output. Hence, it is important to examine macro-agricultural sector linkages to better understand both the causes and the consequences of changes in U.S. farm income.

Many studies have been conducted to analyze the influences of macroeconomic variables on the U.S. agricultural sector (for example, Schuh, 1974; Chambers, 1981 and 1984; Bessler and Babula, 1987; Bradshaw and Orden, 1990; Orden, 2002; Baek and Koo, 2007 and 2008). For example, Chambers (1981) investigates the

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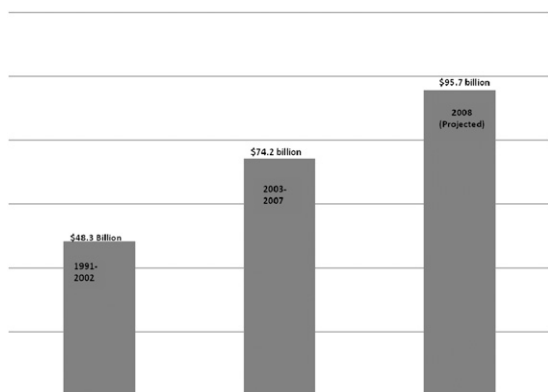


Figure 1. Net Farm Income in the U.S., 1991–2008

short-run effects of changes in money instruments such as money supply and interest rates on U.S. agricultural commodity trade; he finds some evidence of a causal relationship between money supply and agricultural exports and imports. Similarly, Bradshaw and Orden (1990) examine the dynamic relationship between exchange rate and prices and exports of agricultural commodities such as wheat, corn and soybeans; they conclude that exchange rate has a significant effect on agricultural exports, but not on agricultural prices. So far, however, studies have typically concentrated on the effects of macroeconomic variables (i.e., interest rates and exchange rates) on U.S. agricultural trade and commodity prices. Furthermore, those studies have mostly placed their emphasis on the short-run effects of macroeconomic variables on the U.S. agricultural sector (for example, Chambers, 1981 and 1984; Bessler and Babula, 1987; Bradshaw and Orden, 1990). Accordingly, relatively little attention has been paid to the direct and simultaneous assessments of the short- and long-run effects of macroeconomic variables on U.S. farm income. This study thus fills in the gap.

The objective of this study, therefore, is to assess the dynamic interaction between the U.S. farm income and macroeconomic variables. For this purpose, we examine the short- and long-run linkages between changes in U.S. net farm income and changes in agricultural commodity prices, interest rates, and exchange rates using an autoregressive distributed lag (ARDL) approach to cointegration (Pesaran, Shin, and

Smith, 2001). Since an error-correction model (ECM) can be derived from the ARDL model through a simple linear transformation, the ARDL is a convenient tool to estimate both the short- and long-run parameters of the model simultaneously. The remaining sections present model, data, empirical procedure, empirical results, and conclusions.

The Model

In explaining variations in U.S. farm income, we assume a farm with neoclassical properties of production function as follows:

$$(1) \quad Q = f(X, E)$$

where Q is a vector of output; X is a vector of inputs, including both fixed and variable inputs; and E is a vector of shift variables characterizing technology and other factors affecting production (e.g., government subsidy program).

Profit (π) can be written as follows:

$$(2) \quad \pi = Pf(X, E) - CX$$

where P is a vector of output prices, and C is a vector of input prices. Optimal profit is obtained by maximizing Equation (2). According to the first-order conditions, $\partial\pi/\partial X = p \cdot \partial f/\partial X - C = 0$ and thus $\partial f/\partial X = c$, where $c = \frac{C}{P}$ is a vector of real input prices. The first-order condition for profit maximization can be expressed as functions of P, C and E . Substituting these into Equation (2) yields the optimal profit (π^*) or farm income (Y^*) as follows:

$$(3) \quad \pi^* = Y^* = g(P, C, E)$$

Since our main focus is on the estimation of macroeconomic factors, particularly exchange rates and interest rates, on farm income, shift variables (E) such as government subsidies are all treated as constant in Equation (3). To analyze how U.S. farm income is determined, therefore, the following specification is chosen for the empirical analysis:

$$(4) \quad Y^* = g(P, IR, ER)$$

where P is the commodity price; IR is the interest rate; and ER is the exchange rate.¹

Equation (4) is then specified in a log linear form as follows:

$$(5) \quad \ln Y_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln IR_t + \beta_3 \ln ER_t + \varepsilon_t$$

With regard to the signs of the coefficients in Equation (5), it is expected that $\beta_1 > 0$, since an increase in U.S. commodity prices has a positive effect on U.S. farm income. As to the effect of interest rate, it is expected that $\beta_2 < 0$, since an increase in the interest rates, and thus a surge of (credit/borrowing) costs and interest rate risk, have a detrimental effect on U.S. farm income. Finally, it is expected that $\beta_3 < 0$, since a depreciation of the U.S. dollar is expected to increase exports of U.S. agricultural commodities and U.S. farm income.²

Equation (5) outlines the long-run relationships among the variables of interest. The main objective of this study is, however, to analyze dynamic relationships between U.S. farm income and its main determinants. In estimating Equation (5), therefore, it is necessary to incorporate the short-run dynamics into our estimation procedure. This task can be done by

specifying Equation (5) in an error-correction modeling format. For this purpose, following Pesaran, Shin, and Smith (2001), Equation (5) is reformulated as an ARDL form as follows:

$$(6) \quad \begin{aligned} \Delta \ln Y_t = & \alpha + \sum_{k=1}^p \eta_k \Delta \ln Y_{t-k} \\ & + \sum_{k=1}^p \varepsilon_k \Delta \ln P_{t-k} + \sum_{k=1}^p \phi_k \Delta \ln IR_{t-k} \\ & + \sum_{k=1}^p \varphi_k \Delta \ln ER_{t-k} + \lambda_1 \ln Y_{t-1} \\ & + \lambda_2 \ln P_{t-1} + \lambda_3 \ln IR_{t-1} \\ & + \lambda_4 \ln ER_{t-1} + \varepsilon_t \end{aligned}$$

where Δ is the difference operator; p is number of lag; and ε_t is assumed serially uncorrelated. Equation (6) is called the error-correction version of the ARDL, because the linear combination of lagged variables (terms with λ s) replaces the lagged error-correction term (ec_{t-1}) in a standard error-correction model. As such, while λ s represents the long-run (cointegration) relationship, the coefficients following the summation signs (Σ) correspond to the short-run relationship between U.S. farm income and its determinants (P_t , IR_t and ER_t).

The first step in estimating Equation (6) is to examine the existence of a long-run relationship (cointegration) among the variables. For this purpose, we test the null hypothesis of nonexistence of a long-run relationship, namely $H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$ in Equation (6). This can be done by using an F -test with two asymptotic critical values tabulated by Pesaran, Shin, and Smith (2001). A lower value assumes all variables are $I(0)$, and an upper value assumes that they are all $I(1)$. This provides a band covering all possible classifications of the variables into $I(0)$ and $I(1)$ or even fractionally integrated. If the computed F -statistic is above the upper critical value, the null hypothesis of no long-run relationship can be rejected, indicating cointegration. If the computed F -statistic is below the lower critical value, the null hypothesis cannot be rejected, showing lack of cointegration. Finally, if the F -statistic falls between the lower and upper critical values, the result is inconclusive. In this case, following Kremers, Ericson, and

¹ Note that, since agriculture is one of the most capital intensive industries in the U.S. economy, interest rates are a key determinant of (variable) production costs; thus, interest rates should be more relevant than farm wages in explaining the variations in U.S. farm income. In addition, the rapid increase in crude oil prices may have significantly raised the costs of production and shipping agricultural commodities through increases in the prices of fertilizer, diesel, agricultural chemicals, and other inputs. However, significant growth in the use of farm commodities for increased biofuel production driven by high oil prices results in boosting commodity prices to a level that more than offsets the increase in production costs resulting from higher oil prices, thereby increasing farm income. Further, the USDA recently reports that the increase in recent farm income is primarily the result of high commodity prices. For these, therefore, it seems sufficient enough to include commodity prices as a key determinant in our model.

² It is assumed that exchange rate (ER_t) is defined in a way that a decrease reflects a real depreciation of the U.S. dollar against major currencies.

Dolado (1992) and Banerjee, Dolado, and Mestre (1998), the error-correction term (ec_{t-1}) can be used to establish cointegration. After determining the existence of the long-run relationship, standard model selection criteria (e.g., Akaike information criterion (AIC) and Schwartz-Bayesian criterion (SBC)) are used to select the optimum lag length of each first differenced variable in Equation (6) in order to estimate the long-run coefficients and error-correction model.

It is worth noting that, since we also employ the Johansen cointegration approach (Johansen, 1995) along with the ARDL model in estimating the long-run relationship among the variables, we need to emphasize the role of Johansen analysis adopted here. Pesaran, Shin, and Smith (2001) show that the robust results for the ARDL model typically rely on the two assumptions of *exogeneity* of explanatory variables and the existence of a *unique* long-run relationship among the variables. As such, the ARDL approach adopted here could be valid only if the explanatory variable such as P_t , IR_t and ER_t are exogenous in the model, and there exists a *unique* long-run relationship between Y_t and the three explanatory variables. The widely used Johansen cointegration approach seems to be particularly well suited in this respect since it tests for the number of cointegrating relationships among a set of variables, as well as to identify the nature of exogeneity by imposing restrictions on a cointegrating vector, which is known as weak exogeneity test. If the number of cointegrating relationships is larger than one, for example, then the ARDL approach is inappropriate since it is based on a single-equation approach; instead, the Johansen analysis should be used to identify unique cointegrating vectors and interpret them economically. In this study, therefore, the ARDL approach should not be seen as a substitute but as a supplement to the Johansen approach.

Data and Preliminary Analysis

Data

The U.S. agricultural gross domestic product (billions of chained 2000 dollars) is used as a proxy for U.S. net farm income and is

collected from the Bureau of Economic Analysis (BEA) in the U.S. Department of Commerce (USDOC).³ The prices received index for all farm products (2000 = 100) is used as a proxy for U.S. commodity prices and is obtained from the Economic Research Service (ERS) in the U.S. Department of Agriculture (USDA). The effective federal fund rate is used as a proxy for U.S. interest rate and is taken from the Board of Governors of the Federal Reserve System. Finally, the exchange rate is the real trade-weighted exchange rate (2000 = 100) and is collected from the ERS in the USDA. Since the real trade-weighted exchange rate is defined as the currencies of trading partners per unit of the U.S. dollar, a decline in exchange rate indicates a real depreciation of the U.S. dollar. The data set contains 78 quarterly observations for the period 1989:Q1–2008:Q2. All variables except interest rate are in natural logarithms.

Preliminary Analysis

Prior to implementation of the ARDL approach to cointegration, the existence of a unit root of the four variables (Y_t , P_t , IR_t and ER_t) is tested for the following two reasons: (1) to ensure that, although the ARDL is applicable irrespective of whether the variables are $I(0)$ or $I(1)$, none of the variables is $I(2)$ or beyond because the computed F -statistics are not valid in the presence of $I(2)$ variables; and (2) to determine whether the Johansen method can be applied to identify the number of cointegrating relationships among the variables because it requires the selected variables to be nonstationary. For this purpose, we conduct unit root

³ We use agricultural GDP as a proxy for net farm income in the analysis, due mainly to the unavailability of quarterly data of net farm income. In this respect, a possible criticism of our efforts to examine determinants of U.S. farm income is that agricultural GDP may be different from net farm income. Although the two series use different measures of U.S. farm income (gross value added (agricultural GDP) vs. net value added (net farm income)), agricultural GDP and net farm income tend to track each other closely over time; thus, our use of agricultural GDP may not undermine the credibility of our findings.

tests using the Dickey-Fuller generalized least squares (DF-GLS) test (Elliot, Rothenberg, and Stock, 1996). This test optimizes the power of the standard augmented Dickey-Fuller (ADF) test by detrending. The DF-GLS test works well in small samples and has substantially improved power when an unknown mean or trend is present (Elliott et al., 1996). The results show that the levels of all the variables are nonstationary, while the first differences are stationary, indicating that the four variables are nonstationary and integrated of order one, or $I(1)$ (Table 1). The DF-GLS test statistics are estimated from a model that includes a constant and a trend variable. The Schwert Criterion (SC) is used to determine lag lengths for the unit root tests. Thus, before estimating the ARDL model, the Johansen method can be applied to test the number of cointegrating relationships among the four variables in the model.

The Johansen cointegration procedure is applied to determine the number of cointegrating relationships among the four variables. The results show that the trace tests reject the hypothesis of no cointegrating vector ($r = 0$) at the 5% significance level, but fail to reject the null of at most one cointegrating vector ($r \leq 1$) (Table 2), indicating the presence of a unique long-run relationship among Y_t , P_t , IR_t and ER_t . The Johansen test is based on the VAR model with three lags that are chosen by both the Hannan-Quinn and Schwarz criteria. The

Table 2. Results of Johansen Cointegration Rank Tests

Null Hypothesis	Eigenvalue	Trace Statistics
$H_0: r = 0$	0.298	63.40 [0.05]**
$H_0: r \leq 1$	0.219	36.92 [0.18]
$H_0: r \leq 2$	0.157	18.36 [0.33]
$H_0: r \leq 3$	0.071	5.54 [0.53]

Note: ** denotes rejection of the null hypothesis at the 5% significance level. p -values are given in parentheses.

VAR model includes an unrestricted constant and a linear trend. Diagnostic tests for residual serial correlation and heteroskedasticity show no signs of serious misspecification in the model. Notice that the null hypothesis of normality is rejected for the residuals of Y_t , IR_t and ER_t , and the system for the 5% significance level; however, nonnormality of residuals does not bias the results of the cointegration estimation (Gonzalo, 1994).

With identifying one cointegrating vector ($r = 1$), the test for the long-run weak exogeneity is conducted to examine whether any of the variables can be treated as exogenous in a cointegrating vector (Johansen and Juselius, 1990). This test can be done by restricting a parameter in speed-of-adjustment to zero ($\alpha_i = 0$). The results show that the null hypothesis of weak exogeneity cannot be rejected for commodity prices, interest rates, and exchange rates at the 5% significance level, indicating that these three variables are weakly exogenous to the long-run relationship in the model. The finding suggests that commodity prices, interest rates, and exchange rates are driving variables in the system and influence the long-run movements of farm income, but are not affected by farm income; in other words, such variables as P_t , IR_t , and ER_t can be treated as the explanatory variables in the model.⁴

In sum, the Johansen cointegration procedure shows that commodity prices, interest rates, and exchange rates are exogenous in the model and there exists a unique long-run relationship between U.S. farm income and the

Table 1. Results of DF-GLS Unit Root Tests

Variable	Level		First Difference	
	DF-GLS Statistic	Lag	DF-GLS Statistic	Lag
Y_t	-2.01	8	-4.98**	7
P_t	-0.72	6	-3.48**	5
ER_t	-1.80	6	-3.41**	2
IR_t	-2.41	4	-3.75**	3

Note: Y_t , P_t , ER_t and IR_t represent U.S. farm income, U.S. commodity price, exchange rate, and U.S. interest rate, respectively. ** denotes rejection of the null hypothesis of a unit root at the 5% level. The 5% and 10% critical values for the DF-GLS tests are -3.10 and -2.81, respectively. The lag order for the DF-GLS is chosen by the Ng and Perron (2001) new information criterion (NIC).

⁴To save space, we do not report the results here.

three explanatory variables in the model; hence, the ARDL model specified in Equation (6) can be pursued on them.

Empirical Results

The ARDL modeling starts with determination of the lag length (p) in Equation (6). For this purpose, we use the Akaike information criterion (AIC) and Lagrange multiplier (LM) statistics for testing the hypothesis of no serial correlation against lag length 3. With the selected lag lengths, we then test the existence of a long-run relationship (cointegration) among variables. For this purpose, the null hypothesis of nonexistence of long-run relationship, namely $H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$ in Equation (6), is tested using an F -test with the critical value tabulated by Pesaran, Shin, and Smith (2001).⁵ The results show that with three lags ($p = 3$), the calculated F -statistic is 6.87 and lies outside the upper critical value 4.45 at the 10% level.⁶ As a result, the null hypothesis of no cointegration can be rejected, indicating the existence of a stable long-run relationship among farm income, commodity prices, interest rates, and exchange rates. The LM statistic shows that the null of no serial correlation cannot be rejected at the 5% level ($\chi^2(3) = 2.95$, p -value = 0.39). This also confirms the findings obtained from the Johansen procedure.

Having found the existence of the long-run relationship, we then shift to the second stage to estimate the long-run coefficients and error-correction model. Specifically, the long-run model is estimated from the reduced-form solution of Equation (6) in which the first-differenced variables jointly equal zero. The error-correction model is estimated by the ARDL approach. For this purpose, a general-specific

modeling approach guided by the AIC is used to select the optimal lag structure of the ARDL specification.

The results of the long-run coefficient estimates from the ARDL model show that all variables are statistically significant at least at the 10% significance level (Table 3). Specifically, U.S. farm income has a positive long-run relationship with U.S. commodity prices. This implies that an increase in commodity prices leads to a rise in U.S. farm income in the long-run. In fact, significant growth in the use of farm commodities (i.e., corn) for biofuel production under the Energy Security Act of 2005 and the Energy Independence and Security Act of 2007 has indeed resulted in record or near-record prices for key commodities (i.e., corn, soybeans and wheat), thereby substantially contributing a boost in farm income over the last two years. In addition, U.S. farm income is found to have a negative long-run relationship with interest rates, indicating that an increase in interest rates causes a decline in farm income. Indeed, U.S. agriculture is very sensitive to interest rates since it is one of the most capital-intensive industries in the economy. Changes in interest rates thus have an effect on a farmer's decision to borrow credit and thus on farm production and inventory decisions, thereby influencing farm income. Finally, U.S. farm income has a negative long-run relationship with exchange rate. This suggests that a weakened U.S. dollar makes U.S. agricultural exports more competitive abroad, allowing domestically-produced commodities a better chance to compete with foreign markets, thereby enhancing farm income.⁷ Particularly, recent trends in U.S. commodity prices and exports provide a good example of the importance of exchange rate impact on the U.S. farm sector. Specifically, U.S. commodity prices have been at unusually high levels between

⁵To determine whether a deterministic linear trend is required, Equation (6) is estimated with and without a linear trend. However, our findings are more conclusive when the F -test is applied to Equation (6) with a linear trend.

⁶With three regressors and unrestricted intercept and unrestricted trend, F -statistic for 10% critical value bounds is (3.47, 4.45), which is taken from Table CI in Pesaran, Shin, and Smith (2001).

⁷Note that, since U.S. agriculture is twice as dependent on overseas markets as the rest of the U.S. economy, international trade in agriculture is extremely important for the U.S. farm economy; for example, agriculture's export reliance, measured as exports divided by farm cash receipts, ranged from 27% to 37% over the 2000–2007 period.

Table 3. Estimated Long-Run Coefficients Using the ARDL Bound Tests

Variable	Coefficient
P_t	0.39 (8.69)**
ER_t	-0.87 (-5.38)**
IR_t	-0.02 (-1.75)*
Constant	-10.88 (-5.23)**

Note: Y_t , P_t , ER_t and IR_t represent U.S. farm income, U.S. commodity price, exchange rate, and U.S. interest rate, respectively. ** and * denote significance at the 5% and 10% levels, respectively. t values are given in parentheses.

2007 and May 2008, due mainly to a sharp increase in corn-based ethanol production. Under this circumstance, all other things held constant, U.S. exports are expected to decrease as foreign buyers react to these higher commodity prices. Instead, the depreciation of the U.S. dollar over the same period has offset those price increases and made U.S. commodity more attractive in the international market, thereby resulting in a substantial increase in U.S. commodity exports (i.e., corn, soybeans and wheat).

The error-correction model is estimated by the ARDL approach to capture the short-run dynamics that seem to exist between the U.S. food price and its main determinants (Table 4). The results show that, as seen in the long-run results, commodity prices and interest rates are the significant factors affecting U.S. farm income in the short-run. It is also found that exchange rates are not statistically significant even at the 10% significance level, indicating that exchange rate has little short-run effect on the U.S. farm income. In addition, the coefficient of the error-correction term (ec_{t-1}) is found to be negative and statistically significant at the 5% significance level, confirming the existence of the long-run relationship among variables (Table 4). As noted earlier, Kremers, Ericson, and Dolado (1992) and Banerjee, Dolado, and Mestre (1998) show that a highly significant error-correction term is further proof of the existence of stable long-run relationship. The coefficient of ec_{t-1} in our model is -0.45, implying that deviation from the long-run equilibrium is corrected by 45% in one quarter. Finally, the diagnostic tests on the

Table 4. Estimated Short-Run Coefficients Using the ARDL Bound Tests

	Variable	Coefficient
Coefficient estimates	ΔP_t	0.36
		(-1.67)*
	ΔER_t	-0.14
		(-0.31)
	ΔIR_t	-0.02
		(-2.19)**
	ΔIR_{t-1}	0.07
Diagnostic tests		(0.93)
	ΔIR_{t-2}	-0.05
		(-1.99)**
	Constant	0.01
		(1.46)
	ec_{t-1}	-0.45
		(-4.58)**
Diagnostic tests	Serial correlation	1.56
		[0.19]
	Heteroskedasticity	0.81
		[0.53]
RESET		0.26
		[0.61]

Note: ** and * denote significance at the 5% and 10% levels, respectively. Parentheses are t -statistics. Brackets in diagnostic tests are p -values.

short-run models as a system indicate no serious problems with serial correlation, heteroskedasticity, and functional form specification.

Concluding Remarks

While the empirical literature on the macro-agricultural trade linkages in the U.S. is fairly large, relatively little attention has been paid to the direct effects of macroeconomic variables on U.S. farm income. In this study, therefore, we have attempted to analyze the short- and long-run effects of changes in commodity prices, interest rates, and exchange rates on U.S. net farm income. For this purpose, the ARDL approach to cointegration is adopted to estimate quarterly data from 1989:Q1–2008:Q2. The results show that while the exchange rate plays a crucial role in influencing the long-run behavior of U.S. farm income, it has little impact on farm income in the short-run. We also find that commodity prices and interest rates have been significant factors influencing U.S.

farm income in both the short- and long-run over the last two decades. These findings further suggest that movements of macroeconomic variables have had and will continue to have a greater influence on the resiliency and sustainability of the U.S. farm economy as U.S. producers rely more heavily on domestic and international market forces for profits and market opportunities.

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