El Niño and Coffee Price Volatility in 1997

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May 14, 1998

Abstract

Volatility in coffee markets is the norm, but 1997 was unusually volatile. Previous price swings of this magnitude were historically the results of extreme weather events. In 1997, however, low inventory levels and uncertainty about the effects of El were cited as primary reasons for price increases. A structural econometric model is used to estimate historical supply, demand, and supply of storage functions. The hypothesis that 1997's volatility was due to low inventories is tested versus the alternative that El Niño is to blame.

Introduction

The weather event known as *El Niño* and its effects on agricultural commodities have generated questions (http://www.primenet.com/~rfwatts/elnino.html) but little published research. The absence of literature on the economic effects of *El Niño* is unusual because *El Niño* is a cyclical event occurring every five or six years.[1] As an economic event, its effects on markets and prices are an important topic for study.

One of the open questions about *El Niño* is how it affects price volatility. Price volatility in coffee markets is common (Commodity Research Bureau), but 1997 was unusually volatile. Figure 1 shows the 12-month moving standard deviation for U. S. coffee prices from 1985 to 1997. The coffee market is characterized by significant market concentration in distribution and processing, successful cartel behavior, and extensive government intervention. The market is sometimes volatile as a result of these imperfections, yet volatility in 1997 was unexpected. It may have been due to low inventory levels.

Literature concerning inventories and price volatility is abundant. Since Working (1948, 1949) several authors (e.g., Chambers and Bailey 1996) have studied the effect of inventories on price levels and price volatility. Helmberger and Weaver (1982) and Wright and Williams (1991) recognize the possibility that stock-outs can occur along the marketing chain but do not evaluate the implications for price volatility empirically. Rather, they imply that knowledge of the probability of a stock-out would significantly help agents plan for future decisions. In this paper a test of whether low inventories and the increasing probability of a stock-out are responsible for the recent increased volatility in coffee markets is conducted.

Theory

Three primary explanations for increased volatility in 1997 were offered in the main stream print. The first and most compelling reason is that U.S. coffee inventory levels reached 25-year lows in May 1997 (*Wall Street Journal* (WSJ), *New York Times* (NYT)) and did not appear ready to rebound. As inventories are depleted both price and quantity uncertainty increase leading to volatility in markets. The second reason is that roasters adopted Just-in-Time (JIT) inventory procedures (March 3, 1997 WSJ) in which storage by the roaster is nearly eliminated and costs are reduced. While the cost reduction may translate into lower prices, a significant tradeoff in terms of uncertainty about securing supplies may have led to price volatility. The third reason is the oft cited coming of *El Niño* (e.g, NYT May 3, 1997; WSJ Feb 3, 1997). Anticipation of *El Niño* added to production uncertainty in South America. Did expectations of potentially large supply shocks alter anticipated future supply to such a degree as to move the market? Or was volatility due to low inventories coupled with price inelasticity?

In this paper we focus on supply shocks and price volatility. Whereas recent work has focused on volatility stemming from either production or demand uncertainty (Lapan and Moschini 1994), information (Danthine and Moresi 1993), speculative bubbles and mass psychology (Shiller 1992), or market power (Thompson 1986, Lucier 1988) this paper frames the volatility issue in terms of shocks to a market system in which uncertainty is present. Therefore, volatility is generated by either (1) underlying shocks to fundamental economic variables that are highly variable (e.g. *El Niño*), or (2) underlying shocks that are not highly variable, but which are transmitted and amplified by market conditions (e.g., low inventories and price inelasticity).

Although the first category should include both supply and demand shocks, we assume based on past work (e.g., Okunade 1992, Vogelvang 1991), that demand for coffee is inelastic and stable; that is, shocks on the demand side were inconsequential in 1997. For the period 1985-1997 droughts and freezes caused supply shocks and increased volatility in 1985-86 and 1994-95. Price volatility occurred after the weather event, whereas in 1997 volatility preceded the event. When the supply shock is highly variable, production uncertainty clouds both importers' and roasters' decisions. Even when importers and roasters hedge their risk, uncertainty adds to price variability.

The second category, changes in market conditions that amplify supply shocks, includes elasticities of supply and demand, government policy, inventory levels, and real interest rates. Both supply and demand for coffee are inelastic due to harvest schedules (once a year) and consumer preferences. If elasticities were to increase in magnitude, price volatility would tend to increase. An increase in market interest rates would increase volatility as would a decrease in inventories. For the purposes of this paper it is assumed that no sudden elasticity changes occurred, nor did changes in the International Coffee Agreement occur, nor was there a sudden increase in interest rates. Demand is highly inelastic, and even small shocks to supply may translate into relatively large price swings when inventories are low. Therefore the focus is on inventories and their effects on volatility. This can best be examined via the supply of storage equation.

Working (1948, 1949) established the supply of storage relationship. The difference between cash and futures prices indicated the cost of storage between the present and the delivery date. Samuelson (1971) showed that when storage is low, price volatility should be high because suppliers cannot satisfy demand by falling back on inventories. Conversely, an increase in the availability of inventories decreases the probability of a stock-out and reduces expected volatility.

Theory suggests the cause of recent volatility is low inventory levels. The second explanation is that the adoption of Just-in-Time (JIT) inventory procedures may have added to the pressure of low inventories. If the adoption of JIT is accompanied by a negative shock to supply, roasters may have difficulty meeting demand. Similarly, if there is a demand shock, roasters have nowhere to turn to meet that demand. In this paper we will not investigate the effects of JIT but instead assume that JIT contributed to lower inventory levels.

Data

Monthly data were collected from secondary sources: the real price of orange juice (index of frozen orange juice concentrate), real price of sugar (spot price of raw sugar), spot price of coffee (Arabica C Brazil), U. S. imports, and Fed funds rate are from the Commodity Yearbook. Quantity demanded, as measured by quantity roasted in thousands of 32 lb. bags, is taken from the USDA, FAS Tropical goods- *Agricultural Outlook*. Inventories, in thousands of 32 lb. bags, are taken from the Coffee Sugar and Cocoa Exchange via the Green Coffee Association of New York. Weather data is taken from the World Wide Web via National Oceanographic and Atmospheric Administration (NOAA) and the International Station Meteorological Climate Survey, jointly produced by the National Climatic Data Center, Fleet Numerical Meteorology and Oceanography Detachment, Federal Climate Complex Asheville, Department of Navy /Department of Commerce/Department of Air Force. Data included average monthly temperature in Brazil in degrees Centigrade. The optimal temperature range for Arabica coffee is between 18 and 25 (De Graaf 1988).

Econometric Test – Step One

Model Specification

Three stage least squares (3SLS) is used to estimate the supply of storage equation. 3SLS accommodates both simultaneity and cross-correlated errors. The model incorporates three equations – roaster demand, export supply and supply of storage.

(1) Demand: $\Delta \log q^d_t = a_0 + a_1\Delta p_t + a_2\Delta p_t^{sugar} + a_3\Delta p_t^{oj} + a_4\Delta y_t + e^d_t$

(2) Supply: $\Delta \log q^s_t = b_0 + b_1\Delta p_t + b_2 q_{t-1} + e^s_t$

(3) Storage: $\Delta p_t = r_{t-1}p_{t-1} + c_0 + c_1 \log I_{t-1} + c_2 p_{t-1} + c_3 p_{t-2} + e^I_t$

The endogenous variables are real spot price (p_t), import supply (q^s_t), quantity roasted (q^d_t), and U. S. coffee inventories (I_t). The exogenous variables are real price of sugar (p_t^{sugar}), real price of orange juice (p_t^{oj}), the index of industrial production (y_t), the Fed funds rate (r_t), and the shocks (e^d_t, e^s_t, and e^I_t). At this stage, the shocks are assumed to be jointly Normal with zero mean and constant covariance. The instrument set includes p_{t-1}, Δp_{t-1}, q^s_{t-1}, q^d_{t-1}, ${q^d_{t-1}}^2$, q^d_{t-2}, p_t^{sugar}, p_t^{oj}, y_t, I_{t-1}, I_{t-1}^2, r_t, mean temperature in Brazil for the month (T_t), T_t^2, T_{t-1}, average temperature in Brazil for the last six months, a linear time trend, and the month of observation numbered one through twelve.

For the demand equation, coffee purchased by roasters represents quantity demanded. The real price of coffee is the spot price divided by the Consumer Price Index (CPI). The real price of sugar is the average monthly spot price of sugar divided by the CPI and represents the price of a complement whose price should move in concert with the price of coffee. The real price of orange juice is the monthly average producer price index for oranges divided by the CPI and represents the price of a substitute whose price should move in the opposite direction of coffee prices. The index of industrial production represents an income effect; an increase should be matched by an increase in demand for coffee.

The dynamic structure of supply is assumed to include a partial adjustment mechanism. The supply curve is upward sloping in current price, where U. S. imports are a proxy for quantity supplied.[2] If importers over-supply in one period they will react by supplying less in the next period. The coefficient on the lagged adjustment term should therefore be negative.

The supply of storage curve assumes heterogeneous expectations. Fundamentals traders form expectations using economic theory, and chartists use positive feedback rules. Our hybrid model includes the usual Working supply of storage function, in which expected returns depend positively on the interest rate r_{t-1} and the inventory level, I_{t-1}. Lagged price terms are added to account for the existence of chartists.

Results

In the demand equation, coefficients on quantity demanded and the real price of sugar are negative and statistically significant at the 10% level. The demand elasticity estimate at the sample mean is 0.07, which is in line with the characterization of coffee demand as strongly inelastic. The coefficient on the price of orange juice is not statistically significant, and the coefficient on the index of industrial production, the income proxy, is negative and significant at the 5% level, indicating that coffee may be an inferior good in the United States.

The supply elasticity estimate is 0.37, and the coefficient on q_{t-1} is negative. Both are statistically significant at the 10% level and their signs are consistent with theory.

The supply of storage equation exhibits theoretically consistent coefficients for carryout as well as statistically significant lagged price terms. The coefficient on lagged inventories is positive showing the positive relationship between price and holding inventories, consistent with the existence of convenience yield. The lagged price terms cannot be assigned signs *a priori* but their statistical significance shows that prices may be affected by technical analysis.

Econometric Test – Step Two

Model Specification

The second step is to regress the squared residuals from the supply of storage equation and on lagged inventories and lagged squared residuals to test for a systematic relationship between volatility and stocks. Let $\hat{e}^I_t$ represent the estimate of e^I_t from equation (3). The model for step two is then:

$$(\hat{e}^I_t)^2 = a + bI_{t-1} + c(\hat{e}^I_{t-1})^2 + \varepsilon_t \,, \qquad (4)$$

with ε_t distributed Normally with zero mean and constant variance.

The coefficient on the lagged inventory term reflects the degree to which inventories affect price volatility, whereas the coefficient on the lagged error squared term reflects the autoregressive part of price variation. To test whether expectations of *El Niño* were the cause of excess volatility we split the sample into two periods – 1997 and pre-1997 and estimated (4) for each period.

Results

The coefficients b and c were both significant at the 10% level, providing evidence that variance is affected positively by inventories over the sample and that volatility has an autoregressive component. This test calls into question the efficiency of the 3SLS estimates from equations (1) - (3), which assume a constant covariance structure over the sample. Importantly, the null hypothesis that $b = 0$ cannot be rejected at the 10% level in favor of $b < 0$, indicating that low inventories may not have been the source for recent volatility.

Table 3 presents the supply of storage estimates for only 1997 data using ordinary Least Squares. 3SLS could not be performed because only 12 monthly data points exist in 1997. Once again, the convenience yield effect is positive and statistically significant in 1997. However, the positive feedback components of the curve appear to have shifted.

The final regression provides not evidence that low inventory levels were the cause of volatility in coffee markets in 1997 (Table 4). The statistically insignificant coefficient on lagged inventories alters the effects seen in the second regression indicating that some type of structural shift may have occurred in 1997. While it is possible that *El Niño* was the source, the test described here only shows that it was not low inventories that caused the sudden increase in volatility. The results in Table 4 also provide evidence that squared residual term may have lost the persistence of memory in 1997 as the coefficient on the lagged residual squared term is now statistically insignificant. Of course, the small sample size of the regression makes these results less reliable than those using the complete sample.

The focus of the paper was to determine if recent volatility is due to low inventories or some other factor. If by restricting the sample to pre-1997 observations coefficients on lagged inventories are significant we can establish that some factor besides inventories increased volatility. The insignificance of both inventories and past values of residuals in the final regression show that in factors other than inventories played a part in the recent volatility. The possibility that JIT or *El Niño* were responsible for the volatility cannot be ruled out. Low inventories alone, however, can be ruled out as the cause of coffee price volatility.

Conclusions and Implications

This paper provides simple test for examining the possible effects of *El Niño* on U.S. coffee markets by defining and limiting the causes of possible volatility to shocks to the system and changes within the market system itself. Although a direct test is impossible since data is neither available nor precise enough for evaluating the effects of a large weather phenomena, by taking an indirect approach we can evaluate whether or not the standard supply of storage theory holds. If it does not we can safely assume that something other than low inventories caused recent price volatility.

Where theory suggests that low inventory levels of coffee should cause volatility, in reality the causes of market volatility are much more complex. Both rational and irrational expectations of future prices determine price change and corresponding quantities supplied. Quantity uncertainty embedded in expectations of significant supply innovations may, in an already volatile market, cause significant disruption in expectations of future price to alter both present and future conditions.

Several reasons for these results are possible. Information transmission and increased scientific understanding and confidence in forecasting abilities of extreme weather events such as *El Niño* may increase the effects of weather forecasts on price expectations. That is, expectations may be incorporated into price long before the weather event occurs.

Another plausible explanation for the volatility in coffee markets has been that market power may introduce substantial market imperfections in coffee markets to render parameter estimation quite useless. Proper estimation of supply and demand may require accounting for market concentration on both the import supply and roaster demand sides. Assumptions of perfectly competitive markets and ignorance of the market distortions may render the theory of storage helpless in explaining volatility. At the same time the results do not preclude the possible explanation that unexplained volatility is in part determined by low inventories combined with something else. Although *El Niño* could not be proven to be the cause for the 1997 price variations, indirect guilt by elimination is likely. A better test of the role anticipated weather shocks may hold lies in a more complete weather shock specification, following the completion of the storm's cycle. The task of accurately measuring and acquiring data needed to create a precise aggregate measure of *El Niño*'s global effects is formidable.

Adopting this model to account for changes in market structure, especially by accounting for changes in the international coffee agreement (ICA) may help explain some of the random variability in price. The complexity of measuring both effective changes in market power and real effects on inventories is formidable due to data limitations and simply for the fact that production is external to the United States.

Another avenue for future research is to investigate more fully the economics of just-in- time inventory (JIT), especially with respect to its effect on storage and price volatility. In the paper, JIT simply reduced inventories. In reality, JIT adoption could have more significant effects on supply decisions. If JIT was the result of improved demand forecasting and tracking, then it could be a cost reducing reaction to decreased uncertainty. This may tend to reduce volatility. A general model could treat JIT as simply a technological change and evaluate implications for supply and price uncertainty.

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Figure 1
Coffee Price Volatility
1985-1997

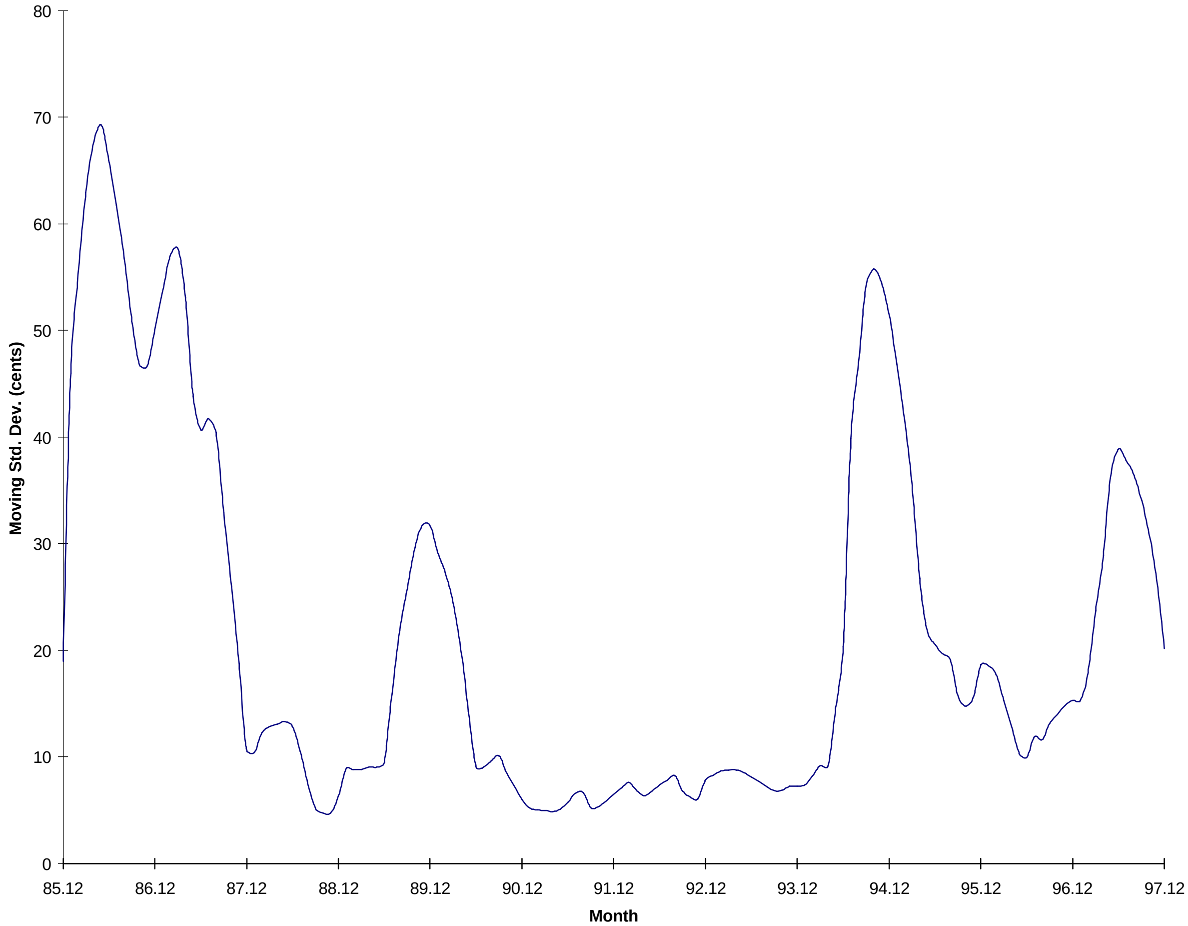

Table 1. Nonlinear 3SLS Parameter Estimates

Parameter	Variable	Estimate	Asy. Std. Error	t-Ratio	P-value
a_0	constant	-0.00803	0.01676	-0.48	0.633
a_1	p_t	-1.62	0.89	-1.82	0.070
a_2	p_t^{sugar}	-120.1	33.6	-3.57	0.001
a_3	p_t^{oj}	0.0486	0.1218	0.40	0.691
a_4	y_t	-0.0375	0.0118	-3.18	0.002
b_0	constant	3.57	0.52	6.91	0.001
b_1	p_t	1.21	0.71	1.71	0.089
b_2	q_{t-1}	-0.488	0.071	-6.91	0.001
c_1	I_{t-1}	0.00178	0.00088	2.01	0.046
c_2	p_{t-1}	0.171	0.077	2.22	0.028
c_3	p_{t-2}	-0.225	0.077	-2.92	0.004

Number of Observations = 148

Table 2. Regression of supply of storage squared residuals on past values and lagged inventories

Parameter	Variable	Estimate	Asy. Std. Error	t-Ratio	P-value
a	constant	-0.000583	0.001417	-0.41	0.682
b	I_{t-1}	3.70×10^{-7}	2.25×10^{-7}	1.65	0.102
c	$(\hat{e}^I_{t-1})^2$	0.174	0.080	2.16	0.032

Number of Observations = 148

Table 3. Supply of Storage (1997)

Parameter	Variable	Estimate	Asy. Std. Error	t-Ratio	P-value
c_1	I_{t-1}	0.0182	0.0079	2.31	0.043
c_2	p_{t-1}	0.0244	0.2848	0.09	0.933
c_3	p_{t-2}	-0.422	0.265	-1.59	0.142

Number of Observations = 12

Table 4. Regression of supply of storage squared residuals on past values and lagged inventories (1997)

Parameter	Variable	Estimate	Asy. Std Err	t-Ratio	P-value
a	constant	0.000629	0.001982	0.32	0.7581
b	I_{t-1}	1.52×10^{-7}	10.25×10^{-7}	0.15	0.8857
c	$(\hat{e}^{I}_{t-1})^2$	-0.0452	0.3274	-0.14	0.8932

Number of Observations = 12

Endnotes

[1] *El Niño* is a local warming of surface waters which takes place in the equatorial zone of the central and eastern Pacific Ocean off the Peruvian coast and disturbs worldwide atmospheric circulation. The effects registered in December 1997 were the strongest *El Niño* ever recorded in December (FAO 1998). The prior strongest *El Niño* occurred in March-April 1982, the prior one before that was in 1972.

[2] Almost all of the coffee consumed and roasted in the United States is imported. In 1996/97 the U. S. produced approximately 200 thousand 60-kilogram bags in Hawaii and Puerto Rico, all of which was for domestic consumption. This quantity represents less than 1 percent of domestic consumption (http://www.fas.usda.gov/htp/tropical/1997/97-06/coff9697.htm).