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Exchange Rates, Foreign Income, and U.S. Agriculture

by

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Abstract

This paper focuses on estimating the effects of trade partner income and real trade-weighted exchange rates on US agricultural exports. For the period 1970-2003, a one percent annual increase in trade partners' income is found to increase total agricultural exports by about 1.6 percent while a one percent appreciation of the dollar relative to trade partner trade-weighted currencies decreases total agricultural exports by about 0.8 percent. We find these effects also carry over to 12 commodity subcategories, although the effects are conditioned by differences between bulk and high value commodities, and differences in the export demand from high compared to low income countries. We also find that the negative effect of exchange rate appreciation on exports often dominates the positive effect from income growth.

JEL *Classification Codes*: F10, F14, Q17

Key Words: Exchange rates, U.S. agricultural trade, U.S. agricultural commodity exports, U.S. agricultural export prices, foreign income.

I. Introduction

The exchange rate and foreign income growth are commonly perceived to be important macroeconomic variables affecting U.S. agricultural exports. Ample evidence suggests the growth in demand for U.S. agricultural exports is caused by growth in trade partner real income, but empirical evidence is lacking on the effect of the value of the dollar relative to trade partner currencies on U.S. agricultural exports[1]. This shortcoming is addressed by drawing upon recently available data on U.S. agricultural trade-partner trade-weighted exchange rates. Trade weighted exchange rates and trade-partner real gross domestic product are found to strongly affect the demand for aggregate U.S. agricultural exports. A similar relationship appears to hold for many sub-categories of

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[1] The dollar became a reserve currency for many countries when the gold standard was abandoned in 1973. Essentially, the dollar became a numeraire against which other currencies are evaluated. In this case, the value of the dollar is influenced by the collective actions of Central Banks and currency traders around the world.

agricultural exports, although differences in magnitude between bulk and high value exports are evident. Some of these differences appear to be linked to the tendency for bulk commodities to be exported to lower income countries while the high value commodities tend to be exported to higher income countries. We also find that growth in trade partner real GDP has positively influenced growth in U.S. exports over the period 1970-2005 while changes in the real trade-weighted exchange rate have tended to constrain exports.

Understanding how exchange rate and foreign income affects U.S. agricultural exports is important for understanding the impact of policies directed toward economic growth and development, compared with those designed to address major macroeconomic imbalances. They also provide insight into how these effects are likely to vary by commodity group. For example, the higher the income elasticity of export demand, the larger the impact of trade partner income growth on increasing U.S. agriculture's value added. The higher the price elasticity of a commodity real trade-weighted exchange rate, the more competitive is the international market for exports of a particular country, and the more sensitive are U.S. exports of this commodity to policy-induced distortions in trade partner currencies.

It has been difficult to find empirical evidence linking the relative value of the U.S. currency to exports in spite of the tendency for conceptual models to predict such a relationship. In his award-winning article, Schuh (1974) argued that a major part of the farm problem of the 1950's could be attributed to an overvalued dollar which depressed agricultural prices and exports. He attributed the post Bretton Woods agricultural export boom of the 1970s to the devaluation of the dollar, a devaluation that was in turn linked to monetary expansion as the U.S. attempted to monetize the effects of the first energy shock.

Conceptual contributions following this earlier work are based on static general equilibrium concepts such as that used by Dornbush and Fischer (1980). They extended the static model of Salter (1959) to show how a shock which increases household expenditures above total factor earnings can cause a country to live beyond its means. In this case, a monetary shock causes an increase in the price of home goods due to expenditure-induced growth in household demand, thus pulling resources from the production of traded goods while at the same time increasing the consumption of both home and traded goods. The country experiences an appreciation of its real exchange rate, a trade imbalance and a corresponding capital inflow. However, if a market for a country's currency is incorporated into this static model, then equilibration causes the nominal exchange rate to depreciate. This, in turn, leads to a rise in the domestic price of traded goods, and depreciation of the real exchange rate which, in a frictionless full information environment, returns the economy to the initial equilibrium. The monetary shock has no effect in real terms.

More recent analysis attempts to model capital markets in an inter-temporal environment in which prices are sticky so that markets do not adjust instantaneously to shocks[2]. Using

[2]Obstfeld, M (2002) studies exchange rate adjustments from the perspective of the New Open Economy

this approach, Chari et al (2002) attempted to explain the observed volatility and persistence in non-trend movements in real exchange rates in eleven OECD countries. They find that if prices are held fixed for at least one year, and risk aversion is relatively high, then the volatility of real exchange rates generated by their model is consistent with the data. However, the model is not able to generate the persistence of exchange rate movements also suggested by the data. Another problem is that their model generates a high correlation between real exchange rates and the ratio of consumption across countries (as suggested by the static framework), but empirical data show no clear pattern between these two variables.

Hughes and Penson (1985) and Rauser et al (1986) focused on the stickiness of prices of non-agricultural goods relative to agricultural goods to explain how monetary shocks that cause real exchange rate appreciation, in turn cause agricultural prices to overshoot their longer-run equilibrium. They suggest this effect is a tax on agricultural producers. Other empirical work (e.g., Bessler 1983, Orden, 1986a, 1986b and Orden and Fackler 1989) has drawn upon modern time series methods. Even here, however, it has been fairly difficult to show that monetary shocks have measurable effects on agricultural prices and trade. Shocks to U.S. financial market variables are found to explain about 20 percent of forecast error variance for exports, and about 10 percent for real agricultural prices one year ahead, and about 50 and 20 percent respectively for a three-year forecast horizon. Rose (1990, 1991) and Ostry and Rose (1992) also found that a real devaluation has generally no significant impact on trade.

Our approach follows that of Senhadji and Montenegro (1998). They construct an inter-temporal model from which they derive a reduced form "total" export-demand function with real weighted GDP per capita and the real trade-weighted exchange rate as activity variables. They fit this model to panel data of 60 countries, and find long-run income elasticities averaging about 1.5, while exchange rate elasticities tend toward unity. We adapted their model to U.S. commodity exports. Our point estimates tend to bracket their results, and suggest that for the period 1970-2003, the growth in demand for U.S. agricultural exports has been strongly enhanced by growth in trade partner traded-weighted real GDP, while often negatively affected by the appreciation of the U.S. traded-weighted exchange rate. We find that these effects also carry over to sub-commodity categories, although the effects are conditioned by differences between bulk and high value commodities. These differences are, in turn, closely associated with export demand from high compared to low income countries, with U.S. exports to low income countries being more exchange rate sensitive than exports to high income countries.

In the next section, the structural model is presented. This is followed by a review of the data used in the analysis. We then discuss the results and implications from fitting the

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Macroeconomics. He argues that some approaches have led to an unwarranted "elasticity pessimism" of adjustment to shocks. His findings for the case of trade between the U.S. and Canada suggest "…exchange rate changes alter relative international prices in conventional ways," (p. 16).

model to data.

II. The Model

We use a Ramsey style general equilibrium framework similar to that used by Senhadji and Montenegro (1998) to derive the specification of the empirical model.[3] Strong assumptions are necessary to derive this equation so that it can be estimated with available data.

Consider a three country world, the United States, a foreign country, and the rest of the world (ROW). Further assume the United States only trades with the foreign country. Let j indicate the source of the foreign country's imports, with j = 1, 2 denoting imports from the United States and the rest of the world, respectively. At each instant in time, infinitely-lived households in the foreign country consume d^* of their domestically produced good, denoted by e^*, and expend m^* on imported goods[4]. The prices of the imported goods, denoted (m_1^*, m_2^*) are (p_{m1}, p_{m2}), and expressed relative to the numeraire price of the domestically produced good, e^*. The difference between domestic supply and consumption $e^* - d^*$ equals the country's exports, denoted x^*. Household earnings accrue from the stock of bonds b^* at the world interest rate r and the flow of factor payments which equal the value of the domestically produced good, e^*. The stock of bonds b^* evolve according to $\dot{b}^*$ which can be positive or negative.

The decision problem of the representative household in the foreign country is to maximize the present value of utility

$$\underset{\{d^*, m_1^*, m_2^*\}_{t=0}^{t=\infty}}{Max} \; : \; \int_{t=0}^{t=\infty} u\left(d^*, m_1^*, m_2^*\right) Exp(-\delta t) dt$$

subject to the flow budget constraint:

$$\dot{b}^* = b^* r + (e^* - d^*) - p_{m1} m_1^* - p_{m2} m_2^*$$

where, $u\left(d^*, m_1^*, m_2^*\right)$ is the period utility function, and δ is the rate of time preference. A transversality condition is also imposed to rule out a Ponzi scheme.

To economize on the number of explanatory variables given our rather short time series of data, and to permit the estimating equations to be linear, we presume that the period utility function is addilog:

$$u\left(d^*, m_1^*, m_2^*\right) = B_o d^{*(1-\beta_o)} \left(1 - \beta_o\right)^{-1} + B_1 m_1^{*(1-\beta_1)} \left(1 - \beta_1\right)^{-1} + B_2 m_2^{*(1-\beta_2)} \left(1 - \beta_2\right)^{-1}$$

which imposes strong separability.

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[3] Strong separability and functional form assumptions are necessary to derive an aggregate export demand equation that can be used with existing data. In spite of this limitation, the estimation results are consistent with the theory.

[4] We use "*" to denote the foreign country.

From the present value Hamiltonian,

$$J = u\left(d^*, m_1^*, m_2^*\right)Exp(-\delta t) + \nu\left(b^*\left(r-n\right) + (e^* - d^*) - p_{m1}m_1^* - p_{m2}m_2^*\right)$$

where ν is the co-state variable, we obtain the first order conditions[5]:

$$\frac{\partial J}{\partial d^*} = B_o d^{*-\beta_o} Exp(-\delta t) = \nu \tag{1}$$

$$\frac{\partial J}{\partial m_1^*} = B_1 m_1^{*-\beta_1} Exp(-\delta t) = \nu p_{m1} \tag{2}$$

$$\frac{\partial J}{\partial m_2^*} = B_2 m_2^{*-\beta_2} Exp(-\delta t) = \nu p_{m2} \tag{3}$$

and

$$-\frac{\partial J}{\partial \nu} = \dot{\nu} = -(r)\nu$$

Eliminating the co-state variable, solving for traded goods, and expressing the result in logs yields

$$\log\left(m_1^*\right) = c_o + \frac{\beta_o}{\beta_1}\log\left(d^*\right) - \frac{1}{\beta_1}\log\left(p_{m1}\right) \tag{4}$$

where c_o contains the terms B_o, B_1 and β_1. U.S. agricultural import demand m_1^* from this country is the same as agricultural exports, which allows us to replace m_1^* by U.S. exports x_1. Since the budget constraint is presumed to hold at each instant in time, then in this model the foreign country's total exports are $x^* = e^* - d^* = GDP - d^*$. Interpreting e^* to be a countries earnings from domestic factors, i.e., GDP, we have

$$d^* = GDP^* - x^*.$$

The export demand equation (4) now becomes

$$\log\left(x_1\right) = c_o + \frac{\beta_o}{\beta_1}\log\left(GDP^* - x^*\right) - \frac{1}{\beta_1}\log\left(p_{m1}\right) \tag{5}$$

where we refer to the term, $GDP^* - x^*$, as the trade adjusted GDP.

The stochastic version of the model leads directly to a stochastic estimating equation similar to (5). The stochastic version of Senhadji and Montenegro (1998) presumes that e^* follows an AR (1) process with unconditional mean $\bar{e}^*$ and unconditional variance $\sigma^2/(1-\rho)^2$ where σ^2, the variance of the identically and independently distributed innovation ξ_t^*, and ρ determines the degree of persistence of the endowment shock at

[5]It can be shown that this problem yields the familiar Euler equation (Barro and Sala-i-Martin 2004, p.90) of optimal expenditure, E, over time; $r - \delta = \dot{E}/E$

each instant in time. The scale parameters in (1) to (3) are specified as

$$B_j = Exp(b_j + \varepsilon_{j,t}), \quad j = 0,1,2$$

where $\varepsilon_{j,t}$ are stationary shocks. In this case, the intercept term in (5) is:

$$c_o = \ln(B_1 / B_o) / \beta_1 + (\varepsilon_{1,t} - \varepsilon_{o,t}) / \beta_1$$

Drawing upon (5) for each category of U.S. commodity i exported to countries k =1,…,K,[6] our basic estimating equation is

$$\ln x_{i,t}^{US} = \alpha_i + \beta_{1,i} \ln(XR_{i,t}) + \beta_{2,i} \ln(\sum_{k=1}^{K} \alpha_i^k (GDP_t^k - x_t^k)) + \bar{\varepsilon}_{i,t} \qquad (6)$$

The dependent variable, $x_{i,t}^{US}$, is the total quantity of the i-th agricultural commodity exported in period t, $XR_{i,t}$ is the trade-weighted real exchange rate over all trading partners, k = 1,..,K importing this commodity. The second term is the weighted sum of the k-th country's real GDP less its exports where the weight α_i^k is the k-th country's adjusted GDP share of all importing country's total adjusted GDP. The construction and commodity specific features of these variables are discussed in the next section. The parameters to be estimated are the intercept term α_i, the price elasticity term $\beta_{1,i}$ associated with the exchange rate, and the income elasticity term $\beta_{2,i}$. The price elasticity term is expected to be negative and the income term is expected to be positive. The nature of $\bar{\varepsilon}_{i,t}$ is discussed below.

III. The Data and Selected Properties[7]

To create a measure of the U.S. exchange rate associated with the export of the i-th commodity in period t, we calculate $XR_{i,t}$, as a geometric exchange rate trade-weighted index. The formula is[8]:

$$XR_{i,t} = Exp(\prod_{ikt} TW_{i,k} XRI_{k,t})$$

The trade weights, $TW_{i,k}$, of the i-th commodity for country k are fixed based on the average U.S. export share during the 1998-2000 period. The exchange rate index $XRI_{k,t}$ for the k-th country is the real exchange rate, $XR_{k,t}$ defined as the product of the country's nominal exchange rate in local currency per dollar deflated by the ratio of the U.S. consumer price index to the country's consumer price index, and normalized to the year 2000,

$$XRI_{k,t} = XR_{k,t} / XR_{k,2000}.$$

[6] We switch from country index j to country index k to acknowledge that we are now working in a multicountry world rather than the simple theoretical world that we proposed above.

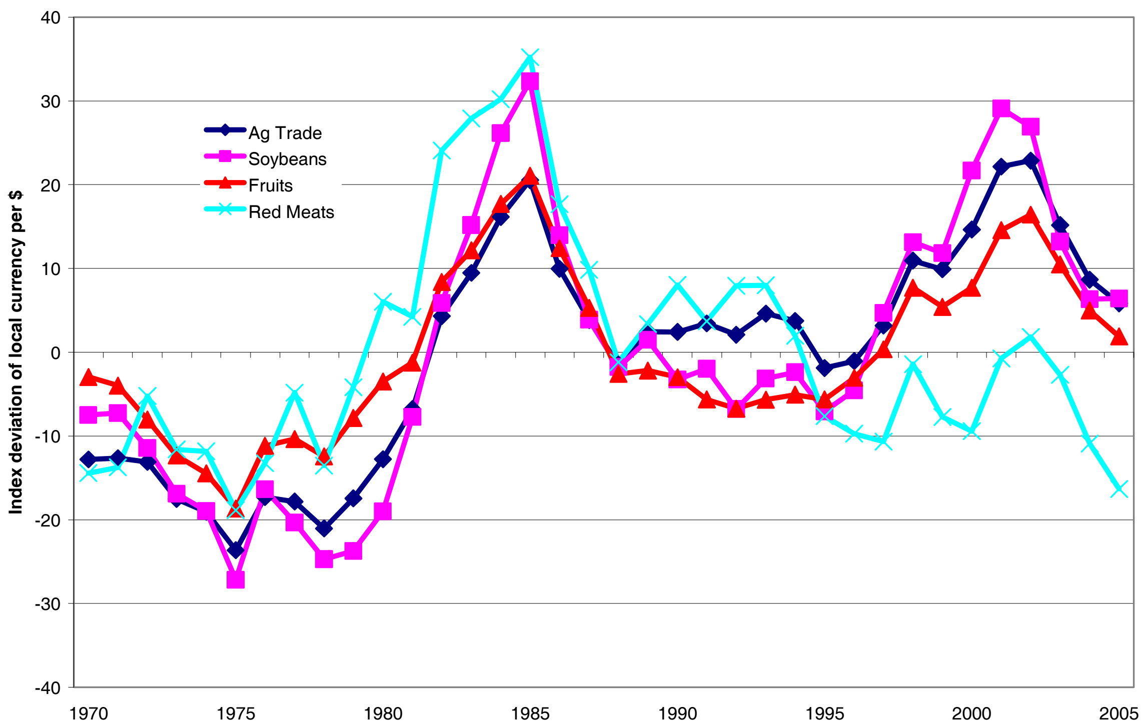
[7] See the data Appendix for definition of variable construction

[8] Thus, the exchange rate is the average trade-weighted index of foreign currencies. Since the composition of trade differs by commodity, each commodity faces a different exchange rate. For more details on exchange rates and access to commodity trade-weighted exchange rates maintained by the Economic Research Service go to www.ers.usda.gov/data/exchangerates/.

Differences among the series can be seen by calculating the deviations from the mean of each series over the period 1970 to 2003. Figure 1 shows these differences for selected commodities. The overall pattern clearly reveals periods of depreciation following the first primary resource shock of the early 1970s, and the period of appreciation following the second oil shock in the late 1970s, early 1980s, and high real U.S. interest rates. The depreciation during the late 1980s is clearly evident, followed by some stability in the early 1990s, a period of relatively stagnant growth of the U.S. economy. Appreciation of the dollar started in about 1995 as the U.S. economy experienced total factor productivity (TFP) growth over the 1995-1999 period that exceed by a factor of 3 TFP growth of the previous two decades (Jorgenson, 2001). Depreciation is apparent since about 2002.

While each sub-commodity series follows a similar depreciation – appreciation cycle, differences among them are apparent, with red meats standing out in recent years. As discussed below, differences in the estimated values of the exchange rate price elasticity, $\beta_{1,i}$ for each commodity, and the cycles of appreciation, will be seen to have important negative effects on commodity exports. In some years, these negative effects will dominate the effects of growth in adjusted GDP.

Figure 1. Deviation from mean of the trade weighted local currency to the dollar exchange rate, selected commodities



The U.S. exported agricultural commodities to over 183 countries during 2001-2005. However, table 1 shows that the bulk of these exports are concentrated in a small number of countries, thus giving them a relatively large weight in the calculation of the trade-weighted exchange rate During 2001-05, 50 percent of total U.S. agricultural exports went to only four countries. While the concentration has increased for total U.S. agricultural exports, the major importing countries have changed. In 1976, ranked from highest to lowest, the major importing countries were, Japan, the Netherlands, Germany, Canada, Korea and India. In 2004, the major importers were Canada, Mexico, Japan, China, Korea and Taiwan[9].

Table 1. The concentration of U.S. agricultural exports by period, in number of countries

	At least 50 % of exports			At least 75 % of exports		
Commodity	1976-80	1991-95	2001-05	1976-80	1991-95	2001-05
			(Number of Countries)			
Total agricultural exports	8	6	4	20	18	17
Corn	5	3	3	11	11	7
Cotton	3	4	5	7	10	18
Rice	5	8	6	12	19	15
Tobacco	5	4	5	13	11	12
Wheat	7	6	7	18	13	18
Soybeans	3	5	3	9	9	8
Soymeal	4	6	5	9	12	13
Soyoil	4	5	5	9	9	13
Fruits	3	2	3	8	6	7
Vegetables	4	2	2	13	10	7
Red Meats	1	1	2	3	2	3
Poultry	6	4	4	11	7	12

Source: Calculated from the Economic Research Service, U.S. Dept. of Agr., U.S. Agricultural Trade Database, www.ers.usda.gov/data/FATUS.

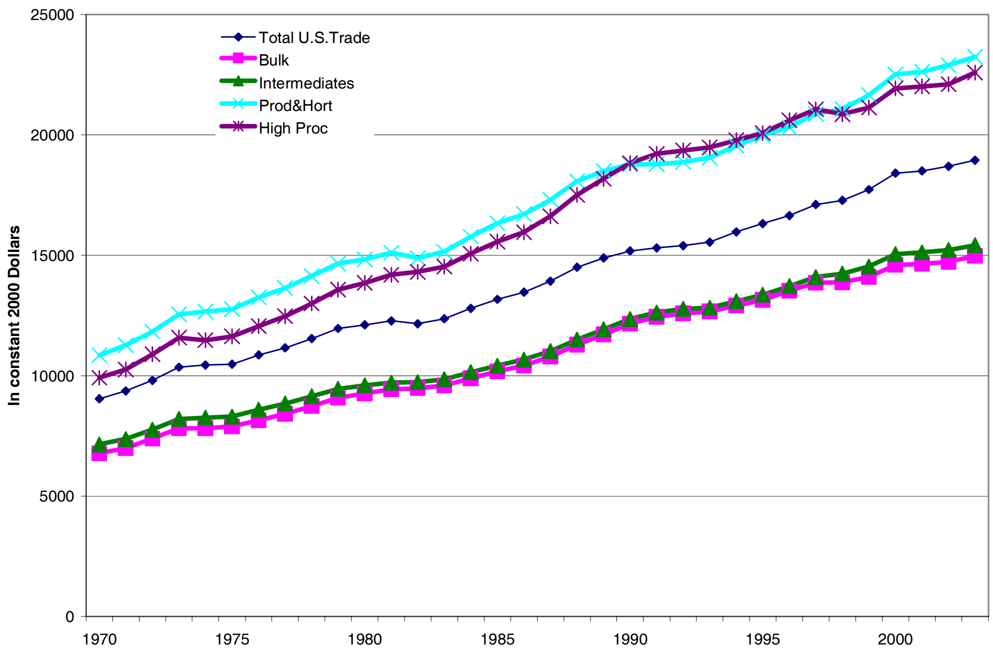
Cotton and soymeal show some departure from the tendency for increased concentration. In the case of red meats, Japan and Canada account for over 50 percent of the total U.S. exports of this commodity over the entire 1976-2005 period. The trade weights of these two countries thus dominate this commodity's trade-weighted exchange rate shown in figure 1.

Next consider the association between the type of commodity exported and the income level of the importing countries. A clear difference exists between the GDP per capita of countries importing bulk commodities and those importing high value products. Bulk commodity exports are accounted for by largely middle income countries while high

[9] This change in countries is consistent with Diao et al (2001) study of regional trade arrangements. They show that starting in about the early 1980s, growth of intra-NAFTA agricultural traded far exceeded the growth of world agricultural trade and the growth of NAFTA country trade with non-NAFTA countries.

value process agricultural products tend to be exported to high income countries (figure. 2). The estimated exchange rate and income elasticities reported in the next section tend to correlate with this trade pattern. The exchange rate elasticities tend to be larger in absolute magnitudes for lower income countries than higher income countries while the income elasticities tend to be larger for high income countries than low income countries.

Figure 2. Trade weighted per capita income of U.S. agriculture importing countries



IV. Results

The results based on estimating the parameters of equation (6) for the selected commodities are reported in table 2. The exact estimated form of the export equations depends on the specific commodity (see column 4, table 2). A number of statistical issues arise. Harris (1995, pp. 27-29) and Kwiatowski, Phillips, Schmidt, and Shin (1992) discuss the well-known augemented Dickey Fuller (or ADF) test's tendency for indicating, falsely, nonstationarity particularly when, as in this study, samples are finite and when variables are stationary but have near-unit roots. That is, in the case where a series is "almost nonstationary.[10]" In such cases, ADF-type unit root tests often fail to reject the null hypothesis of nonstationarity. An accepted procedure in the case has been to treat the variables as stationary without differencing them (Harris 1995, pp. 27-29; Kwiatowski et. al.1992; and Babula, Bessler, and Payne 2004, p. 6). When evidence from the ADF test suggested that evidence was sufficient to reject the null hypothesis of nonstationarity, we concluded that the variable was likely stationary. We employ the Kwiatowski et. al.'s test (hereinafter called the KPSS test) for the presence of unit root.

[10]For details on the Dickey-Fuller and the augmented Dickey-Fuller tests, see Fuller (1976), Dickey and Fuller (1979), and test procedure summaries in Hamilton (1994) and Patterson (2000).

The KPSS test results indicate that all series are stationary or integrated of order 0 (see appendix).

Appendix table 1 reports unit root tests on exports, GDP, and exchange rates by commodity for both ADF and the KPSS. The KPSS test indicate that all of the thirty nine vectors follow level-stationary processes at the $\alpha = 0.10$ level of significance, except six vectors at α=0.05 level of significance. The ADF test suggests that twenty two vectors follow level-stationary process while the remaining seventeen vectors follow unit root processes. We further employ the so-called ADF-KPSS Joint Conformation Hypothesis (JCH) of unit root for simultaneous use of the ADF and KPSS tests for small samples (Keblowski and Welfe, 2004) for the tests conflicts. The tests of the JCH confirm level-stationary processes for the conflicted cases.

Since our estimated models contain lagged dependent variables as control variables and include higher-order ARMA/GARCH specifications, we use the Marquardt nonlinear least squares algorithm (see Davidson and MacKinnon, 1994, pp. 329-341), Greene 1997, pp. 600-607)). Note that the nonlinear least squares estimates are asymptotically equivalent to maximum likelihood estimates and are asymptotically efficient.

Overall, the results show strong evidence of a significant link between total U.S. agricultural exports, and the trade-weighted exchange rate and trade adjusted real income. The estimated standard error of the income elasticity of total agricultural exports is smaller than the error associated with the exchange rate elasticity. A similar pattern holds for each of the commodity sub-categories. The sign of the income term is positive as expected and significant for all commodities with the exception of tobacco leaf exports. The sign of the exchange rate term, as expected, is negative in all equations and significant in seven of the thirteen commodity categories. The estimated equations approximate conditional mean dynamics, except for poultry that approximates conditional variance. The R-squared indicates the goodness of fit.

The estimated income elasticity for total agricultural exports is 1.6 while the estimate of the exchange rate elasticity is -0.8 (table 2). Excluding tobacco, commodity specific income elasticities range from 7.6 for poultry exports to about 0.5 for corn. Exchange rate elasticities range from about -0.15 for soybeans to a -1.23 for soyoil exports. Nine of the 12 commodities have income elasticities larger than the absolute value of their corresponding exchange rate elasticities.

Notice that the income elasticities reported in table 2 appear to be linked to the income level of countries. The income elasticities for the high value products, such as soymeal, red meats, poultry, fresh fruits and vegetables, tend to be exported to higher income countries, and they also tend to have larger income elasticities than do the bulk commodities which tend to be exported to lower income countries. The income elasticities of these commodities are generally larger than the income elasticity of total agricultural exports. Thus, equal growth in income across countries will tend to have a larger effect on exports of high value agricultural products than on the exports of bulk commodities. The absolute value of the estimated exchange rate elasticities for corn, soymeal, soyoil and poultry tend to be larger than the estimated exchange rate elasticity for total agricultural exports, although their standard errors are relatively large.

Decomposing exchange rate and income effects on agricultural exports

To show the effects of income and exchange rates on exports over time, we calculate the contribution of the exchange rate and adjusted GDP variables to predicted exports based upon the estimated parameters reported in table 2. The basic form of the calculation is

$$\frac{\dot{\hat{X}}}{\hat{X}} = \hat{b}\,\frac{G\dot{D}P}{GDP} + \hat{c}\,\frac{\dot{E}x}{Ex}$$

where, for the i-th commodity,

$$\frac{\dot{E}x}{Ex} = (XR_{i,t+1} - XR_{i,t}) / XR_{i,t}$$

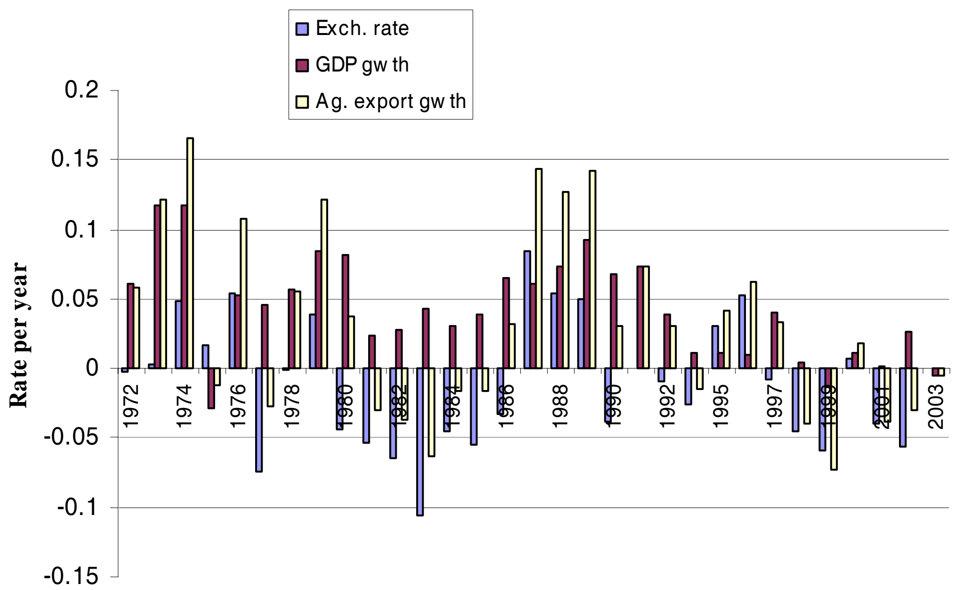
and

$$\frac{G\dot{D}P}{GDP} = [\sum_{k=1}^{K} \alpha_i^k (GDP_{t+1}^k - x_{t+1}^k) - \sum_{k=1}^{K} \alpha_i^k (GDP_t^k - x_t^k)] / \sum_{k=1}^{K} \alpha_i^k (GDP_t^k - x_t^k)$$

The results of these calculations appear in figure 3 for total agricultural exports. The results for all commodities appear in table 3 for yearly averages over the period 1972-2003.

The first two bars of figure 3 show, respectively, the effects of annual rate of change in the exchange rate and trade-adjusted GDP on the predicted growth in total agricultural exports, which is shown by the third bar. The main feature shown is that growth in trade partner trade-adjusted GDP was the main impetus for growth in total U.S. agricultural exports over the period 1972 to the early 1990s. Another feature is the appreciation of the trade-weighted U.S. exchange rate which had a negative effect on growth in total exports in 12 of the 21 years 1972-1993, and almost always tended to counter the positive effects of income growth on exports. Since 1997, the appreciation of the dollar appears to be a major contributor to a generally negative rate of growth in U.S. agricultural exports.

Figure 3. Total U.S. agricultural exports: Effect of exchange rate and trade partner trade-adjusted GDP on growth in predicted exports



The results appear to support Schuh's (1974) argument that the early 1970's boom in U.S. agricultural exports was caused by a depreciating dollar, particularly for the year 1974, although, growth in trade-adjusted GDP appears to have accounted for an even larger positive effect on exports. The U.S. adjustment to the second major oil shock at the beginning of the 1980s entailed a rising real U.S. interest rate, a decline in import demand, and stagnant growth in many external debt impacted developing countries. During 1980-1984, the appreciating value of the dollar out-weighed the more modest effects of growth in trade partner income. The result was negative growth in total U.S. agricultural exports (see also table 3, column 3). In the late 1980s, and prior to the financial crises faced by many developing countries in the early 1990s, both a depreciating dollar and income growth helped lift the growth of U.S. agricultural exports.

For 1990-2003, the results suggest that in spite of relatively rapid economic growth for many of the world's economies, the trade-adjusted income growth in U.S. agricultural trade partners tended to have small positive, and sometimes negative, effects on U.S. agricultural exports. At the same time, the trade-weighted exchange rate effects also tended to be negative and, during 2000-2003, to dominate the income effects on average.

We next focus on the twelve sub-commodity categories and discuss the degree to which they depart from the features shown for total agriculture.

Commodity specific effects

Table 3 shows that the annual average effect of exchange rate appreciation on exports was negative for all commodities for the 1980-84 period and again for the 2000-2003 period. A distinguishing feature of these periods is that the negative exchange rate effect tended to dominate the positive income growth effect for bulk commodities but not for the high value commodities. Another feature is the positive income effects on growth in exports tended to fall for all commodities during the 1995-1999, and 2000-2003 periods. Moreover, this decline tended to exceed the decline in the income effect for total agricultural exports for the bulk commodities, while the decline for the higher value commodities was less severe.

The domination of an appreciating trade-weighted exchange rate over income growth on U.S. commodity exports is most pronounced for corn. The negative effect of an appreciation of corn's trade-weighted exchange rate dominated the positive income effect on average for the periods 1980-84, 1990-1994, 1995-1999 and 2000-2003 (table 3). Of the other twelve commodity categories, exchange rate appreciation dominated income growth for soybean, wheat, soymeal and soyoil exports in three of the seven periods shown.

We noted above that high value products tend to be exported to higher income countries, and their estimated income elasticities tend to be larger than elasticities for bulk commodities. The results reported in table 3 for fresh fruit, fresh vegetables, poultry and meat show that from 1972-1989, the effect of growth in trade partner income on the exports of these higher value commodities tends to be larger than are the same effects for the bulk commodities. An example is the case of soybeans compared to red meat exports. The absolute value of the exchange rate elasticity is smaller for red meat than for soybeans, while the income elasticity for red meat is larger than for soybeans. Soybeans tend to be exported to countries whose per capita incomes are lower than countries importing red meat. While the exports of both of these commodities were affected negatively by exchange rate appreciation, in the case of soybeans, the exchange rate effect dominated the positive income effect in three of the periods shown in table 3.

V. Conclusions

The real trade-weighted exchange rate and trade partner income and are shown to be key determinants of US agricultural exports. The data clearly show the evolution of the real trade-weighted exchange rate to vary by commodity, although general similarities of appreciation and depreciation are evident. The trade data also suggest that bulk commodities tend to be exported to lower income countries than do the higher value commodities such as fresh fruit and red meat. For the period 1972-2003, a one percent annual increase in trade partners' income is found to increase total agricultural exports by about 1.6 percent, while a one percent appreciation of the dollar relative to trade partners' real trade-weighted exchange rate decreases total agricultural exports by about 0.8 percent.

These effects are also found to carry over to 12 commodity subcategories, although the effects are conditioned by differences between bulk and high value commodities. The estimated income elasticities for commodity subcategories are larger in magnitude than the absolute value of the exchange rate elasticities. This indicates that a one percent increase in trade partner real income contributes more to the annual growth in total agricultural exports than a one percent depreciation of their currencies. Furthermore, the income elasticities for the high value products, such as red meats, poultry, fresh fruits, and vegetables, tend to be larger than the elasticities for bulk commodities. Growth in incomes have a larger effect on exports of high value agricultural products than on bulk commodities exports.

We also find from a decomposition analysis that the negative effect of exchange rate appreciation on exports often dominates the positive effect from income growth. Most of the historical increases in agricultural exports are associated with income growth whereas most of the declines in exports are associated with an appreciation of the U.S. traded-weighted exchange rate. This analysis also shows that the income effect has tended to dampen over time. This dampening effect has allowed the appreciation of the exchange rate to dominate the income effect, particularly for the bulk commodities. This dampening effect has been less severe for the higher value commodities.

Table 2. Estimation Results of U.S. Agricultural Exports, the Real Exchange Rate and Weighted GDP

Variable	Intercept	Exchange rate	GDP	ARIMA	GARCH	R2	Durbin-Watson
Total agricultural exports	4.533 0.945***	-0.799 0.353**	1.598 0.323***	***(1,1,1)*** 0.679 0.115*** 0.048 0.239		0.947	1.882
Corn exports	8.277 0.882***	-1.073 0.622**	0.486 0.317*	***(1,1,1)*** -0.088 1.195 0.567 1.199		0.396	2.075
Cotton exports	3.864 0.767***	-0.558 0.518	1.267 0.602**	***(1,1,1)*** -0.548 0.316*** 0.923 0.216***		0.431	1.935
Rice exports	4.496 0.460***	-0.406 0.297	0.920 0.306***	***(0,0,1)*** 0.500 0.154***		0.579	2.161
Soybean exports	5.669 1.168***	-0.154 0.302	0.684 0.445*	***[(1,2),1,1)]*** 0.817 0.820 -0.117 0.702 0.174 0.835		0.740	1.917
Tobacco leaf exports	7.008 0.237***	-0.371 0.103***	-0.329 0.113***	***[(1,2),1,0)]*** 0.343 0.194* -0.272 0.192		0.790	1.908
Wheat exports	7.669 0.709***	-0.429 0.708	0.231 0.568	***(0,0,2)*** 0.634 0.123*** 0.447 0.116***		0.315	2.428
Soymeal exports	4.059 0.479***	-1.158 0.242***	1.975 0.365***	***(1,1,1)*** 0.042 0.182		0.549	2.000
Soyoil exports	5.198 0.324***	-1.229 0.668*	1.337 0.623*	***[(1,2),1,0)]*** 0.278 0.190 -0.254 0.187		0.263	1.958
Fresh fruit exports	1.934 1.666	-0.407 0.238*	1.853 0.567***	***(1,1,1)*** 0.857 0.155*** -0.315 0.264		0.969	2.055
Fresh vegetable exports	0.471 2.374	-0.292 0.701	2.270 0.914**	***(1,1,0)*** 0.803 0.128***		0.912	2.016
Poultry exports	-12.164 6.033**	-0.839 0.429**	7.600 2.245***	***(1,1,2)*** 0.852 0.247*** 0.312 0.194 -0.022 0.261	***(1,1)*** -0.062 0.239 0.730 1.082	0.946	2.095
Red meat exports	-9.527 0.562***	-0.269 0.235	4.796 0.115***	***[(1,4),1,1)]*** -0.270 0.152** 0.398 0.186**		0.990	1.880

*,**, *** Statistically significant at 10%, 5%, and 1% level.

Table 3. Effects of Trade Weighted Exchange Rate and Trade Partner Trade Adjusted GDP on U.S. Agricultural Exports.

	Average Rate per Year						
	1972-1974	1975-1979	1980-1984	1985-1989	1990-1994	1995-1999	2000-2003
Total Ag. Exports							
Exchange Rate	0.017	0.007	-0.063	0.020	-0.009	-0.011	-0.032
Income	0.098	0.042	0.041	0.066	0.041	0.011	0.004
Total Effect	0.115	0.049	-0.022	0.086	0.032	0.000	-0.028
Corn							
Exchange Rate	0.024	0.010	-0.054	0.023	-0.019	-0.026	-0.022
Income	0.032	0.013	0.014	0.021	0.014	0.004	0.003
Total Effect	0.057	0.023	-0.040	0.044	-0.005	-0.022	-0.019
Cotton							
Exchange Rate	-0.001	-0.013	-0.042	-0.018	0.006	-0.022	-0.001
Income	0.079	0.040	0.035	0.049	0.036	0.006	0.006
Total Effect	0.078	0.028	-0.007	0.031	0.042	-0.016	0.005
Rice							
Exchange Rate	0.010	0.008	-0.025	-0.009	-0.021	-0.004	-0.013
Income	0.057	0.025	0.023	0.038	0.022	0.007	0.005
Total Effect	0.068	0.033	-0.001	0.029	0.001	0.003	-0.009
Soybean							
Exchange Rate	0.007	0.004	-0.017	0.006	0.000	-0.006	-0.005
Income	0.039	0.017	0.016	0.028	0.019	0.004	0.002
Total Effect	0.047	0.022	-0.001	0.034	0.019	-0.002	-0.003
Tobacco Leaf							
Exchange Rate	0.022	0.025	-0.040	-0.005	0.002	-0.010	-0.017
Income	-0.018	-0.007	-0.007	-0.012	-0.009	-0.001	0.000
Total Effect	0.004	0.017	-0.047	-0.017	-0.006	-0.011	-0.017
Wheat							
Exchange Rate	0.003	0.004	-0.026	0.004	-0.026	0.008	-0.021
Income	-0.001	-0.002	0.014	-0.002	0.014	-0.004	0.011
Total Effect	0.001	0.002	-0.012	0.002	-0.012	0.004	-0.009
Soymeal							
Exchange Rate	-0.009	-0.003	-0.064	-0.056	-0.093	0.041	-0.037
Income	0.109	0.062	0.048	0.078	0.034	0.015	0.016
Total Effect	0.101	0.058	-0.016	0.022	-0.059	0.056	-0.021
Soyoil							
Exchange Rate	0.012	-0.032	-0.081	-0.034	-0.083	0.006	-0.025
Income	0.059	0.058	0.048	0.081	0.061	0.047	0.002
Total Effect	0.071	0.027	-0.033	0.046	-0.022	0.053	-0.024
Fresh Fruit							
Exchange Rate	0.015	-0.001	-0.022	0.013	0.003	-0.011	-0.008
Income	0.115	0.051	0.046	0.074	0.039	0.013	0.014
Total Effect	0.130	0.050	0.024	0.087	0.041	0.001	0.006
Fresh Vegetables							
Exchange Rate	0.009	-0.002	-0.007	0.006	-0.002	-0.010	-0.005
Income	0.138	0.068	0.050	0.088	0.029	0.015	0.033
Total Effect	0.147	0.066	0.043	0.094	0.027	0.005	0.028
Poultry							
Exchange Rate	-0.148	-0.060	-0.088	-0.016	-0.108	0.189	-0.017
Income	0.447	0.234	0.201	0.266	0.026	-0.044	0.042
Total Effect	0.299	0.173	0.113	0.250	-0.082	0.145	0.025
Red Meat							
Exchange Rate	-0.003	0.001	-0.019	0.013	-0.010	0.010	-0.002
Income	0.317	0.126	0.133	0.206	0.124	0.034	0.027
Total Effect	0.314	0.127	0.114	0.219	0.114	0.044	0.025

Source: Calculated based on the elasticities appearing in table 2 and the data.

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Appendix .

Data Sources

The data underlying this paper comes from four primary sources, the Food and Agricultural Organization of the United Nations (FAO Stat), the International Financial Statistics of the International Monetary Fund (IFS), the World Development Indicators of the World Bank (WDI), and the Federal Reserve Boards International Statistics (FRBFS). While these were the primary source, much of the data was transformed from that provided in the primary source used in this paper. Specifically, the data covers a period of 34 years for total U.S. agricultural exports and 12 U.S. agricultural export commodities. The data used to construct the $x_{i,t}^{US}$, $XR_{i,t}$ and $\sum_{k=1}^{K} \alpha_i^k GDP_{i,t}^k - Ex_{i,t}^k$ were derived from FAOstat, the ERS Exchange Rate Data Set, and the background tables of the ERS International Macroeconomic Data Set (www.ers.usda.gov/data/macroeconomics/). The trade-weighted exchange rates were taken from the ERS Exchange Rate Data Set (www.ers.usda.gov/data/exchangerates). The GDP series were taken from the ERS International Macroeconomic Data Set Background Tables (www.ers.usda.gov/data/macroeconomics). The export data was taken from FAO Stat. Total U.S. agricultural exports values was adjusted by the FAO unit value index to obtain a real U.S. agricultural export series. The export series for the commodities were the quantity of exports in metric tones. The adjusted GDP series involved subtracting total real exports from real GDP both measured in 2000 $. Both the total real exports and real GDP series were taken from WDI. We convert the country current price series to a year 2000 base by dividing the series by the year 2000 number. This converts the year 2000 index to 100. The constant country value of export and GDP series are then divided by their respective 2000 base price indexes. Finally, the country real value of export and GDP series are converted to dollars with a fixed year 2000 exchange rate which converts local currencies into dollars. The adjusted country totals were then averaged using the same trade-weights used to derive the commodity real exchange rates. The country coverage was limited to 80 major export destinations for U.S. exports used in the ERS Exchange Rate Data Set. You can find both the country coverage and the weighting scheme at the ERS website referred to above.

Unit Root Tests

We employ the ADF, KPSS, and JCH tests for all the variables in the analysis. The first column of the Appendix table reports the ADF test results. In particular, there are the *t-values* of the first-difference on a constant, the lagged level, and the lagged-differences of the series. The number of lags is reported in parentheses and determined by EVIEWS 5.0. The second column reports the KPSS test statistics ($\eta\mu$). The KPSS (1992) test differs from the other unit root tests in that the series is assumed to be (level-) stationary under the null or I(0). The KPSS statistic is based on the residual and calculated as the partial sum of the residuals. The residuals are computed from a model in which each vector/series is regressed on a constant and the error variance estimator is a Bartlett kernel weighted-sum of auto-covariances (the Newey-West bandwidth parameter is reported in parenthesis). The third column reports inferences based on the JCH of a unit root and is used when the tests in the first (ADF) and second columns (KPSS) conflict. They are interpreted as follows: if the values of the ADF statistic (column 2) is less than -3.1 or -2.8 and the value of KPSS statistic (column 3) is less than 0.4 or 0.5 then the series is stationary at the level 0.90 and 0.95, respectively.

For example, the ADF test statistic ($\tau\mu$) for the GDP of total agricultural exports is -2.653 (see column 1, row 1). Since the critical value is -2.617 (at 10% level of significance) we reject the null hypothesis of non-stationarity. The value of the KPSS ($\eta\mu$) test for the same vector (column 2, row 1) is 0.312. Since the critical value is 0.347 we accept the null hypothesis of stationarity. GDP of total agricultural exports is stationary or integrated of order zero (I(0) based on both tests. For the exchange rate of total agricultural exports the ADF test indicates that the series is non-stationary as -1.567 is greater than the critical value -2.617. For the same vector, the KPSS indicates that the series is stationary as 0.329 is less than 0.347. In this case we employ the JCH test. Since the ADF test is greater than -3.1 and the value of KPSS is less than 0.42 then the exchange rate of total agricultural exports cannot be confirmed to be a unit root and is therefore considered to be stationary.

Appendix Table 1. Unit Root Tests of Exports, GDP, and Exchange Rate by Commodity

Null Hypotheses	ADF--I(1)τ_μ	KPSS--I(0) η_μ	JCH--I(1) or I(0)
Total agricultural exports			
GDP	-2.653(8)*	0.312(8)	I(0)
Exports	-3.901(8)**	0.340(8)	I(0)**
Exchange rate	-1.567(11)	0.329(12)	I(0) (JCH)
Corn			
GDP	-2.594(8)	0.308(8)	I(0) (JCH)
Exports	-3.418(8)**	0.345(8)	I(0)
Exchange rate	-0.536(4)	0.328(12)	I(0) (JCH)
Cotton			
GDP	-3.107(1)**	0.308(12)	I(0)**
Exports	-3.057(8)**	0.360(8)	I(0)**
Exchange rate	-2.676(6)*	0.315(12)	I(0)**
Rice			
GDP	-2.708(1)*	0.307(12)	I(0)**
Exports	-2.180(1)	0.364(12)	I(0) (JCH)
Exchange rate	-0.120(1)	0.302(12)	I(0) (JCH)
Soybean			
GDP	-2.841(4)*	0.330(12)	I(0)*
Exports	-1.347(8)	0.387(12)**	I(0) (JCH)
Exchange rate	-1.448(1)	0.352(12)**	I(0) (JCH)
Tobacco leaf			
GDP	-2.276(1)	0.311(12)	I(0) (JCH)
Exports	-1.007(2)	0.315(12)	I(0) (JCH)
Exchange rate	-1.134(8)	0.319(12)	I(0) (JCH)
Wheat			
GDP	-2.686(1)*	0.314(12)	I(0)*
Exports	-3.477(8)**	0.238(12)	I(0)**
Exchange rate	-3.584(12)**	0.315(12)	I(0)**
Soymeal			
GDP	-2.893(8)*	0.315(12)	I(0)*
Exports	-3.274(8)**	0.413(12)**	I(0)**
Exchange rate	-0.921(8)	0.296(12)	I(0) (JCH)
Soyoil			
GDP	-2.892(8)*	0.315(12)	I(0)*
Exports	-3.347(1)**	0.485(8)**	I(0)**
Exchange rate	-2.636(12)*	0.308(12)	I(0)*
Fresh fruit			
GDP	-2.809(8)**	0.310(12)	I(0)**
Exports	-0.960(8)	0.314(12)	I(0) (JCH)
Exchange rate	-2.637(3)*	0.429(12)**	I(0)*
Fresh vegetable exports			
GDP	-2.779(8)*	0.317(12)	I(0)*
Exports	-1.161(1)	0.321(12)	I(0) (JCH)
Exchange rate	-1.268(2)	0.369(12)**	I(0) (JCH)
Poultry			
GDP	-4.144(8)**	0.303(12)	I(0)**
Exports	-1.099(2)	0.319(12)	I(0) (JCH)
Exchange rate	-2.556(1)	0.253(12)	I(0) (JCH)
Red meat exports			
GDP	-2.618(8)**	0.314(12)	I(0)**
Exports	-2.609(6)	0.226(10)	I(0) (JCH)
Exchange rate	-4.001(12)**	0.330(12)	I(0)**
10% critical values	τ_μ**=-2.617	η_μ**=0.347	(τ_μ, η_μ)**= (-2.822, 0.572)
5% critical values	τ_μ* =-2.957	η_μ*=0.463	(τ_μ, η_μ)*= (-3.100, 0.420)