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Volatility of primary commodity prices: some evidence
from agricultural exports in Sub-Saharan Africa

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Abstract

This paper utilizes three univariate ARCH-type models to empirically examine persistence and asymmetry in volatility of prices of primary agricultural commodities produced in Sub-Sahara Africa. Maximum likelihood estimation results of the three models ranked the GARCH version as the best statistical fit, lending support for hypotheses of persistence, symmetry and variability in volatility. This pattern of volatility could effectively jeopardize the success of traditional commodity price risk management policies used in this region. Policymakers should appreciate potential benefits associated with market-based strategies for managing commodity exposure of these countries.

1. Introduction

In this paper, we empirically examine a vital characteristic of primary commodity prices -- persistence in the response to shocks and in volatility. This topic is particularly important to the world economy because it is estimated that primary commodities consist of over 40 percent of world trade. Thus, fluctuations in both the short and long-run behaviour of the price of these commodities have important implications for the global economy and economic performance of countries heavily dependent on for export revenue.

The market for primary commodities is markedly dichotomised. Small, poor and highly indebted economies, mainly from Sub-Sahara African (SSA) region, dominate the supply side of the market while rich industrialised countries in Europe and North America dominate the demand side. An understanding of the pattern of volatility of major commodity exports could provide some guidance to policymakers in commodity-dependent countries and commodity traders in making risk management decisions (see Swaray, 2000).

The objective of this paper is to use three 'hybrids' of the ARCH-type model family to characterise the conditional variance of price series of nine leading agricultural commodities that are mainly produced in the SSA region. The commodities considered in this paper include: -- bananas, cocoa, coffee, cotton, groundnut, rubber, sugar, tea and tobacco. It is thought that at least one of these nine commodities is of primary importance in every country in the SSA region. Together, these commodities account for about 70-76 percent of agricultural export of the SSA region (Akiyama and Larson, 1994).

Commonplace measures of volatility such as the standard deviation and the coefficient of variation tend to overstate variability in non-trending series, have no

constant range and the squaring tends to accentuate the effect of outliers (Offutt and Blandford, 1986). Because the confidence intervals of volatility forecasts can vary over time, a more accurate interval can be obtained by modelling the variance of the errors. The GARCH family of models (Bollerslev 1986, Nelson, 1991 and Zakonian, 1994) are more suitable for modelling time varying variances and the persistence in volatility.

The paper is planned as follows: section 2 briefly discusses the pattern of volatility in the price series of primary commodities and the range of GARCH models that available to model them. We develop the univariate GARCH, Threshold GARCH (TGARCH) and Exponential GARCH (EGARCH) models in section 3. Section 4 discusses empirical results of the three models applied to monthly price series (from 1960-1998) of the nine commodities mentioned above. Section 5 discusses some policy implications of the results. And finally, section 6 offers some concluding remarks.

2. Volatility of Primary Agricultural Commodity Prices

The origin of volatility differs for different groups of commodities. In agricultural commodities, volatility originates mainly from supply disturbances; whereas for industrial raw materials (both agricultural and metallic), it originates mainly from demand disturbances. These disturbances coupled with short-run demand and supply elasticities give rise to acute price fluctuations. A price series can be highly volatile yet change over longer periods of time; or show little volatility but a considerably large change over time through discrete adjustments. Primary agricultural commodities generally fall into the former group while industrial products often conform to the latter.

It is common to assume market information and hedging as attributes that only apply to financial markets and physical availability to be akin to primary commodity markets. However, a look at the primary commodity markets reveal that the arrival of information, hedging and speculation, and physical availability of commodities are all crucial factors that influence the volatility of primary commodity markets (see Herrmann, 1983, Gilbert, 1994). Increased volatility in the prices of primary export commodities has made speculation a common place in commodity markets. This feature can justify use of informationally-based processes to modelling the pateren of volatility of the price of these commodities. Cuddington and Liang (1999) used univariate GARCH models to characterise volatility of commodity prices across exchange rate regimes. Cashin et al (2000) used the median-unbiased estimator to examine the persistence of shocks in world commodity prices.

(Insert Figure 1 about here)

Financial asset prices are generally believed to be leptokurtic (i.e. they exhibit "fat tails"). In many respects, commodity prices behave like asset prices. This may not be surprising because a casual inspection of primary commodity price series reveals volatility clustering. Large changes tend to follow large changes, and small changes tend to be followed by small changes and the process tends to die away with time (See Figure 1). This pattern indicates that the variance of the process underlying these price variables may be varying overtime - a phenomenon that can be captured by models of the GARCH class models.

3. The GARCH, TGARCH and EGARCH class of volatility models

Since Bollerslev (1986) proposed an extension to the information set in a simple Autoregressive Conditional Heteroskedasticity (ARCH) model (Engle,1982)

by including a lagged conditional variance to arrive at the Generalized ARCH (GARCH) model, various 'hybrids' of the ARCH family have emerged (see Gourieroux, 1997). This section examines the three ARCH-type models used in this paper.

The ARCH-type models used in this paper are defined in terms of the distribution of errors of a dynamic linear regression model. Assuming that a dependent variable of commodity prices, p_t, is generated by the autoregressive process:

$$p_t = \phi_0 + \sum_{i=1}^{k} \phi_i p_{t-i} + \varepsilon_t. \tag{1}$$

To generate the ARCH(p) process, we express the conditional variance of the above expression as a function of its past values squared:[1]

$$\varepsilon_t | \Omega_{t-1} \sim N(0, h_t), \tag{2}$$

$$h_t = \delta + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2, \tag{3}$$

where h_t^2 denotes the conditional variance of the information set Ω_{t-1} that is available at time t-1, and $\delta_1 > 0, \alpha_i \geq 0$ for all $i = 2...p$ and $\alpha_1 + \alpha_2 + ... + \alpha_m < 1$ are necessary to make ε_t^2 positive and covariance stationary.

Much work has been done on identifying the information set used by agents in the financial market to form expectations. This has given rise to a variety of models to achieve this. Bollerslev (1986) developed the framework to generalise the ARCH process in (3) above to give:[2]

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[1] Note that ε_t is serially uncorrelated but not stochastically independent because they are related through their second moments.
[2] It is interesting to note that equation (4) is an ARMA representation of (3)

$$h_t^2 = \delta + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{q} \beta_i h_{t-i}^2. \tag{4}$$

The GARCH (1,1) model in (4) depicts conditional variance of a price series to depend on a constant, past news about volatility (i.e. the ε_{t-i}^2 terms) and the past forecast variance (the h_{t-1}^2 terms). In effect, including the lagged conditional variances might capture the "adaptive learning" phenomenon that characterises the process. Roe and Antonovitz (1985) used the lagged values of the squared innovations associated with equation (2) as a measure of risk.

A parsimonious and simpler form of (4) is the GARCH (1,1) model specified as follows:

$$h_t^2 = \delta + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}^2. \tag{5}$$

The benefit of the GARCH specification in equation (5) is that it contains fewer coefficient restrictions. Also, the only requirement for a well-defined variance and covariance function of the model is the coefficients to lying inside a unit circle-- $\delta, \alpha > 0; \beta \geq 0$ and $\alpha + \beta < 1$. Persistence of volatility in the commodity series is measured by the sum of α and β.

In financial markets, it is observed that downward price changes are often followed by higher volatility than upward price movements of the same magnitude. This asymmetry (leverage effect) in the variance can be captured by two hybrids of the GARCH family: the TGARCH (Zakonian, 1994; Glosten et al 1994) and EGARCH (Nelson, 1991). The conditional variance of a TGARCH model can be expressed as thus:

$$h_t^2 = \delta + \alpha_1 \varepsilon_{t-1}^2 + \gamma d_{t-1} \varepsilon_{t-1}^2 + \beta_i h_{t-1}^2, \tag{6}$$

where $d_i = 1$ if $\varepsilon_t < 0$ and $d_t = 0$ otherwise. Adverse market conditions and bad news $(\varepsilon_{t-1}^2 < 0)$ such as frost, drought and political instability has an impact of $\alpha + \gamma$. Good news about demand and supply conditions in the commodity market $\varepsilon_{t-1}^2 > 0$ has an impact of α.

In the EGARCH models, the effect of recent residuals is exponential rather than quadratic. The variance equation of this model can be specified as follows:

$$\log(h_t^2) = \delta + \pi_1 \left| \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}^2}} \right| + \pi_2 \frac{\varepsilon_{t-1}}{h_{t-1}^2} + \beta \log(h_{t-1}^2).^3 \tag{7}$$

Asymmetry is achieved in equation (7) when $\pi_2 \neq 0$. The impact of good news such as favourable business cycles conditions in highly industrialised OECD countries is captured by $(\pi_1 + \pi_2)/\sqrt{h_{t-1}^2}$ while the impact of bad news such as political instabilities and unfavourable weather conductions in producing countries is expressed by $(\pi_1 - \pi_2)/\sqrt{h_{t-1}^2}$. A negative and significant π_2 supports evidence of asymmetry and greater impact of negative shocks on price volatility.

Unlike standard time-series models, the unique strength of ARCH-class models lie in their ability to allow the conditional variance of underlying processes to vary over time. Also, the information that is used in forming conditional expectations is similar to that used to predict the conditional mean (i.e. variables observed in previous periods). Hence, the GARCH model maintains the desirable forecasting properties of a traditional time series but extends them to the conditional variance (Holt and Aradhyula, 1990).

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[3] It should be noted that this version of the EGARCH model differs slight from the original specification given by Nelson (1991). However, under the assumption of normal errors the models yield identical estimates of all parameters except for the intercept term.

4. Data

Monthly price data on the nine commodities were obtained from the IMF International Financial Statistics (IFS) period ranging from January 1960 to December 1998. All nine commodities fall under 3 subaggregates of the non-fuel primary commodity aggregation compiled by the IMF.

This study uses the real commodity prices index defined as the ratio of the chosen IMF/IFS nominal commodity index (in U.S. dollar per unit) deflated by the manufacturing unit value index (base year 1990). The manufacturing unit value (MVU) index defined, as the unit value index of exports from 20 highly industrialized countries, is a deflator frequently deployed in commodity price studies. These commodities fall under three non-fuel primary commodity sub-aggregations (viz. food, beverage and agricultural raw material). Table 1 show evidence of significant skewnwess and excess kurtosis in the distribution of price series of the nine commodities examined, results of normality tests confirm significant deviation from the normal distribution in all cases. These findings of commodity prices have shown in previous studies (see Deaton and Laroque 1992, and Cashin, McDermott and Scott, 1999.)

5. Empirical Results

This section discusses empirical results from unit root tests and estimation outputs from the three models under consideration. The Philips-Perron (1988) test (hereafter PP) is used to evaluate statistical significance of ρ in the following linear regression equation:

$$\Delta \log p_t = \omega + \theta \log p_{t-1} + bt + e_t \tag{8}$$

where $\theta = \rho - 1$ and $\Delta \log p_t$ is the logarithm of the first difference of monthly price series of the commodities under consideration. An alternative test to PP is the Augmented Dickey Fuller test. However, the PP can be more appropriate, in this case because of evidence of heteroskedasticity assumed in the error process of the price examined. All PP tests use the fifth degree of Bartlett Kernel's truncation lag.[4]

The actual distribution of the t-statistics in equation (8) depends on whether a constant or time trend is included in the regression. Therefore, equation (8) was first run with both the constant term and time included in the model. If test statistics are unable to reject the null hypothesis of unit root (i.e. $\theta = 0$) for the unrestricted form of the model, the test is explored for more power by examining the significance of the trend and constant in turn by dropping either or both terms. If the null hypothesis is rejected, no further progress is necessary (Enders, 1995).

(Insert Table 1 about here)

Table 1 contains the results of the PP unit root tests show that level data of all commodities (excepting banana and tea) were non-stationary but their first differences were stationary (i.e. implying the presence of unit roots in the series.) The occurrence of unit roots in the price data generation process of these commodities gives a preliminary indication of shocks having permanent or long lasting effect, thus making it very difficult for traditional price stabilisation polices common in SSA countries to survive (Cashin et al. 2000).

(Insert Table 2 about here)

Equation (1) represents a generic mean equation for all three models (i.e. GARCH, TGARCH and EGARCH). The autoregressive part of the mean equations

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[4] Econometric Views (*Eviews)* version 3.1 (Quantitative Micro Software) refers to the software that was used to estimate the models in this paper.

for all nine commodities were set to various lag lengths until a robust model, as dictated by the Schwarz model selection criterion, was obtained. Table 2 contains univariate GARCH(1,1) parameters for the mean and variance equations of all commodities under examination. The estimation output shows six of the commodities with significantly large GARCH coefficients and three insignificant coefficients-- two relatively small (cocoa and tea) and one small (tobacco). The measure of persistence in volatility $(\alpha + \beta)$ is large in eight of the nine commodities in the sample and relatively small in one (tobacco). Moreover, three commodities (coffee, cotton and groundnut) have persistence measures that are approximately equal to one. A persistence measure equal to one signifies the Integrated GARCH (IGARCH) phenomenon. In an IGARCH process, the autoregressive moving average (ARMA) process of the variance is either non-stationary or has an infinite variance. An IGARCH in these commodities implies persistent changes in volatility of their prices, which might indicate that "current information remains important for the forecasts of the conditional variances for all horizons" (Engle and Bollerslev, 1986).

(Insert Table 3 about here)

Similarly, Table 3 outlines empirical results of parameters of TGARCH (1,1) models. Like the GARCH (1,1) model above, the measure of persistence appears to be large for of the eight commodities but relatively small for tobacco. The standard error values for the asymmetric coefficient (γ) are statistically insignificant for all commodities except for banana and sugar. This implies that empirical results of the TGARCH models did not generally support asymmetry in the pattern of volatility of all but two of the commodities examined.

(Insert Table 4 about here)

Finally, Table 4 contains parameters of the EGARCH(1,1) models. The persistence measures (β) for this model were large and statistically significant for all commodities except for tobacco where it is small and insignificant. None the less, the standard errors of π_2 are fairly large and therefore insignificant for eight of the commodities, except for banana whose standard error was relatively small. Thus, like the TGARCH model, empirical results do not generally support the EGARCH(1,1) model in the commodities examined.

6. Policy implications

The pattern of volatility in the price series of key agricultural exports commodities produced in the SSA region leaves little room for countries that are heavily dependent on foreign exchange earnings from these commodities to have adequate control of broader macroeconomic policies that will ensure prudent economic management. In particular, a price decline that persists for several years would translate into a decline in the international purchasing power vital component of their export basket over that period. The large proportion of these commodities in SSA countries' export basket coupled with un-diversified nature of their economies further exacerbates the balance of payment problems that problem generates.

On the other hand a long-lived price shock that affects only a large commodity sector of developing countries has the potential of diverting resources needed to sustain and develop other productive sectors to the dominant commodity sector and appreciation of the real exchange rate of them countries' currency. When the price of the dominant commodity eventually falls, the whole economy will come tumbling down with it. This phenomenon, often dubbed as the "Dutch" or "Nigerian" disease is though to be a contributory factor to major macroeconomic disruptions in developing

countries in the late 1970s and early 1980s (Claessens and Duncan, 1993.) Understanding the pattern of time-varying characteristics of volatility inherent in the prices of these commodities would provide useful information for policy purposes. In addition, the demise of International Commodity Agreements and the comatose of commodity stabilisation and compensatory schemes devised to deal with the effect of these shocks signals the need for alternative ways of dealing with the problem (see Gilbert, 1995.)

The unsuitability of domestic stabilisation schemes and international commodity agreements in dealing with long-lived shocks inherent in primary commodity prices has been recognised by researchers for over decade (see Priovolos and Duncan, 1991, Deaton, 1992) The cost of maintaining a buffer stock scheme (domestic or international) in times of persistent decline in commodity prices will far exceed the benefits of the action itself. Domestic commodity price stabilization methods tend re-distribute the risk it is supposed to manage within the domestic economy (usually from the producers to the government) rather to diversify them to entities outside the country that are better equipped to bear them. Also, the much-needed funds that are tied-up in these schemes could be better used in other sectors of the economy to stimulate growth and development.

The shortfalls of stabilisation schemes in developing countries call for use of marked-based methods to manage the commodity exposure of these countries (see Claessens and Duncan, op.cit.) Market based hedging instruments like commodity futures, commodity-linked bonds, commodity options and commodity swaps have many appealing features that are suitable for dealing with persistence in shocks to agricultural commodity prices. The last decades has seen the emergence of financial

instruments that can facilitate hedging of commodity price risk for short and longer time periods, and at the same time raise finance on commodity price-linked terms.

In addition to managing commodity price risk, commodity derivatives can enable developing countries to manage risks associated with their foreign exchange earnings and income of firms in the private sector. However, the market for commodity derivatives is still in its infancy in most developing countries and fraught with problems of creditworthiness and face with various technical and fundamental barriers (Laeson, et al., 1998) Despite these constraints, market-based hedging strategies can be highly beneficial to developing countries that are heavily dependent on primary commodities for export earnings.

7. Concluding Remarks

This paper has used the ARCH-class models to empirically examine the persistence of shocks to volatility and to determine whether or not there is asymmetry in the pattern of volatility. The paper specifically tested the hypothesis of variability in volatility, which implies that volatility is greater when commodity prices are moving downwards than upwards. Statistical inferences were drawn from the data by means of significance tests and overall goodness of fit of all three models as reported by the Schwarz information criterion.

Results from this paper allow inferences about LDC export commodity market that stand out for a long time. Three main findings from can be summarized as follows: First, volatility of prices of commodities studied generally tends to vary over time. Second, there is evidence of long-term persistence and volatility clustering in the price series of all the commodities studied. This may be due to speculative activities, changes in weather conditions, crop diseases and the effect of traditional

risk management policies. And finally, there is little or no leverage effect in the pattern of volatility of monthly price series commodities examined. This implies that monthly information on prices may not have significant impact on price volatility.

The features observed prices of SSA's leading agricultural exports have important implications for policy purposes. This is because, despite the myriads of political and administrative bottlenecks that domestic stabilisations schemes and commodity agreements face in developing countries, the process underlying volatility of their prices is itself a harbinger of troubled ahead of these ventures. Resources available for these schemes would hardly survive the characteristic long and persistent slumps in world market prices. With increasing liberalisation of trade and globalisation of world financial markets, exotic market-based hedging instruments hold the key managing these countries' commodity price risk.

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Footnotes

[1] Note that ε_t is serially uncorrelated but not stochastically independent because they are related through second moments.

[2] It is interesting to note that equation (4) is an ARMA representation of (3)

[3] It should be noted that this version of the EGARCH model differs slight from the original specification given by Nelson (1991). However, under the assumption of normal errors the models yield identical estimates of all parameters except for the intercept term.

[4] Econometric Views (*Eviews)* version 3.0 (Quantitative Micro Software) refers to the software that was used to estimate the models in this paper.

Figure 1: Change over previous year's price (in logs)
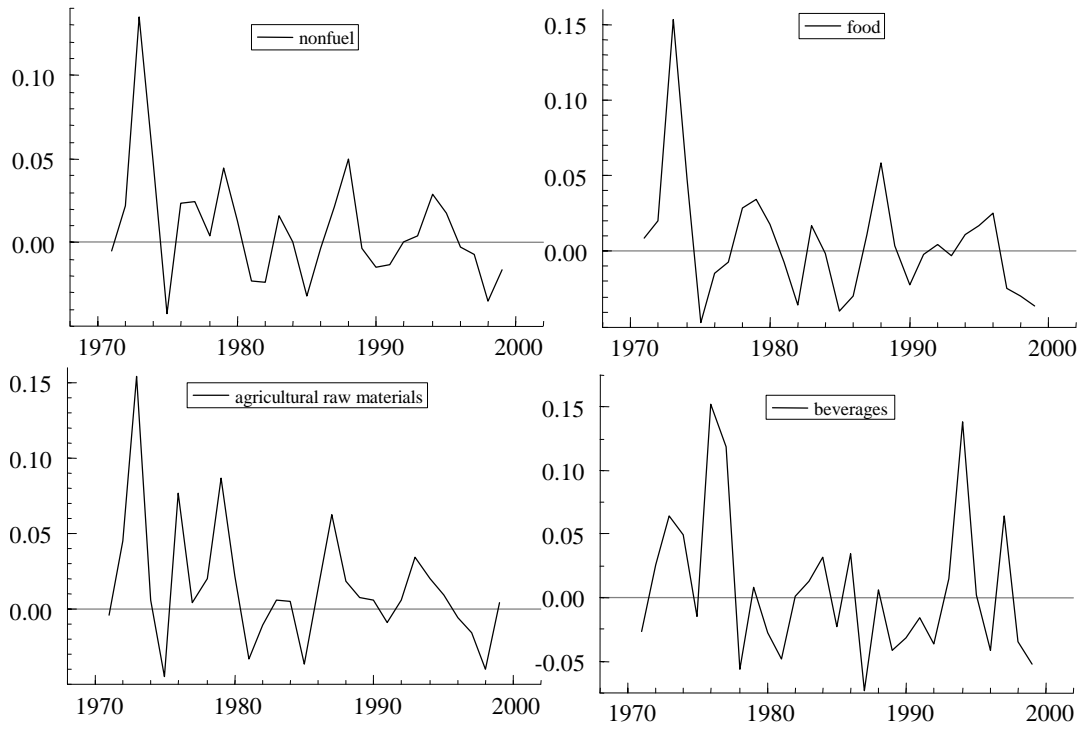
Table 1: Descriptive Statistics

	Banana	Cocoa	Coffee	Cotton	Gnut	Rubber	Sugar	Tea	Tobacco
Mean	6.416	1683.754	140.06	66.092	751.121	39.655	72.392	182.728	2370.107
Std Dev.	2.653	816.230	67.681	20.026	250.340	13.280	32.910	59.937	777.211
Skewness	0.326	0.972	0.700	-0.449	-0.240	0.304	0.842	0.975	-0.360
Excess kurtosis	-0.398	0.669	0.613	-0.628	-1.095	-0.121	2.148	1.850	-0.837
Normality Test $\chi 2(2)$	14.431	98.177	33.349	40.441	43.775	7.484	36.131	50.715	39.738
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.023)	(0.000)	(0.000)	(0.000)
Philips-Perron									
Level	-3.624**§	-1.635	-2.134	-2.240	-2.658	-2.382	-2.600	-3.545**§	-1.266
First Diff.	-	-15.342**	-15.966**	-11.150**	-15.438**	-16.199**	-19.017**	-	13.591**

Note: ** and * denotes test statistic is significance at 1 % and 5 % level of significance respectively. § shows that test produced significant result with constantly (tests remained significant at 1 % when time trend was included). Tests with first differences include constantly only.) PcGive 8.0 (see Doornik and Hendry) was used to compute descriptive statistics in first five rows in the table. Figures in parenthesis below normality tests are probability values.

Table 2: Empirical Results of the GARCH (1,1) Model

	Banana	Cocoa	Coffee	Cotton	Gnut	Rubber	Sugar	Tea	Tob
ϕ_0	0.040	0.001	-0.001	0.000	-0.001	0.000	0.001	0.155	0.001
	(0.021)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.052)	(0.000)
ϕ_1	0.850	0.269	0.323	0.554	0.307	0.319	0.306	1.169	0.302
	(0.049)	(0.053)	(0.059)	(0.053)	(0.075)	(0.051)	(0.058)	(0.051)	(0.056)
ϕ_2	0.118	-0.115	-	-0.125	-	-0.116	-0.125	-0.200	0.240
	(0.048	(0.050)		(0.054)		(0.050)	(0.046)	(0.050)	(0.056)
δ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
α	0.058	0.236	0.192	0.195	0.293	0.149	0.254	0.225	0.298
	(0.023)	(0.076)	(0.065)	(0.048)	(0.077)	(0.049)	(0.075)	(0.145)	(0.075)
β	0.927	0.597	0.836	0.821	0.741	0.844	0.732	0.539	0.220
	(0.027)	(0.116)	(0.042)	(0.035)	(0.042)	(0.053)	(0.062)	(0.194)	(0.159)
$\alpha + \beta$	0.985	0.833	1.028	1.016	1.034	0.993	0.986	0.794	0.518
Schwarz	-1.150	-0.711	-2.979	-4.082	-3.035	-3.222	-2.339	-2.352	-5.433

Note: Numbers in parenthesis are Boolerslev and Woodridge (1992) robust standard errors; Schwarz means the Schwarz criterion for model selection. $p_t = \phi_0 + \sum_{i=1}^{k} \phi_i p_{t-i} + \varepsilon_t.$ is the mean equation used for banana and tea and $\Delta \log p_t = \phi_0 + \sum_{i=1}^{k} \Delta \log \phi_i p_{t-1} + \varepsilon_i$ expresses the mean equation of the other seven commodities. Variance equation of the commodities in this Table is: $h_t^2 = \delta + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}^2.$

Table 3: Empirical Results of the TGARCH (1,1) Model

	Banana	Cocoa	Coffee	Cotton	Gnut	Rubber	Sugar	Tea	Tob.
ϕ_0	0.051	0.000	0.000	0.000	0.000	0.000	0.004	0.174	0.001
	(0.020)	(0.002)	(0.001)	(0.000)	(0.001)	(0.001)	(0.002)	(0.048)	(0.000)
ϕ_1	0.848	0.278	0.343	0.560	0.307	0.317	0.317	1.178	0.299
	(0.048)	(0.050)	(0.061)	(0.053)	(0.075)	(0.052)	(0.054)	(0.049)	(0.055)
ϕ_2	0.118	-0.113	-	0.120	-0.120	-0.113	-0.127	-0.212	0.244
	(0.048)	(0.051)		(0.054)	(0.054)	(0.051)	(0.045)	(0.049)	(0.055)
δ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
α	0.065	0.257	0.224	0.232	0.301	0.163	0.264	0.318	0.257
	(0.033)	(0.096)	(0.075)	(0.070)	(0.128)	(0.065)	(0.068)	(0.194)	(0.096)
γ	-0.018	0.123	-0.107	-0.069	-0.015	-0.062	-0.239	-0.264	0.076
	(0.061)	(0.121)	(0.808)	(0.110)	(0.171)	(0.078)	(0.075)	(0.208)	(0.132)
β	0.927	0.647	0.808	0.818	0.739	0.861	0.833	0.595	0.229
	(0.028)	(0.116)	(0.036)	(0.035)	(0.042)	(0.048)	(0.041)	(0.153)	(0.160)
Schwarz	-1.150	-2.704	-4.073)	-4.073	-4.073	-3.214	-2.863	-2.358	-5.418

Notes: Numbers in parenthesis are Boolerslev and Woodridge (1992) robust standard errors; Schwarz means the Schwarz criterion for model selection. $p_t = \phi_0 + \sum_{i=1}^{k} \phi_i p_{t-i} + \varepsilon_t.$ is the mean equation used for banana and tea and $\Delta \log p_t = \phi_0 + \sum_{i=1}^{k} \Delta \log \phi_i p_{t-1} + \varepsilon_i$ expresses the mean equation of the other seven commodities. Variance equation of the commodities in this Table is:

$$h_t^2 = \delta + \alpha_1 \varepsilon_{t-1}^2 + \gamma d_{t-1} \varepsilon_{t-1}^2 + \beta_i h_{t-1}^2,$$

Table 4: Empirical Results of the EGARCH (1,1) Model

	Banana	Cocoa	Coffee	Cotton	Gnut	Rubber	Sugar	Tea	Tob.
ϕ_0	0.052	0.000	0.000	0.000	0.000	0.000	0.004	0.138	0.001
	(0.020)	(0.002)	(0.001)	(0.000)	(0.001)	(0.001)	(0.002)	(0.050)	(0.000)
ϕ_1	0.857	0.276	0.302	0.587	0.302	0.319	0.319	1.194	0.297
	(0.049)	(0.049)	(0.058)	(0.053)	(0.072)	(0.052)	(0.053)	(0.049)	(0.056)
ϕ_2	0.109	-0.113	0.093	-0.130	-	-0.101	-0.104	-0.220	0.243
	(0.048)	(0.049)	(0.056)	(0.050)		(0.053)	(0.044)	(0.048)	(0.052)
δ	-0.016	-1.465	-0.460	-0.619	-0.766	-0.453	-0.516	-0.426	-4.684
	(0.064)	(0.589)	(0.097)	(0.145)	(0.187)	(0.179)	(0.138)	(0.219)	(1.330)
π_1	0.106	0.425	0.299	0.378	0.046	0.289	0.271	0.122	0.547
	(0.042)	(0.113)	(0.731)	(0.072)	(0.089)	(0.082)	(0.066)	(0.047)	(0.105)
π_2	0.021	-0.052	0.098	0.060	0.018	0.036	0.157	0.156	-0.014
	(0.044)	(0.069)	(0.073)	(0.062)	(0.094)	(0.056)	(0.047)	(0.099)	(0.065)
β	0.979	0.798	0.958	0.950	0.928	0.961	0.945	0.936	0.491
	(0.013)	(0.098)	(0.013)	(0.017)	(0.027)	(0.020)	(0.019)	(0.038)	(0.158)
Schwarz	-1.152	-2.706	-3.011	0.017	-3.048	-3.201	-2.871	-2.361	-5.422

Notes: Numbers in parenthesis are Boolerslev and Woodridge (1992) robust standard errors; Schwarz means the Schwarz criterion for model selection. $p_t = \phi_0 + \sum_{i=1}^{k} \phi_i p_{t-i} + \varepsilon_t$. is the mean equation used for banana and tea and $\Delta \log p_t = \phi_0 + \sum_{i=1}^{k} \Delta \log \phi_i p_{t-1} + \varepsilon_i$ expresses the mean equation of the other seven commodities. Variance equation of the commodities in this Table is:

$$\log(h_t^2) = \delta + \pi_1 \left| \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}^2}} \right| + \pi_2 \frac{\varepsilon_{t-1}}{h_{t-1}^2} + \beta \log(h_{t-1}^2).$$

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