The U.S. Agricultural Sector and the Macroeconomy

Jungho Baek and Won W. Koo

The effects of the exchange rate, the U.S. agricultural price, the domestic income, and the interest rate on the U.S. net farm income are investigated in a cointegration framework. For this purpose, the Phillips-Hansen fully-modified cointegration (FM-OLS) procedure is applied to annual data for the period 1957–2008. Results suggest that there exists the long-run equilibrium relationship between the U.S. net farm income and the selected macroeconomic variables. We also find that the exchange rate and U.S. agricultural price are more important than other variables in determining the U.S. net farm income.

Key Words: agricultural price, exchange rate, gross domestic product, interest rate, net farm income, Phillips-Hansen fully-modified cointegration technique

JEL Classifications: C22, E23, Q11

Changes in the macroeconomy have significant effects on the performance of the U.S. agricultural economy. During the period 2003–2007, for example, the U.S. and global economies had been experiencing strong growth. Over this period, the real U.S. gross domestic product (GDP) grew by nearly 3% annually. The rest of the world (less United States) witnessed approximately 4% of the annual real GDP growth rate during the same period, exceeding the annual growth rate of 2.5% during the 1990s (Figure 1). The U.S. agricultural sector benefited from rising economic prosperity, which resulted in growth in U.S. agricultural exports to record-high levels and historically high agricultural commodity prices (Figure 2). In addition, significant growth in the

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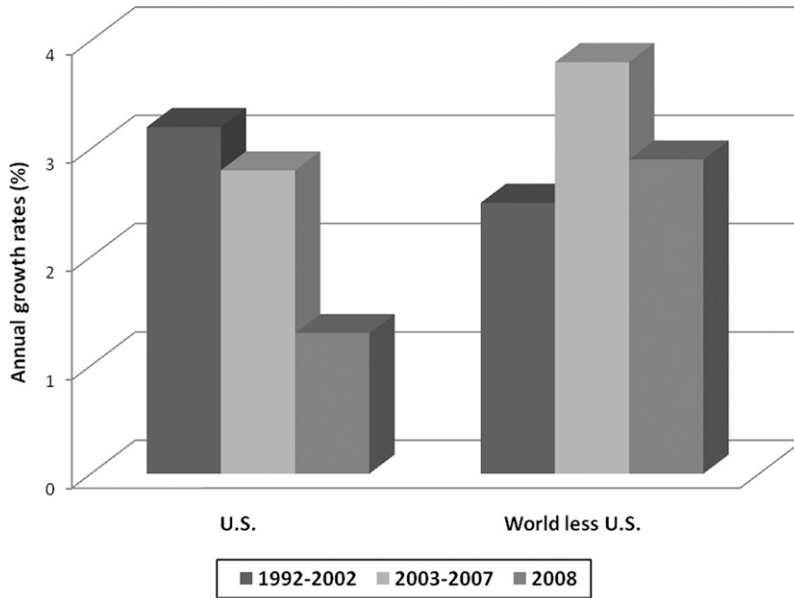
use of farm commodities (i.e., corn) for biofuel production contributed to record or near-record commodity prices in recent years. With double-digit growth rates since 2002, for example, production of fuel ethanol reached a record high of 9.2 billion gallons in 2008, more than 40% increase over 2007. As a result, corn prices climbed up to $4.78 per bushel in 2008, a 43% increase from the average of the past 15 years. The combination of these factors contributed to growth of 43% in the U.S. net farm income during the period 2003–2007 ($60.5 billion in 2003 and $86.8 billion in 2007) (Figure 3). Since 2008, however, this expansion trend has changed dramatically as the financial crisis quickly spread throughout the U.S. economy and the rest of the world, thereby pushing many U.S. trade partners into recessions by the second half of 2008. As a result, the U.S. Department of Agriculture (USDA) projects that U.S. agricultural exports could decline from $115 billion in 2008 to $96 billion in 2009; in turn, the U.S. net farm income is forecast to plunge as much as 33% (around $60

Figure 1. U.S. and World Real GDP Growth Rates

billion) in 2009 (Figure 3).[1] Given the dependence of U.S. agriculture on the macroeconomy, it is important to fully understand the macroeconomic factors that contribute to the ever-changing pattern of the U.S. farm economy.

Over the past decades, many scholars have attempted to investigate the main factors linking U.S. agriculture to the macroeconomy (e.g., exchange rates, interest rates, and income growth patterns), which is referred to as *the agriculture-macroeconomy nexus* (Baek and Koo, 2007, 2008; Bessler and Babula, 1987; Bradshaw and Orden, 1990; Chambers, 1981, 1984; Orden, 2002; Schuh, 1974). These studies can be generally summarized as follows: (1) their empirical focuses have been typically on the impacts of macroeconomic variables on U.S. agricultural trade/prices; and (2) their

attentions have mostly been on analysis of the short-run adjustment process of U.S. agriculture associated with changes in macroeconomic variables. Until recently, however, few studies have considered the effects of macroeconomic variables on the U.S. farm income. To our knowledge, Baek and Koo (2009) is the only study that has attempted to address this issue. They use an autoregressive distributed lag (ARDL) model to examine the short- and long-run effects of changes in macroeconomic variables on the U.S. farm income. They conclude that the commodity price and interest rate are significant determinants of the U.S. farm income in both the short- and long-run, while the exchange rate is a significant factor only in the long-run. However, their time-series analysis includes agricultural GDP as a proxy for the U.S. net farm income. This could be problematic because the two series differ in measuring farm income; e.g., gross value added (agricultural GDP) versus net value added (net farm income), and thus agricultural GDP could be vastly different from net farm income. Net farm income is a value of production measure, indicating the farm operators' share of the net value added to the national economy within a calendar year; in other words, net farm

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[1] Notice that despite the severe economic downturn, the record-high agricultural exports and commodity prices kept continuing in 2008, which, in turn pushed up U.S. net farm income to a record high of $89.3 billion in 2008 (Figures 2 and 3). As a consequence, the recession's impact on U.S. agricultural sector was not as severe as on the overall U.S. economy in 2008.
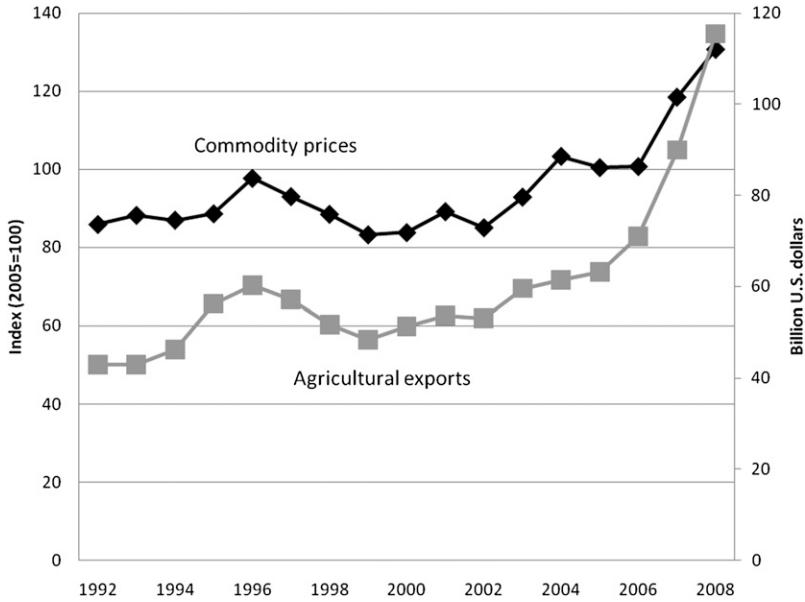
Figure 2. U.S. Agricultural Commodity Prices and Agricultural Exports

income is defined as the difference between value of agricultural sector production and total production expenses (costs).[2] Further, given that empirical results are contingent on the accuracy of the measures of the U.S. farm income, it is crucial to incorporate net farm income, instead of agricultural GDP, when examining macroeconomic effects on the U.S. farm income. Only in so doing, we gain a better understanding and thus more accurate assessments of the nature of these relationships.

The objective of this paper is thus to reexamine the dynamic relationship between the U.S. farm income and macroeconomic variables. To address this issue adequately, unlike previous studies (i.e., Baek and Koo, 2009), we use the most appropriate measure of the U.S. farm income available, that is, the U.S. net farm income, and attempt to identify the long-run equilibrium relationships between U.S. net farm income and macroeconomic aggregates, such as exchange rates, interest rates and income, and agricultural variables, including commodity prices and input prices. For this

purpose, using annual data for the period 1957–2008, we adopt the fully-modified cointegration technique (FM-OLS) developed by Phillips and Hansen (1990). Since the FM-OLS is less sensitive to changes in lag structure and performs better for small or finite sample sizes than other cointegration techniques (e.g., Engle and Granger, 1987; Johansen, 1988), this approach is a fully efficient method of estimating long-run equilibrium relationships among the selected variables (Hargreaves, 1994). The remaining sections present analytical framework, empirical methodology, empirical findings, and conclusions.

The Linkages between U.S. Agriculture and the Macroeconomy

Changes in macroeconomic variables have direct and indirect effects on the U.S. farm sector (Shane et al., 2009). The direct effects primarily come from demand and supply side changes within the U.S. economy. Specifically, on the demand side, changes in the U.S. real income (GDP) often dramatically impact the agricultural economy. A decrease in the U.S. GDP, for example, is likely to decrease demand for agricultural goods through the decreased purchasing power of U.S. consumers, which, in

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[2] In fact, the USDA recommends that for analytical purposes, net farm income is the more appropriate framework for presenting the farm sector's income statement.
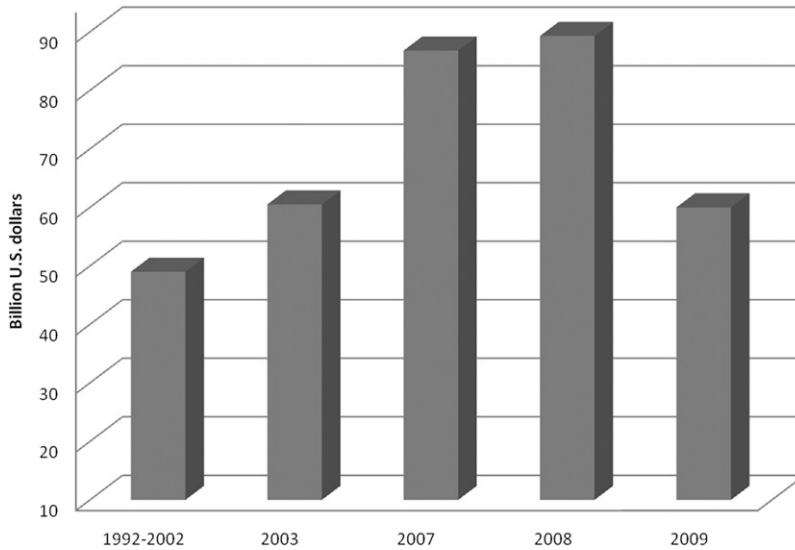
Figure 3. U.S. Net Farm Income

turn pushes down agricultural commodity pri-
ces and thus farm income. On the supply side,
on the other hand, since U.S. agriculture is
a highly capital-intensive industry, changes in
U.S. financial markets (i.e., interest rates) sig-
nificantly influence agricultural markets
through the changing costs, influencing in-
vestment decisions and interest rate risk. A
decrease in interest rates, for example, reduces
a farmer's cost of borrowing money for short-
term production (operating) costs (e.g., fertil-
izer, seed, and livestock expenses) and long-
term capital investments (e.g., land, machinery,
equipment, and inventories), thereby resulting
in a positive effect on farm income. By con-
trast, the increasingly unexpected and adverse
movement of interest rates could be a source of
operating risk for farmers and agribusinesses.
A sudden spike in interest rates, for example, is
likely to reduce profitability of farms and in-
vestment through the increased interest ex-
penses, thereby resulting in a detrimental effect
on farm income.

The indirect macroeconomic effects on ag-
riculture mainly originate from their impacts on
exchange rates and energy prices (which are
fluctuating as changes in U.S. and world eco-
nomic activities occur). According to economic
theory, for example, a decrease in U.S. interest
rates relative to foreign interest rates causes the
demand and value of the U.S. dollar to decrease
(depreciation) as foreign investors tend to in-
vest in alternative assets (e.g., foreign govern-
ment securities). The depreciation of the U.S.
dollar makes U.S. agricultural goods more
competitive in both domestic and foreign
markets through a decline (rise) in exports
(import) prices, thereby contributing to higher
farm income. A decrease in U.S. GDP, on the
other hand, leads to a decline in world eco-
nomic growth, which, in turn causes energy
prices (i.e., crude oil prices) to fall. Generally,
the drop in energy prices has a negative de-
mand-side effect and positive supply-side ef-
fects on farm income (Shane et al., 2009). A
decrease in energy prices tends to reduce the
costs of production through decreases in the
prices of energy-based agricultural inputs (e.g.,
fertilizer, diesel, and agricultural chemicals),
thereby resulting in a positive effect on farm
income, known as a positive supply-side effect.
Lower energy prices (i.e., crude oil prices), on
the other hand, may lead to significant decline
in the use of farm commodities (i.e., corn)
through decreased biofuel production, which,
in turn pushes down commodity prices to
a level that more than offsets the decrease in
production costs resulting from lower energy
prices, thereby having a negative effect on farm
income, known as a negative demand-side

effect. As such, the fall in energy price may not affect the U.S. farm income uniformly.

Empirical Methodology

The FM-OLS Approach

We adopt the FM-OLS procedure developed by Phillips and Hansen (1990) to examine dynamic interrelationship between the U.S. net farm income and macroeconomic factors. The FM-OLS method uses an econometric model as follows:

(1) $\quad z_t = \alpha + \beta_1' x_t + \varepsilon_t$

where z_t is an $I(1)$ variable (i.e., $z_t = FY_t$); and x_t is a $(k \times 1)$ vector of $I(1)$ regressors (i.e., $x_t = [P_t, GDP_t, ER_t, IR_t]$), which are assumed not to be cointegrated among themselves. In addition, it is assumed that x_t has the following first-difference stationary process:

(2) $\quad \Delta x_t = \mu + v_t$

where μ is a $(k \times 1)$ vector of drift parameters; and v_t is a $(k \times 1)$ vector of $I(0)$, or stationary variables. Finally, it is also assumed that $\xi_t = (\varepsilon_t, v_t')'$ is strictly stationary with zero mean and a finite positive-definite covariance matrix Σ.

The OLS estimators of α and β_1' in Equation (1) are consistent even if x_t and ε_t (equivalently v_t and ϵ_t) are contemporaneously correlated (Engle and Granger, 1987; Stock, 1987). In general, however, the OLS regression involving nonstationary variables no longer provides the valid interpretations of the standard statistics such as t- and F-statistics in Equation (1). Further, unless nonstationary variables combine with other nonstationary variables to form stationary cointegration relationships, the estimation can falsely represent the existence of a meaningful economic relationship (i.e., spurious regression) (Harris and Sollis, 2003). To address these problems adequately, it is required to correct the possible correlation between v_t and ε_t, and their lagged values. The Phillips-Hansen fully-modified ordinary least squares estimator takes account of these correlation in a semi-parametric manner. As a result, the FM-OLS is an optimal single-equation technique for estimating with $I(1)$ variables (Phillips and Loretan, 1991).[3]

Equation to be Estimated

The macroeconomic aggregates and agricultural factors described earlier are employed to guide the selection of variables for the cointegration analysis. Since the main focus of this paper is the explanation of variations in the U.S. net farm income (FY_t), variables that are considered to be of central importance in affecting the U.S. net farm income are selected for inclusion in our empirical model as follows:

(3) $\quad FY_t = f(P_t, GDP_t, ER_t, IR_t)$

where P_t is the agricultural price; GDP_t is the real U.S. income; ER_t is the exchange rate; and IR_t is the interest rate.[4] Equation (3) can be specified in a log linear form as follows:

(4)
$$\ln(FY_t) = \alpha + \beta_1 \ln(P_t) + \beta_2 \ln(GDP_t) \\ + \beta_3 \ln(ER_t) + \beta_4 \ln(IR_t) + \varepsilon_t$$

Note that the agricultural price (P_t) here is defined as the ratio of the commodity price to the input price, providing an indication of the change that has occurred in the prices farmers receive for their commodities relative to the change in the cost of inputs, referred to as the agricultural output-input price ratio. When this ratio is greater (less) than 1.0, it indicates that farm commodity (input) prices increase at a faster rate than farm input (commodity) prices, thereby having a positive (negative) effect on farm income; hence, it is expected that $\beta_1 > 0$. Since an increase in U.S. income leads to an increase in demand for agricultural products

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[3] Of course we can handle the nonstationarity of time-series data using first or higher order differences rather than in levels in a framework of ordinary least squares. By differencing, however, we may lose valuable information concerning long-run properties inherent in the levels of time-series data (Perman, 1991). With the long-run information embedded in the levels data, cointegration approach (i.e., FM-OLS) offers a solution to this dilemma.

[4] Energy prices were also included in the model to capture the indirect macroeconomic impacts on agriculture, but were excluded from the final model because of coefficient insignificance.

and boosts farm income, it is expected that $\beta_2 > 0$. As to the effect of exchange rates, it is expected that $\beta_3 < 0$, since the depreciation of the U.S. dollar causes an increase in exports of agricultural goods and thus farm income. Finally, it is expected that $\beta_4 < 0$ since a rise in interest rates have a negative effect on farm income through the increased production costs and interest rate risk.

Data

Our data used for the analysis contains 52 annual observations for the period 1957–2008. The U.S. net farm income is obtained from the Economic Research Service in the USDA. The prices received index for all farm products and prices paid index for commodity, services, interest, taxes and wage rates on the 2005 base (2005=100) taken from the National Agricultural Statistics Service are used proxies for agricultural commodity prices and input prices, respectively. The U.S. agricultural price used in Equation (1) is then defined as the ratio of prices received index to prices paid index. The U.S. real gross domestic product index (2005 = 100) is used as a proxy for the real income of the United States and is obtained from the International Financial Statistics (IFS) database published by the International Monetary Fund. The effective federal fund rate is used as a proxy for U.S. interest rate and is obtained from the Board of Governors of the Federal Reserve System. The exchange rate is the trade-weighted (effective) exchange rate (2005 = 100) and is collected from the IFS. Since the exchange rate is expressed as the number of trading partner's currency per unit of the U.S. dollar, a decline in exchange rate indicates a real depreciation of the U.S. dollar. The GDP deflator (2005 = 100) obtained from the IFS is used to derive real values of U.S. net farm income. Finally, all variables are in natural logarithms.

Empirical Results

The first requirement for the use of the FM-OLS cointegration procedure is that the variables in Equation (4) must be nonstationary $I(1)$ processes. The presence of a unit root in the five variables is tested using the augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) and the more recent Dickey-Fuller generalized least squares (DF-GLS) test (Elliott, Rothenberg, and Stock, 1996). The results show that, for the level series, the ADF and DF-GLS tests fail to reject the null of nonstationary for all the five variables at the 5% level (Table 1).[5] For the first-differenced series, on the other hand, the results of these tests indicate that all the variables are stationary; thus, we conclude that all the variables are nonstationary $I(1)$ processes. Both unit root tests include deterministic components of an intercept and a trend.

It should be pointed out that, since the FM-OLS is a single-equation cointegration procedure, it is essentially valid in the presence of a single cointegration vector. As a preliminary investigation to identify the number of cointegration vectors, therefore, we employ the widely used Johansen multivariate cointegration procedure (Johansen, 1988) using the same set of variables. The results of rank tests show that, with a lag length of one ($k = 1$) and an unrestricted constant and a linear trend, the trace statistics reject the null of no cointegrating vector (r = 0), but fail to reject the null of one cointegrating vector (r = 1) at the 5% significance level (Table 2), suggesting the existence of a unique long-run relationship among the five variables. With one identified cointegrating vector, the test for long-run exclusion is then conducted to examine whether any of the five variables can be excluded from a cointegrating vector.[6] The results show that all five variables are

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[5] It should be pointed out that, although the ADF test has been popular and widely used in empirical work, it is also known to have notoriously low power (Maddala and Kim, 1998). The DF-GLS test, on the other hand, optimizes the power of the ADF test by detrending. As Elliott, Rothenberg, and Stock (1996, p. 813) note: "Monte Carlo experiments indicate that the DF-GLS works well in small samples and has substantially improved power when an unknown mean or trend is present." In this paper, therefore, we use the DF-GLS test as a supplement to the standard ADF test in order to infer overwhelming evidence in determining the presence of nonstationarity in the data.

[6] The null hypothesis of exclusion test is formulated by restricting the matrix of long-run coefficients to zero ($\beta_i = 0$) (Johansen and Juselius, 1990). The results are not reported here for brevity, but can be obtained from the authors upon request.

Table 1. Results of Unit Root Tests

	ADF Test			DF-GLS Test		
Variable	Level	First Difference	Decision	Level	First Difference	Decision
ln (Net farm income)	−2.08	−7.45**	$I(1)$	−1.99	−6.86**	$I(1)$
	(2)	(1)		(1)	(1)	
ln (Price)	−2.27	−4.36**	$I(1)$	−2.57	−5.63**	$I(1)$
	(2)	(2)		(1)	(1)	
ln (Exchange rate)	−2.95	−4.60**	$I(1)$	−2.79	−4.35**	$I(1)$
	(2)	(1)		(2)	(1)	
ln (GDP)	−2.51	−5.47**	$I(1)$	−1.97	−5.16**	$I(1)$
	(1)	(1)		(1)	(1)	
ln (Interest rate)	−2.02	−7.04**	$I(1)$	−1.29	−5.71**	$I(1)$
	(2)	(1)		(2)	(1)	

Notes: The 10% and 5% critical values for the ADF (DF-GLS), including a constant and a trend, are −3.18 and −3.50 (−2.88 and −3.18), respectively; Parentheses are lag lengths. ** And * denote the rejection of the null hypothesis of nonstationarity at the 5% and 10% significance levels, respectively.

statistically relevant to the cointegrating space and cannot be excluded from the long-run relationship. Finally, using the relevant long-run coefficients (β_1) estimated by the Johansen method and normalizing on the U.S. net farm income (FY_t), the signs and magnitude of other four variables (P_t, GDP_t, ER_t, and IR_t) in the long-run relationship are consistent with those estimated using the FM-OLS estimator.[7] From these findings, therefore, the use of the FM-OLS cointegration analysis can be justified to estimate Equation (4).[8]

With strong evidence that each of our data series is nonstationary $I(1)$ processes, the FM-OLS is applied to estimate the long-run cointegration relationship in Equation (4). The results of the ADF and DF-GLS tests performed on the residuals from the estimated Equation (4) show that the null hypothesis can be rejected at the 5% level (Table 3). This suggests the existence of long-run relationship between FY_t and the set of explanatory variables (P_t, GDP_t, ER_t, and IR_t) in Equation (4); in other words, even though individual series may have trends or cyclical or seasonal variations, the movements in one variable are matched (at least approximately) by movements in other variables (Perman, 1991).

Additionally, the results show that all estimates are statistically significant at the 5% level and have the expected signs (Table 3). A positive coefficient of the agricultural output-input price ratio on the net farm income suggests that, in the long-run, U.S. farm income goes up as agricultural commodity prices increase at a faster rate

[7] After normalizing the coefficient of U.S. net farm income, the long-run equilibrium relation among the five variables can be represented as; $FY_t = 0.89\,P_t + 0.26\,GDP_t − 0.80\,ER_t − 0.06\,IR_t − 0.01\,trend$.

[8] The sample size could be an issue of concern for a cointegration model, since finite-sample analyses can bias the cointegration test toward finding the long-run relationship either too often or too infrequently. Hakkio and Rush (1991) note: "Our Monte Carlo studies show that the power of a cointegration test depends more on the span of the data rather than on the number of observations. Furthermore, increasing the number of observations, particularly by using monthly or quarterly data, does not add any robustness to the results in tests of cointegration." Following these authors, the annual data used in this study (52 observations for the period 1957–2008) are considered to be long enough to reflect the long-run relationship among the selected variables. Further, Hargreaves (1994) shows that the FM-OLS is highly accurate and preferable to several other estimators of cointegrating vectors, particularly for small or finite sample sizes.

Table 2. Results of Johansen Cointegration Test

Null Hypothesis	Eigenvalue	Trace Statistics
$H_0:r = 0$	0.499	90.89 [0.03]**
$H_0:r \leq 1$	0.445	57.07 [0.16]
$H_0:r \leq 2$	0.206	28.16 [0.62]
$H_0:r \leq 3$	0.203	16.84 [0.44]
$H_0:r \leq 4$	0.110	5.71 [0.51]

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

Table 3. Estimated Long-Run Coefficients of the U.S. Net Farm Income Model

Variable	ln(Net Farm Income)	
	Coefficient	*t*-Statistic
ln (Price)	0.96	53.52**
ln (Exchange rate)	−0.84	−14.72**
ln (GDP)	0.14	11.86**
ln (Interest rate)	−0.04	−6.33**
Constant	−4.27	−11.69**
ADF statistic	−4.19 [1]**	
DF-GLS statistic	−3.86 [1]**	
ec_{t-1}	−0.15 (−2.15)**	

Notes: The 10% and 5% critical values for the ADF (DF-GLS), including a constant and a trend, are −3.18 and −3.50 (−2.88 and −3.18), respectively. ec_{t-1} indicates an error-correction term.
** Denotes significance at the 5% level. Brackets are lag lengths.

than agricultural input prices. A negative coefficient of the exchange rate on the net farm income indicates that the weakening U.S. dollar makes the price of U.S. agricultural goods more competitive abroad and leads to an increase in U.S. agricultural exports, thereby boosting the farm income. In fact, since U.S. agriculture is a heavily trade-dependent sector, agricultural trade is a significant contributor to the U.S. farm economy; during the period 2000–2007, for example, the farm share of U.S. economic activity generated by agricultural exports ranged from 26% to 41%. A positive coefficient of the real GDP on the net farm income implies that a rise in real domestic income leads to an increase in demand for agricultural goods through the increased purchasing power of U.S. consumers, thereby enhancing the farm income. Finally, a negative coefficient of the interest rate on the net farm income suggests that an increase in interest rates have a significant adverse effect on the farm income through the increasing costs and interest rate risk.

It should be pointed out that among the macroeconomic factors, the exchange rate is more pronounced than the real GDP and interest rate in determining the U.S. net farm income (Table 3). For example, a 1% decrease in the exchange rate causes the farm income to increase by approximately 0.84%, while the farm income increases by only 0.14%, given

a 1% increase in the real GDP. The most likely explanation for a relatively smaller income effect is that, since U.S. consumers spend a small portion of their disposable income for food and have a sufficiently high standard of living, demand for agricultural goods may not be sensitive to changes in real income; in other words, the income elasticity of demand for most types of food is pretty low in the United States. As for a weak interest rate effect, on the other hand, one plausible explanation is that farmers now have a wider range of risk management tools such as hedging, crop insurance, and forward contracts to manage financial risks and thus increase their resilience to the temporary shocks resulting from financial uncertainty.

For completeness, we also estimate the error-correction model using the residual obtained from Equation (4) in order to examine the short-run adjustment to long-run steady state, as well as to confirm the existence of the cointegration relationship.[9] The results show that the coefficient of the error-correction term (ec_{t-1}) is negative and statistically significant at the 5% level (Table 3). The negatively significant coefficient of ec_{t-1} implies that the equilibrium relationship will hold in the long-run, even with shocks to the system; with a shock to the U.S. agricultural market, for example, the U.S. net farm income adjusts by 15% to the long-run equilibrium in a year. Additionally, the statistically significant ec_{t-1} further supports the validity of cointegrating relationship in Equation (4). Finally, the multivariate diagnostic tests on the estimated model as a system indicate no serious problems with serial correlation, heteroskedasticity, and normality; hence, the model is well defined.

Concluding Remarks

In this paper we re-examine the main factors linking the U.S. farm income to the U.S. macroeconomy. To address this issue adequately, we use the more appropriate framework for representing the farm sector's income statement, that

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[9] The Granger representation theorem shows that, if the variables are all *I*(1) and cointegrated, then the error-correction model must exist (Engle and Granger, 1987).

is, the U.S. net farm income, and attempt to assess the effects of the exchange rate, the U.S. agricultural price, the domestic income (GDP), and the interest rate on the U.S. net farm income in a cointegration framework. For this purpose, the FM-OLS cointegration procedure is applied to annual time-series data from 1957–2008. The results of the FM-OLS suggest that there is one stable long-run equilibrium relationship between the U.S. net farm income and the selected macroeconomic variables. The negatively significant coefficient of the error-correction term in the vector error correction model further validates the existence of an equilibrium relationship among the variables. We also find that the exchange rate and U.S. agricultural price are more powerful determinants of the U.S. net farm income than other variables such as domestic income and interest rate.

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