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What explains price volatility changes in commodity markets? Answers from the world palm-oil market ☆

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Abstract

What are the sources of commodity price volatility changes? Based on observation of the palm-oil market (1818–1999), our hypothesis is that the superimposition of short-distance operators located near the export supply, whose expectation horizon is limited to a few weeks, and long-distance operators further from the export supply, whose expectation horizon exceeds six months to one year, is responsible for volatility changes and market instability. Because of the superimposition of expectations horizons, volatility grows along with the development of short-distance trade. We support this hypothesis using a trader-behavior model derived from Day and Huang [J. Econ. Behavior Org. 14 (1990) 299] and Day [Complex Economic Dynamics, Vol. I. MIT Press, Cambridge, MA]. Our simulation results challenge the argument that trade liberalization and market enlargement necessarily reduce commodity prices volatility.

Keywords: Price insurance; Volatility; Commodity market; Chaotic dynamics

1. Introduction

The World Bank response to commodity price instability is to improve the access of less developed countries (LDCs) to existing future markets and to design, when possible, market tools and exchanges appropriately to risk hedging within LDCs (World Bank, 1999). It is known that incomplete markets (markets where not all risks can be hedged) lead to inefficiency. Hence, market completion should be the next logical step on the world-trade agenda if efficiency is to be fully assured and all benefits of free-trade realized.

However, one of the major difficulties facing a market-friendly answer to price risk can lie in the movement of prices itself. Market-based risk management instruments, such as futures and options, hinge on specific properties of price volatility which determine their cost and thus their price. In particular, in the presence of non-normal price distributions and, consequently, changing volatility — when volatility is simply measured by a spread variable like the variance or standard deviation (S.D.) — numerous international prices do not fit the standard hedging tools developed after Fama (1965) and Black and Scholes (1973) for both futures and options models. In such models, price variance is assumed to be constant and the price distribution stationary, so that a perfect hedge with zero loss is always possible. With non-normal prices, losses can be significant and global welfare reduced, even with free-trade.

Designing mathematical hedging tools appropriate to non-normal laws is one possible response to real price movements — mainly being carried out in finance theory. Another response is to look for sources of volatility to help predict its major shifts. This is

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Table 1
Properties of the first DPALM, 1818–1999[a]

Mean	S.D.	Skewness	Kurtosis	Normality tests		
				χ^2	Kolmogorov–Smirnov	Anderson–Darling
0.000813	0.060	0.727	10.589	954.446 Rejection	0.20 Rejection	45.494 Rejection

[a] Source: text.

the approach we apply to a particular commodity market, the palm-oil market, using end-of-the-month prices from January 1818 to January 1999. We briefly describe how this market functions in Section 2. Subsequently, a model of volatility changes is built following Day and Huang (1990) and Day (1994). Finally, the simulation results are presented and discussed.

2. Problem and hypothesis

Palm-oil, in terms of volume now the most important vegetable-oil traded in the world, was imported into Europe from the Gulf of Guinea for non-food purposes as of 1790. It became the most important vegetable-oil consumed in Great Britain, its first food market, in the 1930s. After the second World War, African producers started to lose ground against Southeast Asia (namely Indonesia and Malaysia). Beginning in the 1970s, new sources of supply and demand appeared in Asia. Ever since, alongside historical and long-distance trade with Europe, short-distance trade within Asia has been taking place.

Palm-oil is now used as a cooking oil in tropical countries as well as in catering, on industrial scales (fried food such as rice, noodles and chips) and in blends in the EU and Asia. The solid consistency of palm-oil favors its use in the manufacture of margarine and shortening in temperate countries.

An original 182 year monthly series of crude palm-oil (CPO) prices was collected at the Colindale Newspaper Library in London. Sources reporting early CPO prices were found in Latham (1978). These are The Liverpool Mercury (1817–1843), which provides cost, insurance and freight (CIF) end-of-the month prices in Liverpool over the period January 1818 to December 1843, and the The Economist (1843–1946), which covers the period January 1843 to December 1946. The data were complemented by CIF Rotterdam end-of-the month prices obtained from Oléagineux (1946–1959) and Oil World (1959–2000). [1]

The main statistical properties of the time series, the first difference of the logarithm of monthly palm-oil prices (DPALM) are shown in Table 1. Normality is clearly rejected. An ARCH-test (Engle, 1982) easily proves correlation in variance and, consequently, non-stationarity in volatility (the χ^2 statistic with one degree of freedom equals 62.15 which is significant at the 1% level).

There is no generally accepted theory of shifts in variance (or volatility) nor a theoretical explanation of non-stationarity (see Voituriez, 1999, for a survey). Literature on the subject mainly focuses on the violation of the perfect information hypothesis (which involves, for example, mimetic behavior and sudden shifts in volatility), whereas, empirical studies focus on the historical shocks a market faces over the long-run (Schwert, 1990). Without resorting to exogenous shocks, we build a model of CPO-trade that is able to generate time-varying volatility by incorporating the three following features characterizing the vegetable-oil market.

2.1. Feature 1: substitution between oils subject to technical limitations

The consistency of an oil determines its direct uses. Liquid oils (soybean- and rapeseed-oil, for example) are preferred for direct consumption (table-oils), whereas, solid oils like coconut-oil are used in the food and non-food industries (manufacture of mar-

[1] These prices are originally weekly prices. We have selected for each month, the last (weekly) quotation to build and end-of-the-month price series.

garine as well as soaps and surfactants). Processing techniques, mainly hydrogenation, harden oils and allow fluid oils to compete with solid-oils within specific technical ranges, and consequently, enlarge the number of competitors a particular oil, fluid or not, is likely to face in the world market.

2.2. Feature 2: shifts in trade leadership among oils

Two major periods of palm-oil supremacy in world-trade can be identified. In the early 1930s, palm-oil became the first vegetable-oil consumed in Great Britain (where our prices were registered). The World War II ended in this first period. The second period of supremacy started in 1972, when palm-oil replaced soybean-oil as the leader on world markets whose core had shifted from Great Britain to Europe (from 1946, our price series is registered in Rotterdam). Palm-oil has remained the most important vegetable-oil traded in the world ever since.

2.3. Feature 3: shifts in the geography of trade

European palm-oil imports represented more than 70% of world palm-oil imports until 1972–1973. They have represented somewhat less than 20% since the early 1980s. From less than 20% until 1972–1973, Asian palm-oil import shares have been fluctuating between 40 and 60% since. On the supply side, from less than 1% at the beginning of the 1960s, Malaysian and Indonesian palm-oil export share now exceeds 80% of the world total. African countries export share was 99% at the beginning of the 1960s, but has fallen to below 10% since. Thus, the market is now functioning on two scales. Besides, the historical and long-distance trade between Europe and the Gulf of Guinea, a short-distance trade within Asia has been taking place since the mid-1970s.

We hypothesize that together, substitution thresholds, shifts in trade leadership and shifts in the geography of trade generate time-varying volatility. To test this hypothesis, we build a dynamic trader-behavior model derived from Day and Huang (1990) and Day (1994) in which Walrasian tatonnement is formalized according to Samuelson (1947). It is set up following three steps.

3. A Walrasian tatonnement model of the world palm-oil market

3.1. Step 1: modeling Walrasian tatonnement

Let $S(p)$ and $D(p)$ be the supply and demand for palm-oil where p is the CPO price. Excess demand is given by the difference $S \sim D$: $e(p) = D(p) - S(p)$. Samuelson emphasizes that price changes should be a monotonically increasing function of e. In discrete time, this can be written as $p_{t+1} = p_t + g[e(p_t)]$ where g is a monotonically increasing function. We generally assume the form $g[e(p)] = \lambda e(p)$, where λ is a positive constant called the speed of adjustment. Besides, we consider classes of demand and supply functions generated by a shift parameter μ. We write $D_\mu(p) = \mu D(p)$ and $S_\mu(p) = \mu S(p)$. Excess demand becomes

$$e_\mu = \mu e(p) \tag{1}$$

where μ is the market strength or the size of the market, and the base situation is $\mu = 1$. Because price cannot be negative, the price adjustment equation takes the following form:

$$p_{t+1} = \theta_\mu(p_t) = \max\{0, p_t + \lambda\mu e(p_t)\} \tag{2}$$

In the case of Walras' downward-bending supply curve (Walras, 1926), as in the case of stylized stock markets (Day and Huang, 1990), irregular fluctuations and randomly switching bear and bull markets can be generated, depending on initial μ and λ values.

3.2. Step 2: a palm-oil model based on Day and Huang (1990)

We assume that two types of traders operate in the palm-oil market like long-distance or Rotterdam traders and short-distance or 'Bombay' traders. Rotterdam traders believe that over the long-run prices must reflect fundamental values (u) which they estimate with respect to a given expectation horizon. This horizon, which is induced by shipping times and demand requirements, exceeds six months and forces traders to hedge. Rotterdam traders calculate u on the basis of their knowledge of fundamentals, such as stocks, floating stocks, and the past consumption of their customers. A comparison between u and the

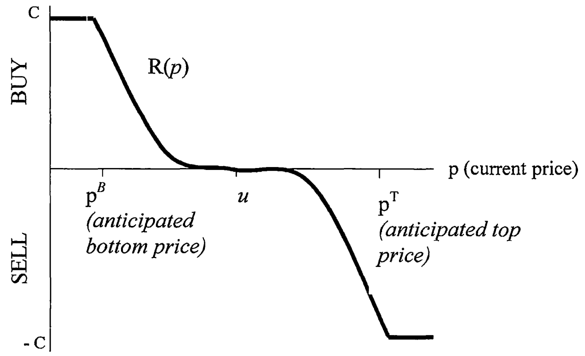

Fig. 1. Rotterdam traders' strategy *R*(*p*) (based on Day and Huang (1990)).

current CPO price, p directs their strategy. When p is less than u, a profit can be made by buying. Lower the p, greater the perceived probability of making a profit. At an anticipated bottom price p^B, the perceived probability of profit is almost 1. Inversely, when $p > u$, a loss is expected. Higher the p, greater the perceived probability of incurring a loss. At an anticipated top price p^T, the perceived probability of loss is almost 1.

Rotterdam traders' strategy, denoted by $R(p)$, is to weigh the spread of $p - u$ by the chance of gain or loss. Rotterdam traders' strategy, $R(p)$, is constant (c) and positive (traders buy) below the bottoming price and falls monotonically as p increases. When $p = u$, traders hold their position as $R(p) = 0$. And when p is above u, $R(p)$ is negative ($-c$) along with traders sell (Fig. 1).

Bombay traders' strategy $B(p)$ is more rudimentary. They buy spot, and their expectation horizon is below one month. They base their expectations on an extrapolation of the current price p and a fundamental value v with respect to their horizon. They buy when the market is bullish ($p - v > 0$; $\beta(p) > 0$), sell when it is bearish ($p - v < 0$; $\beta(p) < 0$), and hold their position $B(p) = 0$ when $p = v$ (Fig. 2).

Aggregate excess demand is the sum of buy and sell orders for Rotterdam and Bombay

$$e(p) = R(p) + B(p).$$

Hence, price adjustment based on Eq. (2) takes the form

$$\begin{aligned} P_{tt1} &= \theta_\mu(p_t) \\ &= \max\{0, p_t + \lambda\mu[R(p_t) + B(p_t)]\} \end{aligned} \quad (3)$$

3.3. Step 3: three additions to Day and Huang (1990) — the final model

1. Above a certain amount $p^Z - v > 0$, we assume that a gain is expected by immediate selling, whatever the future values of p. This gain exceeds the expected gain of further buying. Thus, above p^Z, Bombay traders revert from buy to sell. Inversely, below a certain amount $p^Y - v < 0$, an almost certain gain is expected whatever the future values of p, and positions switch from sell to buy. We limit the Day–Huang short term behavior to $[p^Y, p^Z]$, where, thresholds p^Y, p^Z are the opportunity costs of immediate sell or buy positions.
2. To distinguish the fast adjustment of Bombay traders, who buy spot, and the slower adjustment of Rotterdam traders, who hedge and deliver palm-oil past the year, we split λ into λ_B and λ_R respectively. Because, they reflect the speed of adjustment, we assume that λ_R and λ_B are inversely

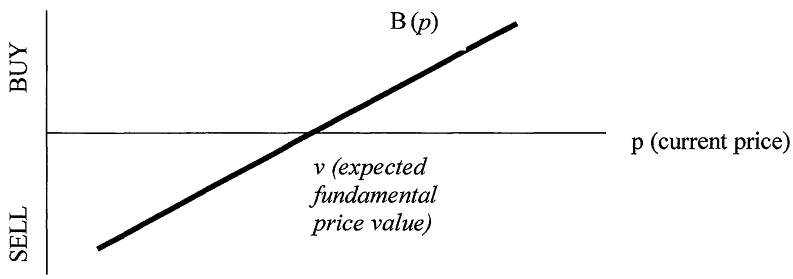

Fig. 2. 'Bombay' traders' strategy *B*(*p*) (based on Day and Huang (1990)).

commensurate with the transportation time in local Rotterdam and Bombay sub-markets.

3. Finally, we consider a substitute for palm-oil. Let us call it soybean-oil. We suppose that Rotterdam and Bombay traders can switch from palm to soybean as a function of the price-ratio (palm-oil to soybean-oil spot prices). Soybean-oil is traded in two spots, Rotterdam and Chicago. Rotterdam soybean-oil-traders are long-distance traders, Chicago soybean-oil-traders are short-distance traders. We have thus four types of homogenous traders (Rotterdam–Soybean, Chicago, Rotterdam–Palm and Bombay), and two markets (the CPO market as the Rotterdam/Bombay market, and the soybean-oil market as the Rotterdam/Chicago market). Substitution costs per ton are assumed constant in each trading spot. Let them be SUB_{Rott} in Rotterdam, SUB_{Chic} in Chicago and SUB_{Bomb} in Bombay. Let p_s be the world soybean-oil price and p_{PA} the world palm-oil price. A comparison of the difference $p_{PA} \sim p_s$ with the cost of substitution from one oil to the other at delivery spot (Rotterdam, Bombay or Chicago) serves as the basis of traders' strategy. As long as $p_{PA} - p_s$ is below the local substitution's cost, traders' strategies are left unchanged. When $p_{PA} - p_s$ exceeds the local substitution cost, traders sell palm-oil to buy soybean-oil. Analogous rules govern substitution from soybean-oil to palm-oil.

4. Simulation results

More details on the model, parameter values and calibration can be found in Voituriez (1999). In the following, we confine our attention to the parameters λ and μ and use these to illustrate the impacts of features 2 and 3 (shifts in trade leadership and shifts in the geography of trade, respectively) discussed in Section 2. Recall that, λ measures the speed of adjustment, and μ measures the size of the market.

First, the ratio of the transport time from Indonesia or Malaysia to India (a representative Asian consuming country) to the transport time from Indonesia or Malaysia to Rotterdam equals roughly 1–5 (five days against somewhat less than one month). Setting λ_R, the speed of adjustment in the long-distance market, to 1, we can simply assume that λ_B, the speed of adjustment in the short-distance market, is inversely proportional to the transport time ratio, i.e. $\lambda_B \approx 5$. The bifurcation diagram, Fig. 3, demonstrates that variations in λ_B about this level lead to changes in price behavior. On the vertical axis are the 200 last prices of simulations of 10,000 prices as λ_B ranges roughly 5–6. The emergence of short-distance trade along with a long-distance trade, as λ_B increases, drives prices to chaotic behavior.

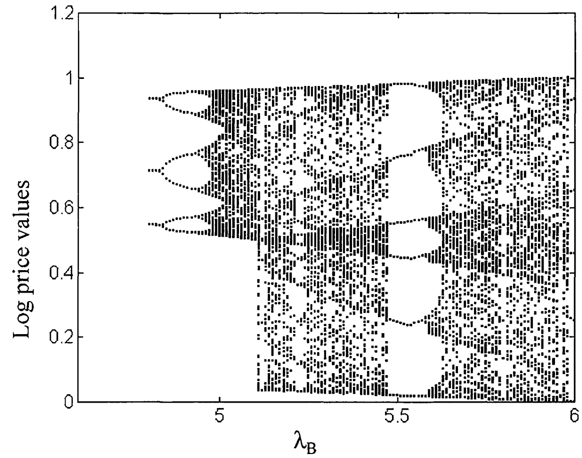

Fig. 3. The impact of the emergence of short-distance trade on price behavior (source: own simulations).

Second, the dates of shifts in leadership are given by the years when palm-oil started supplanting its major competitors, namely tallow (1930) and soybean-oil (1972), the former trade leaders in the non-food and food markets, respectively.

Third, to determine a value for μ is a tedious task. Because of the lack of data and empirical indicators, we fall back on IIA (1939) market share data and set $\mu = 5$, reflecting a five-fold increase in British consumption since 19th century.

To simplify, we assume that the parameters of the competing soybean-oil market are exogenous and constant. Finally, we decide in the period of rising size of the market (1972–1998) to only consider variations of λ_B, since μ is difficult to measure except for the 1929–1939 period. The parameter values that are assumed to apply over different periods are summarized in Table 2.

A number of 2159 clearing prices of our palm-oil market are simulated. The first clearing is set in

Table 2
Values of μ and λ in different sub-periods of the simulation

	λ_R	λ_B	μ
January 1818 to December 1929	1	0	1
January 1930 to December 1939	1	0	5
January 1940 to December 1971	1	0	1
January 1972 to January 1998	1	5	1

January, 1818, the second in February, 1818 and so on. Simulated and actual prices are compared in Fig. 4. Low volatility periods succeed high volatility periods in both simulated and actual prices. Simulated prices match the two main features of actual prices (Fig. 5). First, the actual price series kurtosis equals 10.59 and the simulated price series kurtosis reaches 10.22. Normality is rejected in either case. Second, the ARCH-test reveals a strong correlation in variance ($\chi^2(1) = 310.812$, 1% significance) which is indicative of time-varying volatility as observed in the actual data.

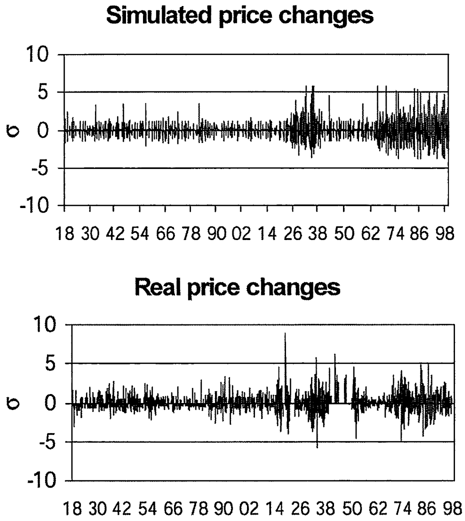

Fig. 4. Simulated and actual normalized palm-oil price changes, January 1818 to January 1999 (source: actual prices (see text) and own simulations).

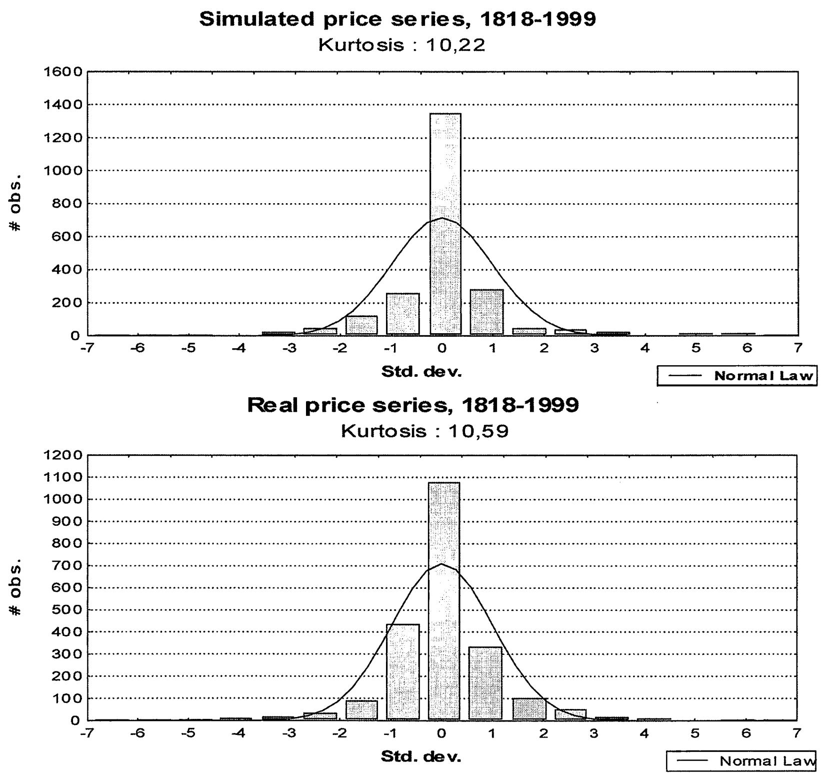

Fig. 5. Simulated and actual distribution of palm-oil price changes, January 1818 to January 1999 (source: actual prices (see text) and own calculations).

5. Conclusion

Though highly sensitive to the chosen parameter values, as are all chaotic models, our price simulation results duplicate the time-varying volatility that is observed in actual markets. Four practical consequences can be drawn.

1. Our results challenge the argument that increases in the size of the market lead to a reduction in world price volatility. They instead suggest that price volatility can increase as long as short-distance trade superimposes on historical long-distance trade. This could be the case for many tropical products.
2. Hence, market liberalization, which generally increases the size of markets, will not necessarily reduce price volatility.
3. In the case of vegetable-oils, it appears that the shorter the horizon, the higher the speed of adjustment of the market and the higher the volatility. On financial markets, the role of short term investors has been highlighted in connection with the 1997 Asian crisis. The time horizon in finance can be considered the analogue of the geographical horizon in commodity markets.
4. This result, if convincingly reproduced on other commodity markets, would moderate the enthusiasm recurrently raised by market-based approaches to commodity price risk management. Financial instruments, such as options, can undoubtedly help to mitigate price risk and to insure farmers' incomes. The issue remains the cost one has to pay to acquire such contracts. Basically, volatility changes increase the risk faced by option sellers, and consequently the additional premium that farmers (option purchasers) pay above the optimal or fair premium level given by standard pricing formula where volatility is not expected to change. More subtly, volatility changes in a commodity market where prices are driven by expectations on fundamentals can degenerate in bullish or bearish crashes, the social costs of which might not be covered by individual financial instruments.

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