

The behavior of commodity prices in Ethiopia

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Abstract

In an attempt to identify price stabilization strategies and rationalize public intervention in buffering markets, this article investigates the intertemporal dynamics of commodity prices in Ethiopia. A classical rational expectation model is modified to account for seasonal correlation of shocks. Model predictions are reduced to computable periodic threshold autoregression. Several nonlinearity tests are applied to detect threshold effects. A regime-switching normalized maximum likelihood method is formulated to estimate thresholds and threshold autoregression parameters using monthly data from Ethiopia for the period 1996–2006. The result indicates the presence of periodic price thresholds that could be formed as a result of speculative storage. Comparison of price movements below and above thresholds indicates that prices are more correlated below the thresholds than above them. However, the effect on error variance is not very strong. Temporal arbitrage, which is the gross return from speculative storage, appears to be modest. The long- and short-term implications of the findings are discussed within the context of ongoing policy debates.

JEL classifications: C22, E31, Q11, Q13

Keywords: Speculation; Price volatility; Price thresholds; Intertemporal arbitrage; Ethiopia

1. Introduction

The justification for state intervention in stabilizing agricultural prices has long been questioned (Newbery and Stiglitz, 1981). Nevertheless, continually increasing price uncertainty and its adverse effect on producers and consumers (Sadoulet and deJanvry, 1995; Sahn and Delgado, 1989) present a challenge for policy making with regard to defining an appropriate state role in terms of price risk management. The challenge becomes greater if the sources of price volatility are unknown. Deaton and Laroque (1992) argue that the variability of commodity supply shocks, inelastic demand, and the behavior of speculators are the major drivers of this volatility. Many observers in Ethiopia, including government,¹ believe that oppor-

tunistic speculation² (hoarding) by grain traders is one of the culprits for the ever-increasing price instability (Loening et al., 2008). The claim poses an important empirical question: how important and competitive is speculative storage in characterizing commodity price behavior?

Since Gustafson (1958), many economists have attempted to systematically investigate the role of commodity storage in price dynamics using classical commodity storage theory (Deaton and Laroque, 1992; Scheinkman and Schechtman, 1983; Wright and Williams, 1982). In the presence of adequate information on stock and price time series, analyzing the effects of speculative storage on price dynamics is not very problematic. However, information on stock time series is scant. Commodity price data, on the other hand, are easily available and can be obtained for years and months. The issue then is whether we can provide a robust judgment using the available price information alone. Previous studies that used only price

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Data Appendix Available Online

A data appendix to replicate main results is available in the online version of this article. Please note: Wiley-Blackwell, Inc. is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

¹ The Ethiopian government has repeatedly stated that opportunistic or greedy behavior by traders is causing the price volatility and sustained price rise. The government is suspicious of the rationality of speculators' expectations and

believes that the movement of prices is associated with noneconomic factors, such as political interests, is gaining popularity.

² "Speculation" in this article refers to the act of keeping inventories, with the expectation that the future price will be higher than the current price. The primary motive of speculative trade is to generate profit. Government storage for stabilizing prices is not considered speculative storage. Terms such as "storage trade" and "intertemporal arbitrage trade" are used synonymously with the term "speculative storage." "Hoarding" is a term sometimes used to indicate a higher degree of speculative storage.

data applied two competing methods. The first method relies on simulation of the structural equation using dynamic programming (Osborne, 2004) and the second method relies on estimation of the reduced equation using threshold analysis of observed price series (Shively, 2001). The latter assumes an identically and independently distributed shock at harvest that translates into a constant threshold in all periods. This assumption could be restrictive, particularly for developing countries where production remains constant over seasons and varies over years. Chambers and Bailey (1996) relaxed this assumption and developed dynamic threshold models. However, their estimation requires extensive algorithms and makes the model less attractive for empirical applications.

In response to these perceived shortcomings in the previous approaches, we refine the Chambers and Bailey (1996) periodic threshold model to make it suitable for explaining speculative behavior under different circumstances and testing using regime-switching maximum likelihood estimation. Then, we apply it in a developing country setting where markets are thin, production is stochastic, and interregional trade is limited. The article is guided by three major objectives. First, it tests the presence of threshold effect within the Ethiopian grain prices dynamics. Second, it examines the effect of speculation on price volatility (autocorrelation and variance). Third, it evaluates the efficiency of the temporal arbitrage. By doing so, we find that price formation in Ethiopia is consistent with the prediction of storage model in which investment on speculative storage is made under rational expectation. This finding contributes to the ongoing debate regarding the behaviors of commodity prices and anti-speculative storage policy interventions.

2. Grain prices and storage in Ethiopia

The grain marketing system and the spatial movements of Ethiopian grain prices have been widely studied (Getnet, 2007; Getnet et al., 2005; Negassa, 1998; Negassa et al., 2004; Tadesse and Shively, 2009). The studies implied that the spatial integration of major regional markets into central and other regional markets is fairly strong; vertical integration between wholesale and retail markets is satisfactory; and intercommodity price transmission is very strong. Such integrations are realized as a result of increased expansion of road and communication networks. However, little is known about how prices are evolving over time and how the storage behavior of traders and farmers affects this evolution.

Monthly retail price data from 1996 to 2006 for two commodities (teff and maize) do not show any significant downward or upward trend until the end of 2005, when the 2007–2008 food price hike commences (see Fig. 1). More surprising is that there was no significant difference between nominal and real price trends before 2006. However, the relative price trend changed after this time. Nominal prices show an increasing trend for both teff and maize. The real price for teff also increased, although the trend is not as sharp as the nominal price trend. Contrary to

expectations, the real price of maize declined despite the sharp increase in its nominal price. In addition, it has been observed that the difference between nominal and relative (real) prices has been growing in recent times. However, more recent information indicates that the price of food has increased more than the general price level (Loening et al., 2008).

A rise or decline in price trend is not as bad as its variability. In Ethiopia, price volatility and, more recently, food price inflation remain the overriding national concerns. Post reform grain prices are subject to significant and continuing interannual price volatility that ranks among the highest in the developing world. Monthly price instability, an indication of a market's relative performance in realizing arbitrage opportunities, has also worsened in the most recent period. Between 1996 and 2006, the average coefficient of variation of monthly grain prices was 23%. A substantial price collapse in 2001 resulted in a situation where many farmers were unable to cover even their fertilizer costs. By contrast, in 2006, the price of all food grains in all markets increased by as much as 80% (MoARD, 2006). There is a growing belief that prices in Ethiopia tend to keep on rising once they have experienced an initial increase. This implies that market prices are generated in a process that operates differently at different times and does not favor a random walk hypothesis. Fig. 2 shows monthly real price changes from February 1996 to July 2006. Both teff and maize prices experience long spikes in their downward and upward swings. However, the spikes were less frequent in the upward swing than in the downward swing. In other words, price slumps were more frequent than booms.

The functioning of storage and speculation may explain the presence of long spikes and extended troughs in grain price dynamics. Information related to the functioning of commodity storage in Ethiopia is very scarce. A few studies on market structures and performances (Dessalegn et al., 1998; Gabre-Madhin and Amha, 2005) indicate that the major economic agents who hold grain stock for speculation purposes are wholesale private traders and farmers. Grain commodities are stored for a range of periods. Whereas short-term storages are meant to overcome the fixed costs of transacting, long-term storages are intended to earn profits from future price speculation, which we sometimes refer to as temporal arbitrage. Most wholesale traders store grain in order to earn profits from price differences across seasons (Amha and Gabre-Madhin, 2005). Prices are usually lower during harvest and hence, traders buy during this time with the expectation that the price will rise during lean seasons. If the price remains the same, they keep the grain for the next year. However, such a decision is very stochastic and dependent on an individual trader's risk-aversion behavior, expectations about future harvests, and other possible shocks. According to Dessalegn et al. (1998), more than 80% of wholesale traders hold grain stocks for up to six months, 13% for up to 12 months, and 5% for more than one year. Although few traders keep grain for more than one year, the amount of grain that they hoard is relatively large.

Smallholder farmers sell the bulk of their produce right after harvest to pay taxes and loans and to meet their cash

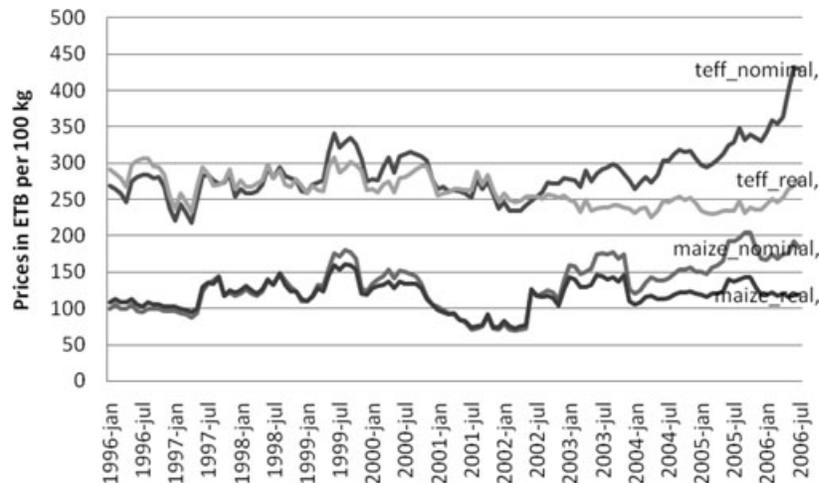


Fig. 1. Monthly commodity price trends in Ethiopia (Jan 1996–Jul 2006).

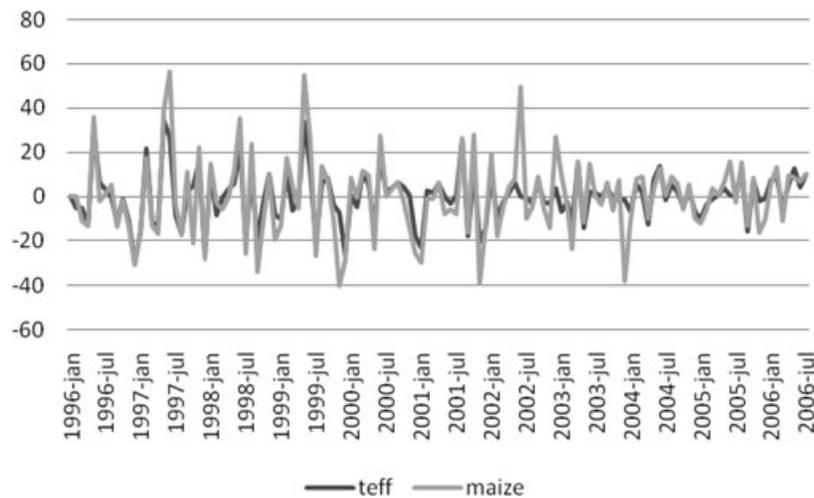


Fig. 2. Monthly price changes (Jan 1996–Jul 2006).

requirements for social services. They sell their produce piece by piece, in small quantities, depending mainly on the cash requirements of families. However, few farmers store grain for long periods in order to benefit from temporal arbitrages.

Storage cost is generally very high in Ethiopia. Based on a trader survey in 1996, Dessalegn et al. (1998) estimated an average storage cost of ETB 54/ton/month. This is composed of storage losses (9.2%), storage rent (16.15%), fumigation costs (9%), and the opportunity cost of tied capital (24%), labor (12.77%), materials (9.67%), and others (19.21%). These costs vary greatly from commodity to commodity because of differences between commodities in terms of storage losses and the value of tied capital.

Institutional interventions to stabilize grain prices are limited to buffer stocking and organizing producer cooperatives to hedge price risks by themselves. Buffer stocking is officially handled by the Ethiopian Grain Trade Enterprise, which

is mandated to stabilize producer and consumer prices, and maintain buffer stocks for market stabilization. The Enterprise has a storage capacity that holds about seven million quintal, which accommodates only 18% of the total grain marketed every year. As a strategy for stabilizing price, the Enterprise buys when grain prices are low and stores grain until the price goes above a ceiling price. However, the Enterprise's operations have an insignificant impact on market prices. For example, in 1996, the Enterprise's direct purchases from farmers represented only 2% and 2.6% of the total marketed quantity of maize and wheat, respectively (Bekele, 2002). The other new initiative to hedge price uncertainty is the establishment of the Ethiopian Commodity Exchange (ECX) in 2008. The ECX is established to formally coordinate the exchange of commodities and futures among wholesalers, exporters, speculators, and millers. It has targeted six commodities: maize, wheat, teff, pea beans, sesame, and coffee. However, it is not yet fully functional.

3. The theory of commodity storage

Speculation has long been recognized as having a substantial impact on the price dynamics of storable commodities (Williams and Wright, 1991). The explanation is straightforward. If the market offers temporal arbitrage opportunities because of supply fluctuations, profit-maximizing traders will engage in intertemporal trading. These speculators buy when the price is low and sell when the price rises so that the price difference across time will depend only on storage costs and the opportunity cost of capital. Thus, speculative storage could cause prices to stabilize over seasons in the short run. However, because of the nonnegativity constraint on stocks, stockholding behavior will be more effective in moderating the downward than the upward movement. This leads to the observation that commodity price cycles will typically exhibit a long flat bottom, interrupted by occasional sharp spikes, commonly referred to as nonlinearity³ in price dynamics. The nonlinearity is primarily attributed to the fact that inventories cannot be negative (Gustafson, 1958). The nonnegativity constraint imposed on the optimization of stock holding allows prices to behave differently below and above certain thresholds. To comprehend this conjecture, the rational expectation model of Williams and Wright is reformulated (Williams and Wright, 1991). To begin, the basic theoretical price formation process is presented with independently and identically distributed (i.i.d.) supply shocks and a constant opportunity cost of tied capital. Consider a grain market in which risk-neutral speculators engage in storage trade.

Further, assume that the traders utilize all available consumption and production information to set future expected prices. Let the grain price at time t be p_t , and the annual harvest be h_t , which is i.i.d. because of weather variability. In the absence of storage, in a closed economy,⁴ the total consumption is exactly equal to the total harvest so that price entirely depends on the stochastic harvest:

$$p_t = f(h_t). \quad (1)$$

Equation (1) represents the inverse demand function, where demand is equal to supply at equilibrium ($q_t = h_t$). In this framework, price follows an i.i.d. process. Serial correlation of price is not expected as long as the harvest is i.i.d.

In the presence of profit-maximizing and risk-neutral speculators in the market, both the demand and the supply will change to account for storage in such a way that:

$$x_t = h_t + (1 - c)S_{t-1}, \quad (2)$$

³ “Nonlinearity” is the term used to indicate structural breaks in price dynamics. Nonlinearity can be caused by a range of structural conditions, such as policy changes, shocks, storage, etc. “Threshold nonlinearity” is used to refer to structural breaks in price series owing to a threshold variable (lagged price) that affects storage decisions.

⁴ The closed economy assumption will be maintained throughout the article. The assumption is particularly realistic in the case of Ethiopia, where exports are officially banned for some grains including teff and where commercial imports are very rare. Food aid might be relevant but it affects the price level more than price volatility.

where x_t is the state variable that consists of the stochastic harvest and the net carryover level of grain from the previous period ($S_{t-1} \geq 0$). This is the available grain at any time, either for current consumption or for storage. c is a part of the stored grain wasted or decayed. Using Eqs. (1) and (2), the price formation equation becomes:

$$p_t = f(x_t - S_t). \quad (3)$$

Equation (3) specifies the inverse demand function in which price depends on the total harvest and the net inventory change. Storage in this case is a decision variable that must be determined from the speculator’s problem. The speculator’s problem is to determine the discounted optimal level of storage that maximizes net profit, subject to storage cost, and the equation of motion (3). Deaton and Laroque (1992) showed that a formal derivation of the problem provides unique stationary rational expectation equilibrium (SREE) at the optimal market price p_t :

$$p_t = \max\{f(x_t - S_t), (E(f(h_{t+1} + (1 - c)S_t - S_{t+1}))(1 - c)/(1 + r))\}, \quad (4)$$

where c is equivalent to the marginal cost of storage, which includes all variable costs related to managing inventory and inventory decay, and r represents the market interest rate. The first term in parentheses in Eq. (4) indicates the gain from consuming a unit of grain currently, whereas the second term shows the expected and discounted gain from storing grain for one more period. The expectation is made based on the realized current period stock and the expected future harvest. Here, storage is assumed to be a windfall strategy whereby speculators do not plan to store ahead of time. This means that expected future storage has no effect on current period price expectations.

The SREE of Eq. (4) implies the following temporal arbitrage conditions.

- a. If $f(x_t - S_t) \geq (E(f(h_{t+1} + (1 - c)S_t - S_{t+1}))(1 - c)/(1 + r)$, then $S_t = 0$ and the future price reduces to (1), where $S_{t+1} = 0$. Substituting $E(f(h_{t+1} + S_t)) = E(P_{t+1})$, one obtains:

$$P_t \geq (E(P_{t+1}))(1 - c)/(1 + r). \quad (5)$$

As consuming today provides higher value than storing, storage becomes zero and the price depends only on the current level of harvest. The intertemporal connection will be broken and the price series is expected to be less correlated than under an assumption of storage. Zero storage is a temporary outcome in response either to future speculation or to a high storage cost due to price risk, high costs of storage, or a high opportunity cost of capital. If there exists any storage under such conditions, as commonly observed in developed economies, it must be attributed to a desire either for convenience or for ease of transaction (Chavas et al., 2000).

- b. If $(E(f(h_{t+1} + (1-c)S_t - S_{t+1}))(1-c)/(1+r) > f(x_t - S_t))$, then $S_t > 0$ and the market price is less than the expected gain from storage. That is:

$$P_t < E(P_{t+1})(1-c)/(1+r). \quad (6)$$

Equation (6) states that, along the optimal storage path, the current price must be lower than the discounted expected future price and the marginal storage costs. As storage is positive, prices are expected to be serially correlated. Furthermore, price volatility should depend not only on the stochastic harvest but also on the predetermined level of stocks. Thus, lower volatility is an equilibrium outcome of such a condition.

The i.i.d. assumption is restrictive and fails to adequately explain price dynamics at higher prices (Chambers and Bailey, 1996; Deaton and Laroque, 1996). Though the correlation of harvest shocks is less likely in annual and rain-fed crops, their distribution could possibly be time dependent (nonrandom). An important insight to deal with this problem is the use of periodic disturbances, where a period is represented by a month (Chambers and Bailey, 1996). The idea behind this approach is that harvest shocks in every period, say July in each year, are an i.i.d. but the harvest shocks of July and other months, say August, might have different distributions across periods. In this extension, however, we still assume that disturbances are independent across time periods. Periodic disturbances offer a plausible and realistic assumption for empirical work using monthly price data. Let a period is represented by $j = 1, 2, \dots, n$, such that the mean and disturbances of the harvest are \bar{h}_j and v_j , respectively. The SREE can be modified to accommodate periodic disturbances as follows:

$$p_{tj} = \max\{f(x_{tj} - S_{tj}), (E(f(h_{t+1} + (1-c)S_{tj} - S_{tj+1})) \times (1-c)/(1+r)), \quad (7)$$

where $t \in j$.

Equation (7) implies that each period will have different rational expectation equilibrium, conditional on observed, and expected harvests. Harvest shocks are identically distributed within a period and across years but different across periods (seasons).

4. Estimation strategy

The major testable prediction derived from the commodity storage model in Section 3 is that storage causes prices to behave differently above and below a certain decision price. The two-arbitrage conditions described by Eqs. (5) and (6) imply that there exists a price level p^* below which speculators maintain stock and prices are functionally related over time, and above which speculators do not maintain any stock and prices are disconnected. Thus, the reduced form of the SREE when storage is positive as in Eq. (6) is specified as:

$$E(p_{t+1}) = (1+r)/(1-c) \min(p_t, p^*), \quad (8)$$

where p^* is a “threshold” price. Assuming rational expectations on the part of agents, the stochastic form of (8) is:

$$p_t = (1+r)/(1-c) \min(p_{t-1}, p^*) + e_t, \quad (9)$$

where e_t is the disturbance associated with deviations from the actual price caused by demand and supply shocks.

The probability distribution of the random disturbance term (e_t) has an important implication for the formulation and estimation of (9). The disturbance term could exhibit i.i.d., time-dependent, and/or periodic behavior. Furthermore, the opportunity cost of capital (r) may change over time as a result of structural policy changes. Such distinctions give rise to several different possible forms of Eq. (9). The i.i.d. assumption of supply shocks implies that the threshold remains constant over the entire sample period (Deaton and Laroque, 1992). The model⁵ is specified as:

$$p_t = \begin{cases} \gamma_1 p_{t-1} + e_{1t} & \text{if } p_{t-1} < p^* \\ \gamma_1 p_{t-1} + e_{1t} & \text{if } p_{t-1} \geq p^* \end{cases}, \quad (10)$$

where the $\gamma_1 = (1+r)/(1-c)$ and e_{1t} is the error term in the presence of storage. As shown by (10), there is no intercept term to impose the arbitrage conditions restrictions. Equation (10) holds in the presence of speculative storage. Since we want to compare price behavior with and without storage, using the SREE in Eq. (5) and following the same reasoning, we can formulate Eq. (10) for the without storage case.⁶

Under the assumption of periodic harvests, disturbances within a period and in different years are i.i.d. but different across periods. The major implication of the periodic disturbance assumption is that the threshold price, p^* , is no longer constant, but instead varies across periods. In particular, each period will have its own threshold price that speculators use for decision making (Chambers and Bailey, 1996). Thus, the periodic threshold form of (10) is:

$$p_t = \begin{cases} \gamma_1 p_{t-1} + e_{1t} & \text{if } p_{t-1} < p^{*k} \\ \gamma_1 p_{t-1} + e_{1t} & \text{if } p_{t-1} \geq p^{*k} \end{cases} \quad (11)$$

$k = j \quad \text{where } t \in j.$

We impose the same restriction on p^{*k} as Chambers and Bailey (1996). However, we restrict p^{*k} to take only two values, one for six consecutive months followed by another value

⁵ We restrict the model to a first-order autoregression based on the Akaike Information Criteria (AIC) test. For countries such as Ethiopia where speculators are poor, arbitrage may not last for more than a single period.

⁶ Redefine Eq. (8) as $E(p_{t+1}) = \gamma_2 \max(p_t, p^*)$, where γ_2 is a parameter from observed prices. Equation (10) can be re-specified for without storage case as $p_t = \begin{cases} \gamma_2 p_{t-1} + e_{2t} & \text{if } p_{t-1} \geq p^* \\ \gamma_2 p^* + e_{2t} & \text{if } p_{t-1} < p^* \end{cases}$.

for the rest of the months. The first six months are defined to be harvesting or surplus months and the others as nonharvesting or deficit months. This is because, first, the harvest for agricultural commodities occurs within a range of few months. Thus, harvest is identically zero for the rest of the months. This gives rise to the possibility that the disturbances within harvesting or nonharvesting months are identical but different across seasons. Second, traders' and producers' storage behaviors and decisions differ greatly over seasons compared with over months. Thus, besides controlling for periodic distribution of harvest shocks, our definition of a period based on a season helps to examine behavior under different seasons. Traders and producers usually presume a higher expected price during nonharvesting period than harvesting period to keep positive inventory. More importantly, allowing p^{*k} to take 12 values one for each month is very difficult for empirical estimation using small samples. Imposing restriction on p^{*k} , however, introduces additional assumption that shocks are identically distributed within the group of months. Empirically, the Durbin–Watson d-statistic is computed for each commodity and each group showed that disturbances are indeed i.i.d. within the group of months.

Provided that the error terms are normally distributed, Eqs. (10) and (11) are estimated using regime-switching maximum likelihood estimation. For T independent observations, the log-likelihood function is given by:

$$L(\theta) = f(p_1, p_2 \dots p_T | \theta) = -\ln \sigma + \sum_{t=2}^T \ln \phi(z_t), \quad (12)$$

where $z_t = \frac{(p_t - \gamma p_{t-1})}{\sigma}$, $\theta \in \{\gamma, \sigma\}$ and $\phi(\cdot)$ denotes the standard normal distribution.⁷ Equation (12) is modified for regime-switching regression using a probability function that identifies the probability of a given observation falling in a particular regime, i . The probability function, ρ_{it} , denoted as $\rho(p_t \in i | p^*)$, is defined as the probability of an observed price at time t falling in the i^{th} regime where $i = 1$ if $p_t < p^*$ and $i = 2$ if $p_t \geq p^*$. Furthermore, it has been normalized using the proportion of observations within the regime (Hamilton, 1994). The normalized log-likelihood function is:

$$L(\theta) = \left(-\ln \sigma_1 + \sum_{t=2}^T \ln \phi\left(\frac{e_{1t}}{\sigma_1}\right) \right) \omega_1 \rho_{1t} + \left(-\ln \sigma_2 + \sum_{t=2}^T \ln \phi\left(\frac{e_{2t}}{\sigma_2}\right) \right) \omega_2 \rho_{2t}, \quad (13)$$

⁷ The derivation of Eq. (13) from the probability density function proceeds as follows. Given the normal probability density function $f(p | \gamma, \sigma) = \left(\frac{1}{2\pi\sigma^2}\right)^{1/2} \exp\left(-\frac{(p_t - \gamma p_{t-1})^2}{2\sigma^2}\right)$, substituting $z = \frac{p_t - \gamma p_{t-1}}{\sigma}$, and factoring out $\frac{1}{\sigma}$, we obtain $f(p | \gamma, \sigma) = \frac{1}{\sigma} \frac{1}{\sqrt{2\pi}} \exp(-0.5z^2)$, which is equivalent to the standard normal distribution $f(p | \gamma, \sigma) = \frac{1}{\sigma} \phi(z)$. For a sample of T i.i.d. normal random variables, the likelihood is $f(p_1, p_2 \dots p_T | \gamma, \sigma) = T \frac{1}{\sigma} \phi(z_1) \cdot \phi(z_2) \cdot \phi(z_3) \dots \phi(z_T)$. Taking the logarithm of this gives us Eq. (13).

where ω_i is the proportion of observations under regime i , $\omega_i = \frac{t_i}{T} = \frac{\sum_{t=2}^T \rho_i}{T}$ and $\omega_1 + \omega_2 = 1$. σ_i is the variance for each regime; $i = 1$ for the first regime where storage is positive and $i = 2$ for the second regime where storage is zero. As implied by the storage model, the variance of the disturbance varies across regimes because of the existence of carryover stock in regime 1 that stabilizes price, whereas in regime 2, price depends entirely on the stochastic harvest and any other demand shocks (Wright, 2001). Thus, the error term is heteroscedastic for the entire sample but homoscedastic for each regime.

Estimating the parameters in Eq. (13), $\theta \in \{\sigma_i, \gamma_i, p^*\}$ is difficult because of the nonlinearity of the equation with respect to p^* . Many complicated algorithms and methods are available in literatures that could estimate the parameters simultaneously (Hamilton, 1994). However, once ρ is exogenously determined, it is easy to estimate. Such probability determination requires a prior identification of the threshold value and its functional form. We assume a uniform switching probability function in which a given observation receives a probability of falling in a regime of either 1 or 0. A grid search method is applied to establish the threshold value. For a constant threshold model, 10–90 percentiles of the threshold variables were considered as candidates and Eq. (13) is run for each candidate. The one with the highest log-likelihood is taken as the optimal threshold value. The approach here follows Shively (2001), who studied the Ghanaian grain market. For periodic threshold models in which two thresholds are considered at a time, $n_1 \times n_2$ candidates are evaluated, where n_j is the number of observations in period j that lies within the range of 10–90 percentiles.

5. The data

The data are obtained from the records of the Central Statistics Agency of Ethiopia (CSA). We used prices from the Addis Ababa grain market. Addis Ababa represents the major central market that receives grain from surplus-producing areas and distributes it to deficit areas. It is the major consumer market as it contains Ethiopia's largest urban population. It also serves as a producer market, particularly for surrounding teff-growing farmers, who are the major suppliers of teff in the country. In general, it best characterizes activities in the country's commodity markets and is conjectured to embody the basic pattern of the nation's food price dynamics.

Two major cereal grains, teff and maize, are included in the study. These crops account for more than 50% of national annual cereal production and consumption. Teff is a crop indigenous to Ethiopia and is widely used for making soft bread called *injera*. It appears in a range of qualities, with significant differences in prices. In this study, the price of the highest quality teff, called white teff, is used. Although both teff and maize grains are storable, teff is more storable than maize because of its resistance to pests in storage. However, teff is more expensive

than maize and therefore requires more capital investment than maize.

A series of empirical models were estimated using monthly retail real prices covering the period from January 1996 to July 2006. This series was deflated using the monthly general consumer index published by the National Bank of Ethiopia. Prices were tested for nonstationarity using augmented Dickey–Fuller unit root tests. Although a hypothesis of nonstationarity cannot be rejected for nominal prices, real prices appear to be stationary. Not surprisingly, however, the price series are highly autocorrelated. First-order autocorrelation coefficients are above 0.9 for all commodities. Higher-order autocorrelation coefficients are insignificant and a partial autocorrelation function graph shows a sharp decline after the first lag.

6. Results and discussion

6.1. Threshold effects

Analyzing the intertemporal dynamics of commodity prices assists in ascertaining whether real prices exhibit nonlinearity. In this section, we explore the presence of threshold nonlinearity to determine the role of speculative storage in characterizing commodity price formation. Several test procedures were employed, including a general nonlinearity test (Tsay, 1991), a threshold nonlinearity test (Tsay, 1989), and Hansen and cumulative sum of squares (CUSUMQ) tests (Greene, 2003). These tests generally test the presence of threshold effects without prior identification of the threshold value. All the tests are made on residuals of arranged recursive regressions in which the data are first arranged based on the threshold variable and then a series of regressions are carried out, starting from the full observation and advancing by dropping one observation at a time until a sufficient number of observations remains to run the last regression. Thus, each observation has its own parameters and residuals. The association of the parameters and residuals with the threshold variable is used to test the presence or absence of threshold nonlinearity. Test statistics of these types are presented in Table 1.

The test results provide clear evidence of price thresholds. All tests confirm that there exists strong threshold nonlinearity in both teff and maize price dynamics, although the degree varies across tests and commodities. Tsay tests predict threshold effects more strongly than do Hansen and CUSUMQ (see Fig. 3) tests. This is in line with previous findings that claim

that the former tests are more powerful than the latter (Tsay, 1991, 1989). The threshold effect appears to be stronger in teff than in maize. As teff is storable for longer periods than maize, extended slumps are more apparent in teff than in maize. However, CUSUMQ graphs reveal the possibility of more than one single threshold in maize price dynamics as the cumulative sum of the squared residuals exceeds the band formed by the lower and higher values of the threshold variable.

Table 2 reports the threshold values and stock-out rates identified by grid search methods. The thresholds are expected prices above which speculators will not store grain and below which they tend to store grain expecting future price improvements. These prices are higher than the respective long-term average prices by about 10 and 13 average points for teff and maize, respectively. As the thresholds are identified based on rational expectations framework, a comparison of the threshold autoregression with a restricted first-order full-sample autoregression indicates whether the threshold effect is due to speculative storage. The likelihood ratio test reconfirms the presence of threshold effects and that these are indeed caused by speculative storage. The parameters of the restricted first-order autoregression are significantly different from those of the unrestricted threshold autoregressions. Both constant and periodic thresholds are statistically significantly different from zero. However, the periodic threshold for the teff price shows a very large chi-square value, which supports the view that threshold values change periodically because of the seasonality of shocks. The stock-out rates, which indicate the probability of no speculative trade, are generally low. However, the rates observed here remain higher than stock-out rates in developed countries, where commodities are generally in surplus (Chambers and Bailey, 1996; Deaton and Laroque, 1996). As expected, maize has a higher stock-out rate than teff. This is consistent with the fact that speculative trade is more common for teff than for maize. Correcting the seasonal effects of price distribution increases the likelihood of a stock-out in the market. By contrast, the incidence of stockpiling falls when separate decisions regarding threshold prices are established for harvesting and nonharvesting periods. In general, the result indicates a very low incidence of trader holdups and confirms the significance of speculative behavior on price formation. In the next section, we will see the impact of such speculation on price correlation and volatility and examine whether the temporal arbitrage caused by the speculation is efficient.

6.2. Effects of price thresholds on price volatility

The effect of threshold nonlinearity on price correlation and variability was assessed using the parameters obtained from the regime-switching maximum likelihood estimation. We measure price volatility based on the size and variability of spikes generated by price shocks. If the correlation between price series is very high, then the size of amplitude will be smaller and hence the price is less volatile. If the variance of the current price series is very high, then the amplitude size is very variable and so is the price volatility. To compare autocorrelations and

Table 1
Threshold tests for the Ethiopian commodity price series

Tests	Teff	Maize
Tsay_GNL_F test	3.19***	2.67**
Tsay TAR_F test	5.63**	5.87**
Hansen test	1.57**	0.9318*
CUSUMQ test	0.43	0.51

The CUSUMQ test values are the mean of the cumulative sum of squared residuals.

*, **, and *** indicate statistical significance at 10%, 5% and 1% levels.

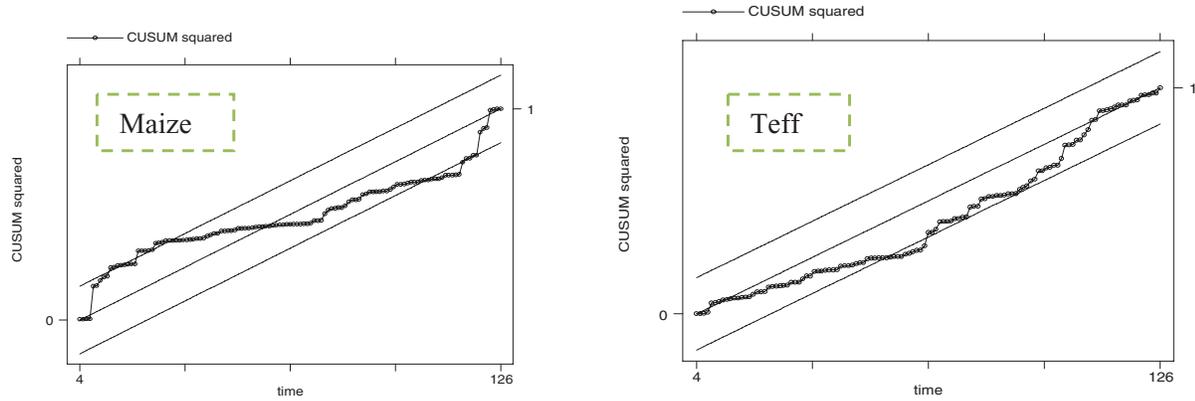


Fig. 3. Cumulative sum of squares (CUSUMQ) of recursive autoregressions of commodity prices.

Table 2
Threshold prices and speculative storage estimated using switching maximum likelihood

Parameters	CTAR		PTAR	
	Teff	Maize	Teff	Maize
P ¹	2940 (12)	1360 (15)	2780 (8)	1270 (12)
P ²			2980 (12)	1370 (11)
Stock out rate	0.11	0.19	0.14	0.24
LR test against AR	3.10***	10.64***	27.54***	10.96***

CTAR = Constant Threshold Autoregression, PTAR = Periodic Threshold Autoregression.

P¹ = harvesting season threshold, P² = nonharvesting season threshold.

Numbers in the parentheses are percentage changes of the threshold prices from the long-term average price.

*** indicates statistical significance at the 1% level.

variances during price slumps where stock is positive, and during price booms where stock is zero, we estimated constant and periodic threshold autoregression models using the maximum likelihood method.

Table 3
Effects of price thresholds on volatility and returns from speculative storage investment

Parameters	AR	CTAR			PTAR		
		Above threshold ^a	Below threshold ^a	Change	Above threshold ^a	Below threshold ^a	Change
Autocorrelation coefficient (γ)							
Teff	0.999 (0.004)	0.982 (0.009)	1.002 (0.0053)	0.02**	0.957 (0.0089)	1.004 (0.0051)	0.05***
Maize	0.997 (0.0074)	0.9531 (0.0238)	1.011 (0.0125)	0.06***	0.960 (0.0197)	1.014 (0.0135)	0.05***
Variance (σ)							
Teff	11.753 (0.7404)	9.357 (1.9271)	9.303 (0.9282)	-0.054	10.176 (1.8476)	8.773 (0.9077)	1.403
Maize	9.953 (0.627)	12.323 (2.470)	9.218 (1.009)	-3.11*	11.4686 (1.979)	9.265 (1.0777)	-2.2*
Rate of gross margin (%)							
Teff		2.4			5.5		
Maize		13.4			16.6		

^aNumbers in parentheses are standard errors of the estimates.

** and *** indicate statistical significance at 5% and 1% levels. A zero intercept restriction was imposed in all models to satisfy the arbitrage conditions.

The results of the models are comparable (Table 3). The models seem essentially equivalent in explaining the observed price dynamics. However, a distinction is required to characterize the decision behavior of speculators and rationalize the right way of modeling commodity price dynamics in Ethiopia. A likelihood ratio test is used to test the hypothesis that thresholds are constant over periods. The test statistic is given as follows:

$$LR = 2 * (\ln L_0 - \ln L_p) \sim \chi^2(k = 1), \tag{14}$$

where L_0 is the log-likelihood of the null hypothesis ($H_0 : P^{*1} = P^{*2} = P^*$) and L_p is the unrestricted periodic threshold (their values are in Table 3). The test statistics for teff and maize were 6.32 and 2.34, respectively. The hypothesis is rejected at a 5% level of significance for the teff price but cannot be rejected for the maize price. This implies that the periodic threshold model fits better than the constant threshold model, at least for the teff price series. In other words, unlike maize, teff production shocks are seasonally different. The difference in price dynamics across commodities could be attributed to the

Table 4
Sensitivity analysis for the change in period intervals

Parameters	Six-month interval		Four- and eight-month interval*	
	Teff	Maize	Teff	Maize
P ¹ (surplus periods threshold)-ETB/ton	2780	1270	2380	1180
P ² (deficit periods threshold)-ETB/ton	2980	1370	3080	1370
γ_1 (coefficient above the threshold)	0.957 (0.009)	0.960 (0.019)	0.975 (0.009)	0.97 (0.017)
γ_2 (coefficient below the threshold)	1.004 (0.005)	1.014 (0.014)	1.008 (0.006)	1.015 (0.015)
σ_1 (variance above the threshold)	10.176 (1.847)	11.469 (1.979)	11.63977 (1.675)	11.06548 (1.652)
σ_2 (variance below the threshold)	8.773 (0.908)	9.265 (1.078)	9.243 (1.146)	9.439326 (1.211)

*The four months are surplus periods (harvesting months) while the eight months are nonharvesting months. Numbers in parentheses are standard errors and all the estimates are statistically significant.

nature of production of the crops. As teff is a rain-fed crop, it is produced once per year and hence, supply shock persists for a single season. Unlike teff, maize is produced using *belg*⁸ rains or irrigation so that production shocks are identical throughout the year. Thus, maize speculators have a constant mean threshold price whereas teff speculators adjust their threshold (decision) price seasonally.

The sensitivity of the periodic model estimation for period interval has been checked by defining only four months such as November, December, January, and February as harvesting/surplus periods and the remaining eight months as non-harvest or surplus periods. The result shows that despite few differences in the level of thresholds and variances the estimation is consistent (see Table 4). As expected when the harvesting season is defined narrowly and more accurately⁹, the threshold price during this season becomes lower and the periodic model predicts more accurately. However, the change is not very significant.

The overall result indicates that price autocorrelation is stronger with a stock regime (below the threshold) than it is without stock (above the threshold). A robust Wald-statistic corrected for unequal variance is used to test the equality of the correlation coefficients above (without storage) and below the thresholds (with storage). The test statistics, calculated following Greene (2003), show that the two price autocorrelation coefficients are statistically different for both commodities. The difference becomes more significant when a periodic threshold is used. This implies that speculative storage indeed moderates the downward movement of food prices in Ethiopia.

The effect of price thresholds on the variability of agricultural prices during slumps and booms is tested by comparing the variance of the disturbances above and below the thresholds. Slumps are less variable than booms in three of the four cases. To ensure the statistical significance of such differences, the following *F*-statistics were calculated:¹⁰

$$F = \frac{\sigma_2^2}{\sigma_1^2} \sim F(n_2 - k, n_1 - k). \quad (15)$$

The test reveals that storage trade has a significant impact on the volatility of the maize price but not on the volatility of the teff price, indicating that the incidence of stock holding per se makes no significant contribution to price stabilization. The demand structure of teff may help to explain why the teff market failed to stabilize price. The demand for teff is price elastic; when price is lower, the consumption demand increases, which immediately causes the price to increase as supply is constant in the short run. Such fluctuations outweigh the stabilization effect of storage, unlike the case of maize, for which the demand is inelastic.

6.3. Efficiency of temporal arbitrage

We evaluated the extent of grain markets' intertemporal efficiency by comparing the gross margin rate of return from investment in storage and the costs of storage. The annual rate of gross margin from investment in speculative storage was estimated as follows. Assuming that $p_{t-1} < p^*$ and that $S_t > 0$, the monthly gross internal rate of return from intertemporal trade, R , is estimated as $R = \frac{p_t - p_{t-1}}{p_{t-1}} = \gamma - 1$. The annual gross internal rate of return expressed in percentage terms is, thus, $(\gamma - 1) * 12 * 100$.

The result indicates that the annual gross margin rate of return ranges from 2.4% to 16.6% (Table 3). These values represent the risk-free gain from storing grain for one more year. The variation in the rate of return across commodities is also in line with the variability in storage costs. Maize storage is more costly than teff. This is because maize has higher losses when stored for a longer period of time. The storage loss of maize over a six-month period in rural Ethiopia was reported as 23%–33% (Dadi et al., 1992). In 1996, storage cost accounts for 2% and 5% of the gross values of teff and maize, respectively (Dessalegn et al., 1998). Given the high cost of storage and the low level of expected gross margin, temporal arbitrage generates insignificant profit. In other words, on average, the Ethiopian grain market provides less attractive temporal arbitrage for risk-averse and risk-neutral traders. Only those traders who are risk-loving could engage in temporal arbitrage and benefit from

⁸ A short rainy season during winter.

⁹ Since the data are taken at the national level, defining accurate and specific season for each crop is very difficult.

¹⁰ By convention, the larger variance appears as the numerator (see Gujarati, 2003).

windfalls. Therefore, there is insufficient evidence that there is an opportunistic temporal arbitrage and that intertemporal trade is inefficient. In general, since the rate of return on speculative storage is modest, we believe that intertemporal trade appears to be competitive and optimal.

7. Concluding remarks and some policy implications

In an attempt to identify price stabilization strategies and rationalize public intervention in commodity markets, this article analyzes the presence of price thresholds and their effect on commodity price volatility. Theoretical arguments attribute the presence of thresholds to speculative storage. This prediction is tested using threshold models. The result reveals the following findings: (1) There exists strong nonlinearity and threshold effect in Ethiopian grain price dynamics, which may be linked to speculative storage. Price thresholds appear to be an important aspect of the price dynamics. (2) Such speculative storage causes strong price autocorrelation, which is larger than unity, but the effect on the variability of price spikes caused by shocks is not very strong. (3) The temporal arbitrage (expectation formation) appears to be rational and efficient. We found that the gross margin rate on intertemporal trade is not very different from the cost of storage. This implies that hoarding (deriving monopolistic profits through hoarding grain) was not a money-spinning business, at least during the study periods. Private grain traders had very limited power to destabilize the market and generate risk-free opportunistic profits.

The major implication that arises from the analysis is that speculative behavior is an important determinant of Ethiopian grain price formation. It leads to temporal market integration in the long run, with temporary breaks to adjust for critical thresholds. Therefore, speculative behavior has to be presumed while price stabilization policies are formulated and implemented. The effect of any policy intervention made today will last longer in the presence of speculative trade. For example, it is possible that government interventions during harvesting time may be transferred beyond the harvest period by disrupting traders' expectation formation. The huge government-sponsored cooperatives' grain purchase during the 2006 harvest created unusual increases in the harvest time price, and that shock might have been carried through to the overall market via traders' expectations. Therefore, the 2007/08 food price inflation might have been aggravated by inappropriate interventions that assume speculative storage is either ineffective or inefficient.

Should policy makers ban or control speculative storage? In most developing countries, including Ethiopia, policy makers attempt to control private speculative storage, on the assumption that private speculators disrupt the market through stockpiling. As the intertemporal price formation is in line with the prediction of rational expectations and the temporal arbitrage is competitive, there are little grounds for designing antispeculative storage measures. A rising food price is likely to relate to supply shortfalls rather than to speculators' stockpiling, unless

an increasing price carries information that predicts a further increase in future price. However, we did not find that to be the case, at least during our study periods. Moreover, anti-speculative storage measures instead create opportunism and intertemporal dissociation of supply, which further aggravates price volatility. As a result, we recommend that the government encourage intertemporal private trade to be more competitive. A reduction in storage costs, specifically storage loss and transaction costs, may increase the efficiency of intertemporal trade and reduce any potential price explosion. A lower-cost public intervention could focus on formalizing the grain trade so that speculators become effective and more efficient. The recent initiation of a commodity exchange program is an example of this kind of intervention, which assists speculators to actively engage in speculative storage and future trading.

Although this article provides plausible baseline information, we recognize that reliance on retail prices alone may limit its wider generalization and, hence, the implications presented above have to be interpreted cautiously. To improve the analysis, it will be helpful to include detailed data on stocks. The article uses price data up to 2006. Price trends have dramatically changed since then, and the speculative behavior and its effect on price dynamics might have changed as well. Thus, the methods and arguments developed here can be used to provide updated empirical evidence using recent data sets and to provide timely information for policy makers.

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