

Gupta, Sanjeev; Mayer, Thomas

Working Paper — Digitized Version

A test of the efficiency of futures markets in commodities

Kiel Working Paper, No. 119

Provided in Cooperation with:

Kiel Institute for the World Economy – Leibniz Center for Research on Global Economic Challenges

Suggested Citation: Gupta, Sanjeev; Mayer, Thomas (1981) : A test of the efficiency of futures markets in commodities, Kiel Working Paper, No. 119, Kiel Institute of World Economics (IfW), Kiel

This Version is available at:

<https://hdl.handle.net/10419/47213>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Kieler Arbeitspapiere Kiel Working Papers

Working Paper No. 119

A TEST OF THE EFFICIENCY OF FUTURES
MARKETS IN COMMODITIES

by

Sanjeev Gupta and Thomas Mayer

Institut für Weltwirtschaft an der Universität Kiel

Kiel Institute of World Economics
Department IV
2300 Kiel, Düsternbrooker Weg 120

Working Paper No. 119

A TEST OF THE EFFICIENCY OF FUTURES
MARKETS IN COMMODITIES

by

Sanjeev | Gupta and Thomas Mayer

March 1981

Kiel Working papers are preliminary Papers written by staff members of the Kiel Institute of World Economics. Responsibility for contents and distribution rests with the authors. Critical comments and suggestions for improvement are welcome. Quotations should be cleared with the authors.

Ag 1313 81 Weltwirtschaft
Kiel

A Test of the Efficiency of Futures

Markets in Commodities*

I. Introduction

The role of the futures markets in stabilising spot prices has been widely discussed.¹ However, the success of these markets in performing the stabilising function critically depends on whether they are "efficient" (Fama [8], page 383) in the sense that the futures prices "fully reflect" the available information. The question of futures market efficiency has assumed greater relevance in view of the recent UNCTAD proposals to stabilise the prices of primary commodities exported mainly by the developing countries. The Integrated Programme for Commodities put forward by the Group of 77 at UNCTAD IV in 1976 calls for the establishment of buffer stocks for 18 such commodities.²

* This paper reports research undertaken in the "Sonderforschungsbereich 86" (Hamburg - Kiel) "Teilprojekt 3" (Die Wirkungen internationaler Rohstoffmarktregulierungen auf Wachstum und Allokation in Entwicklungsländern) with financial support provided by the "Deutsche Forschungsgemeinschaft." We wish to thank J.B. Donges, E. Gerken, P. Gupta, M. Salden and H. Voigt for helpful comments.

¹ For instance, see Dower and Anderson [7], Danthine [5], Leuthold and Hartmann [13] and Streit [18].

² The ten 'core' commodities are made up of Copper, Tin, Cotton, Sisal, Jute, Natural Rubber, Coffee, Cocoa, Tea and Sugar. The other eight are Lead, Iron Ore, Zinc, Maize, Rice, Wheat, Wool and Beef.

The recent developments show, however, that the political as well as the economic success of the UNCTAD schemes is rather doubtful.³ Under these circumstances, the feasibility of other efficient market oriented alternatives for stabilising commodity prices needs to be examined. Further, it could be argued that theoretically the case for buffer stocks for stabilising prices rests in part on the lack of sufficient and rational speculators in these markets. For, if futures markets reflect the available information and provide efficient forecasts of the future spot prices, the rationale for UNCTAD schemes is somewhat weakened. In this paper, we test the efficiency of futures markets for five of the commodities in the UNCTAD list. At the outset, we discuss various approaches for testing the efficiency of futures markets. A 'semi-strong' test is then performed. The data, the models and the results are presented in sections III through V. The concluding comments and the economic implications are discussed in the last section.

It should be noted, however, that the issue of price stabilisation is different from the issue of transferring real resources to the developing countries (Donges [6]). Only when schemes are justified on the grounds of stabilising prices is the question of efficiency of futures markets relevant.

II. Tests for Market Efficiency

Several economists have examined the accuracy of futures prices as forecasts of subsequent cash prices (Tomek and Gray [19] and Kofi [10])⁴. In these studies, the following

³For instance, see Neue Zürcher Zeitung, 2 October, 1980 and International Herald Tribune, 27 February, 1981.

⁴Tomek and Gray studied the futures markets for Corn, Soybeans and Potatoes whereas Kofi's sample consisted of Potatoes, Cocoa, Wheat, Corn, Soybeans and Coffee.

regression was run:

$$S_t = \beta_0 + \beta_1 F_{t-i} + U_t$$

where S_t is the final cash price, F_{t-i} is the futures price, $t-i$ months prior to maturity, and U_t is the error term. The test centered on whether the intercept term equalled zero and the slope coefficient unity. If the constant was found to be significantly different from zero and/or the slope coefficient significantly different from unity, it was concluded that futures markets were inefficient forecasters of future spot prices. This is because the futures market is a biased predictor of the future spot price. A speculator armed with a priori knowledge of the respective coefficients then has the possibility of making extra-normal profits. The evidence from this test is mixed.

The major problem with the above approach is that the coefficients were estimated using ex post knowledge of the data, a knowledge that was not available to the actual speculator in the market forecasting ex ante.⁵ Therefore, the tests which make use of more knowledge than 'efficient' speculators are likely to possess are not strictly speaking valid tests of the efficiency of futures markets. Under these circumstances, an efficient market could fail the efficiency test and further, an inefficient market may even pass it.⁶ Nevertheless, this approach can be interpreted as a test of the "effectiveness" of futures market in predicting the future spot price. That is, it evaluates ex post the forecasting ability of the speculators.

⁵This point has been recognized in the tests dealing with the efficiency of forward markets in foreign exchange. For example, see Bilson and Levich |1|.

⁶This is because the above test deals with alternative forecasts which are only linearly related with the futures prices. For details, see Bilson and Levich |1|.

Other economists⁷ have concentrated essentially on the so-called weak-form tests of market efficiency which rely on the historical sequence of prices and often have consisted of testing the randomness of the futures price series. By their nature, they do not examine whether all obviously publicly available information is being reflected in the prices. In these tests the market would be considered "weak-form" efficient if it utilised the past futures prices in the expectation formation. The most recent evidence as presented by Cargill and Rausser [4] rejects the hypothesis that commodity futures markets are "weak-form" efficient.

When prices reflect all obviously publicly available information, the market is said to be "semi-strong" efficient. The latter is tested by examining if the expectations in the market reflect the current information as it is released to the public. As is obvious, this test of market efficiency is more rigorous than the "weak-form" tests. Leuthold and Hartmann [13] performed this test on the U.S. futures market in hogs. They employed an econometric model to forecast future prices and concluded that "...live-hog futures market has not consistently utilised all the available information. It appears to react slowly", (p. 487). However, they did not perform any statistical test to determine whether forecasts from their model were significantly different from the futures market forecasts.

In what follows, we conduct a semi-strong form test of the efficiency of five of the commodity markets in the UNCTAD list namely, Copper, Tin, Sugar, ~~Cocoa~~ and ~~Coffee~~.

⁷For instance, see Cargill and Rausser [3], Labys and Granger [10], Leuthold [12] and Cargill and Rausser [4]. Others like Houthakker [9], Smidt [16], and Stevenson and Bear [17] employ mechanical filters to determine whether profits could be realized.

For this purpose, ARIMA⁸ models are identified and fitted to the spot prices and forecasts obtained.

III. Data

In this study weekly price series are employed for forecasting purposes. The data for Copper (wirebars) and Tin (standard) refers to £ per metric ton buying cash price prevailing on Tuesdays in London.⁹ This data has been collected from the Far Eastern Economic Review. The period covered is from September 3, 1976 to December 21, 1979.

The daily sugar price used is for raw cane sugar 96⁰ in bulk per tonne c.i.f. U.K., whereas Cocoa prices are for good fermented Ghanas quoted on the spot. Both of these prices are in £ Sterling prevailing in the London market on Fridays. In the case of Coffee, prices of Colombian mild Arabicas and other mild Arabicas expressed in terms of U.S. cents (per lb ex-dock New York) in the New York market on Thursdays have been used. We have used the aforementioned Coffee price series separately to forecast the future price of mild Arabicas in New York, as the spot prices of the group of mild Arabicas to which New York futures contracts apply are not available. The price information for Sugar, Cocoa, Colombian mild Arabicas and other mild Arabicas has been obtained from the Public Ledger and the period

⁸For a detailed discussion on identification and estimation of ARIMA models, see Box and Jenkins [2] and for a somewhat simpler treatment, see Nelson [14].

⁹In few instances, where information was missing the observations either refer to the price prevailing on the previous Tuesdays or on Monday.

runs from January 3, 1976 to December 22, 1979.¹⁰ The plots of the price series employed in this study are given in figures 1 through 6.

IV. The ARIMA Models

The ARIMA models are "efficient" instruments for forecasting as they make use of all information concerning systematic patterns inherent in the time series such that the unexplained component is nothing but white noise. It may seem that an approach which relies on historical prices is naive since there is no way of incorporating the structural information in it. However, if spot prices reflect publicly available information in the market, then the information concerning the economic structure is a part of it. The model forecasts reflect that information which is readily available to the market at the time of the forecast, and therefore provide a norm against which the futures prices are compared and evaluated.

In brief, the ARIMA approach is to first difference the time series say Z_t until it is stationary. This is important because the (ARMA) models can only be used to represent a stationary time series (equilibrium about a constant mean). Then estimates of the autocorrelation and partial autocorrelation functions are computed. These functions are compared with their theoretical counterparts to identify the order (p, d, q) of the process where p and q are the orders of the autoregressive and moving average parameters, respectively, and d is the order of differencing. In expanded form the model of order p, d, q is written as,

¹⁰ An extension of the estimation period backwards in time was not judged to be worthwhile given the atypical behaviour of commodity prices during the period 1973 - 1975.

$$(1 - \phi_1 B - \dots - \phi_p B^p) (1 - \theta_1 B - \dots - \theta_q B^q) U_t = Z_t$$

where ϕ and θ are the coefficients of the autoregressive and moving average parameters respectively and B is a backshift operator. The estimates of ϕ and θ are obtained by non-linear estimation procedure which minimises the residual sum of squares in the fitted model. The final step consists of applying diagnostic checks to test for model adequacy. These tests include (i) overfitting the model and testing if the additional parameters are insignificantly different from zero, (ii) examining the value of the Q statistic to test if the residuals are white noise and (iii) a visual inspection of the plot of residuals for detection of non-homogeneity. The Box-Jenkins models can be used to forecast future prices since the probability distribution generating future observations is the same as for past observations and the conditional probability distribution for future observations can be estimated from past data.

For Tin, Copper, Sugar and Colombian mild Arabicas first differencing was not judged to be necessary to achieve stationarity. Therefore, models were fitted on the raw series. All the three series were best modelled by an autoregressive process of order one. That is, $(1,0,0)$.¹¹

However, in the case of Cocoa and other mild Arabicas, raw series were differenced and moving average process of order two and autoregressive process of order two respectively best represented the process generating these series. The fitted models are reported in Table 1.

¹¹ It is worth noting that $(1,0,0)$ is a 'kind' of random walk-model without the restriction that the coefficient of the lagged term of the dependent variable be unity.

V. The Results

The various diagnostic tests suggested that the models were adequate. The plot of the residuals did not show any non-homogeneity. The estimated Q for all models fell below the critical value of chi-square at .05 level of significance implying that the residuals had been reduced to random noise. Also by fitting more elaborate models it was found that the t-values of the additional parameters were insignificant.¹²

Because Tin and Copper markets have continuous three month futures markets, thirteen weeks ahead forecasts were made twenty-six times by varying starting points. To allow the forecasting model as much information as the market, the ARIMA models for both of these commodities were updated as many times as the number of thirteen weeks ahead forecasts, namely twenty-six. The forecasting horizon ranges from September 19 to December 21, 1979. However, due to space limitation, only coefficients of models up to the time period December 21 are reported in Table 1.

For Sugar, Cocoa and the two types of Coffee, the forecasting horizon was determined by the length of the futures contracts. Since the models estimated by us yield weekly forecasts and the futures contracts for these three commodities are monthly, the weekly forecasts were averaged to get the respective monthly forecasts. For the reasons already noted above, the models for Sugar, Cocoa and the two types of Coffee were estimated three times by first restricting the data set up to December 8 and then December 15 and finally December 22, 1979. The actual number of forecasts depended on the length of futures contracts in

¹²The identified model was not expanded by adding autoregressive and moving average terms simultaneously, to guard against the problem of parameter redundancy. See Nelson [14], ch. 5.

Table 1 Parameter Estimates for ARIMA (P, D, Q) Models of Several Commodity Prices

Commodity	(P, D, Q)	Identified Model	SER	Q	DF	N
Copper	(1, 0, 0)	$z_t = 18.74 + 0.98z_{t-1} + u_t$ (50.43)	28.57	17.50	34	174
Tin	(1, 0, 0)	$z_t = 244.68 + 0.96z_{t-1} + u_t$ (58.14)	190.07	18.03	34	174
Sugar	(1, 0, 0)	$z_t = 2.79 + 0.98z_{t-1} + u_t$ (61.75)	6.45	37.75	40	208
Cocoa	(0, 1, 2)	$w_t = 4.21 + u_t + 0.14u_{t-1} - 0.12u_{t-2}$ (2.06) (- 1.68)	124.19	38.50	39	208
A-Coffee	(1, 0, 0)	$z_t = 7.55 + 0.96z_{t-1} + u_t$ (60.11)	10.64	41.16	40	208
B-Coffee	(2, 1, 0)	$w_t = 0.77 - 0.46w_{t-1} - 0.11w_{t-2} + u_t$ (- 6.58) (- 1.51)	17.18	46.54	39	208

Notes:

$$w_t = z_t - z_{t-1}$$

SER = Standard Error of the Residuals

$$Q = Q = N \sum_{i=1}^k \hat{f}_i^2 \sim \text{Chi-square } (K - p - q - 1)$$

Box-Pierce test for randomness of residuals

DF = Degrees of freedom for Q statistic

N = sample size

A-Coffee = "Colombian Mild Arabica"-Coffee

B-Coffee = "Other Mild Arabicas"-Coffee

Selected values of chi-square distribution; significance level by degrees of freedom

χ^2	34	40
1%	56.1	63.7
5%	48.6	55.8

these markets.^{13,14}

The forecasts from the estimated models and from the futures markets were compared with the actual (future) spot price and the Mean Squared Error (MSE) computed. The MSE's are reported in table 2. The results indicate that for Copper, the MSE from ARIMA forecasts is significantly higher than the MSE from the futures markets. However, in the case of Tin the MSE from futures market forecasts is higher. But the difference between the two MSE's for Tin is not statistically significant.¹⁵ This suggests that the hypothesis that the futures markets for Copper and Tin are semi-strong efficient cannot be rejected.

For the remaining three commodities namely Sugar, Cocoa and Coffee, the forecasts from the futures market outperform the ARIMA model forecasts on the MSE criteria. Further, the difference between these forecasts was found to be significant at .05 level. This better forecasting performance by the futures market could perhaps be attributed to the fact that speculators have information extraneous to that embodied in the spot prices.

¹³ In December 1979, futures contracts were available for March, May, August and October in the case of Sugar. For March, May, July and September for Cocoa and for Coffee. Therefore by updating our parameters three times, we got twelve forecasts each for Sugar, Cocoa and Coffee.

¹⁴ Forecasts from the two coffee series were averaged to get a forecast for 'mild Arabicas' for lack of a better alternative. This is mainly because in New York, futures contracts do not distinguish between the 'Colombian mild Arabicas' and 'Other mild Arabicas'. But since the futures contracts in New York refer to mild Arabicas from most of the producing countries, the averaging of two forecasts would then tend to reflect broadly the future price of the 'mild Arabicas'. For operational details of the New York Coffee Exchange, see Reidy and Edwards [15].

¹⁵ For a detailed description of this test, see bottom of Table 2.

Table 2: Mean Square Errors of ARIMA and Futures Markets
Forecasts of the Future Spot Price

Commodity	MSE ₁	MSE ₂	T-Test
Copper	43,018.23	27,920.85	$ \hat{t} = 5.48$ $t_{0.05,25} = 1.71$
Tin	402,444.65	427,398.08	$ \hat{t} = 1.04$ $t_{0.05,25} = 1.71$
Sugar	32,148.59	21,020.83	$ \hat{t} = 5.87$ $t_{0.05,11} = 1.80$
Cocoa	270,375.35	61,481.77	$ \hat{t} = 5.89$ $t_{0.05,11} = 1.80$
Coffee	1,169.35	211.31	$ \hat{t} = 3.38$ $t_{0.05,11} = 1.80$

Notes: MSE₁: Mean Square Error of the ARIMA forecast

MSE₂: Mean Square Error of the Futures market forecast

T-Test: It is tested whether the two mean square errors MSE₁ and MSE₂ belong to the same distribution, i.e. are not statistically significantly different. For this hypothesis to hold, $|\hat{t}|$ must be t-distributed.

It is defined as $|\hat{t}| = \left| \frac{\bar{d}}{s_d} \sqrt{n} \right|$,

where $\bar{d} = 1/n \sum_1^n d_i$, $s_d^2 = \frac{1}{n-1} \sum_1^n (d_i - \bar{d})^2$;

d_i indicates the difference of squared ARIMA and futures markets forecast errors of step i , and n is the number of forecasts.

Therefore, if $|\hat{t}| > t_{\alpha,m}$, where α indicates the significance level and $m = n-1$ denotes the degrees of freedom, the hypothesis that MSE₁ = MSE₂ is rejected.

VI. Concluding Comments

In this paper, we performed a 'semi-strong' form test of market efficiency on five of the commodities in the UNCTAD list. The test consisted of comparing forecasts made by futures market and ARIMA models with the actual future spot prices. This approach is more rigorous than the 'weak-form' tests and is an improvement over the studies which regressed the final spot price in period j on the future price $j-i$ period prior to maturity. On the basis of MSE criteria and Student's t -test it was found that the futures markets forecasts fared as well as or better than the forecasts from the estimated models for Copper, Tin, Sugar, Cocoa and Coffee. This implies that for the time period studied, we cannot reject the hypothesis that futures markets for these commodities are efficient in the sense that market employs all publicly available information in forming expectations about future spot prices.

In the cases where futures market outperformed the ARIMA models in forecasting ability, it could be argued that speculators have more information than the obviously available public information embodied in the spot prices. Such information could come from informal sources. With regard to the UNCTAD plans, it should be noted that any price stabilisation authority by its very structure is unlikely to have access to this information.

However, there is a need for caution when interpreting these results. It is possible that more sophisticated forecasting models provide forecasts superior to the forecasts from models estimated in this study. Subsequent researchers could, for example, use a combination of

ARIMA and structural econometric models.¹⁶ But till forecasting models are constructed which yield statistically significant lower forecasting errors than the futures market forecasts, we are unable to reject the hypothesis of market efficiency for the above mentioned commodity markets. In this context, the implications of this study with regard to buffer stock schemes are worth noting.

¹⁶For instance, Leuthold and Hartmann |13| employ a pure econometric model to test market efficiency in semi-strong form for the U.S. futures market in Hog.

Figure 1: Copper

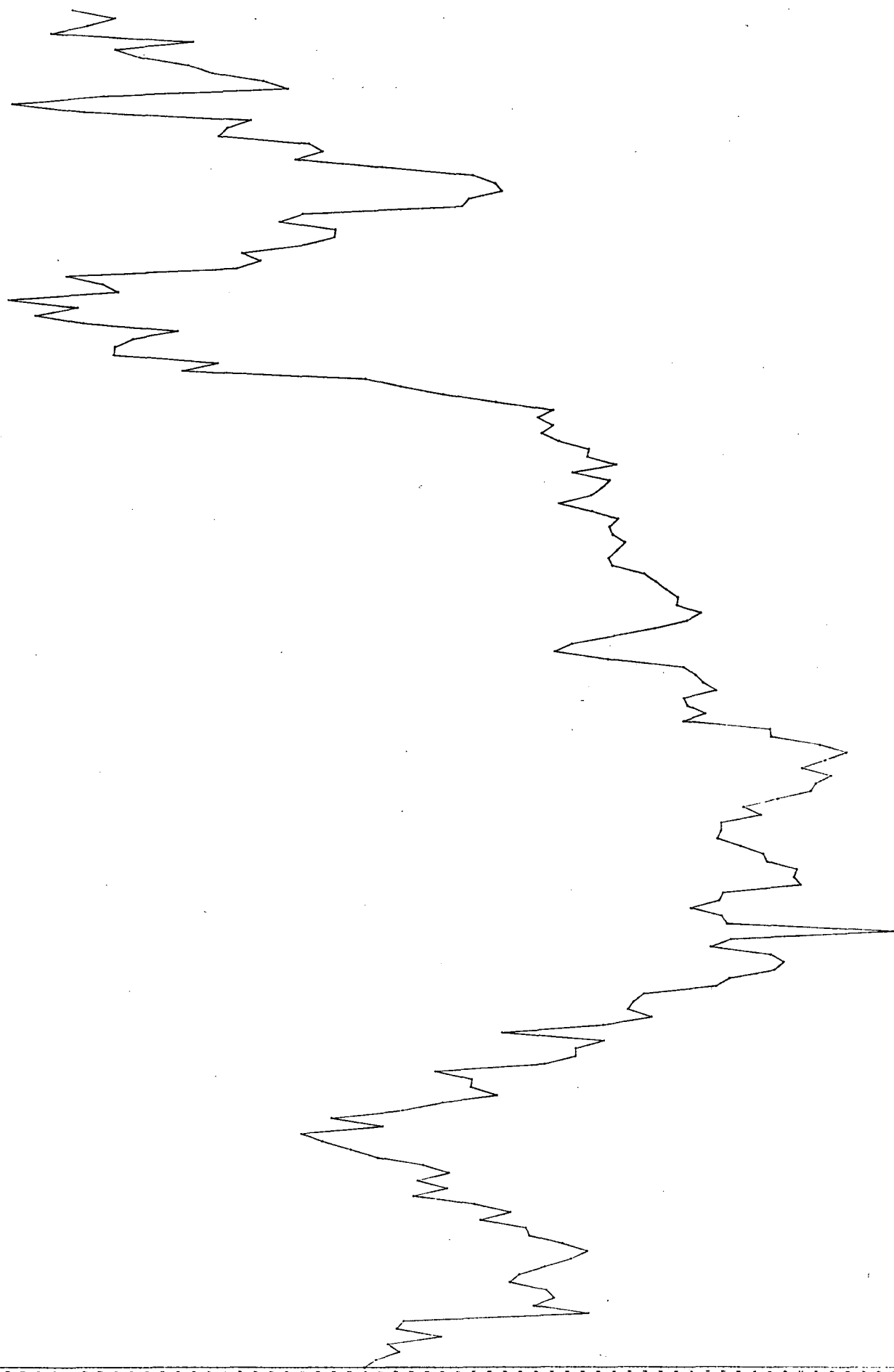


Figure 2: Tin

- 15 -

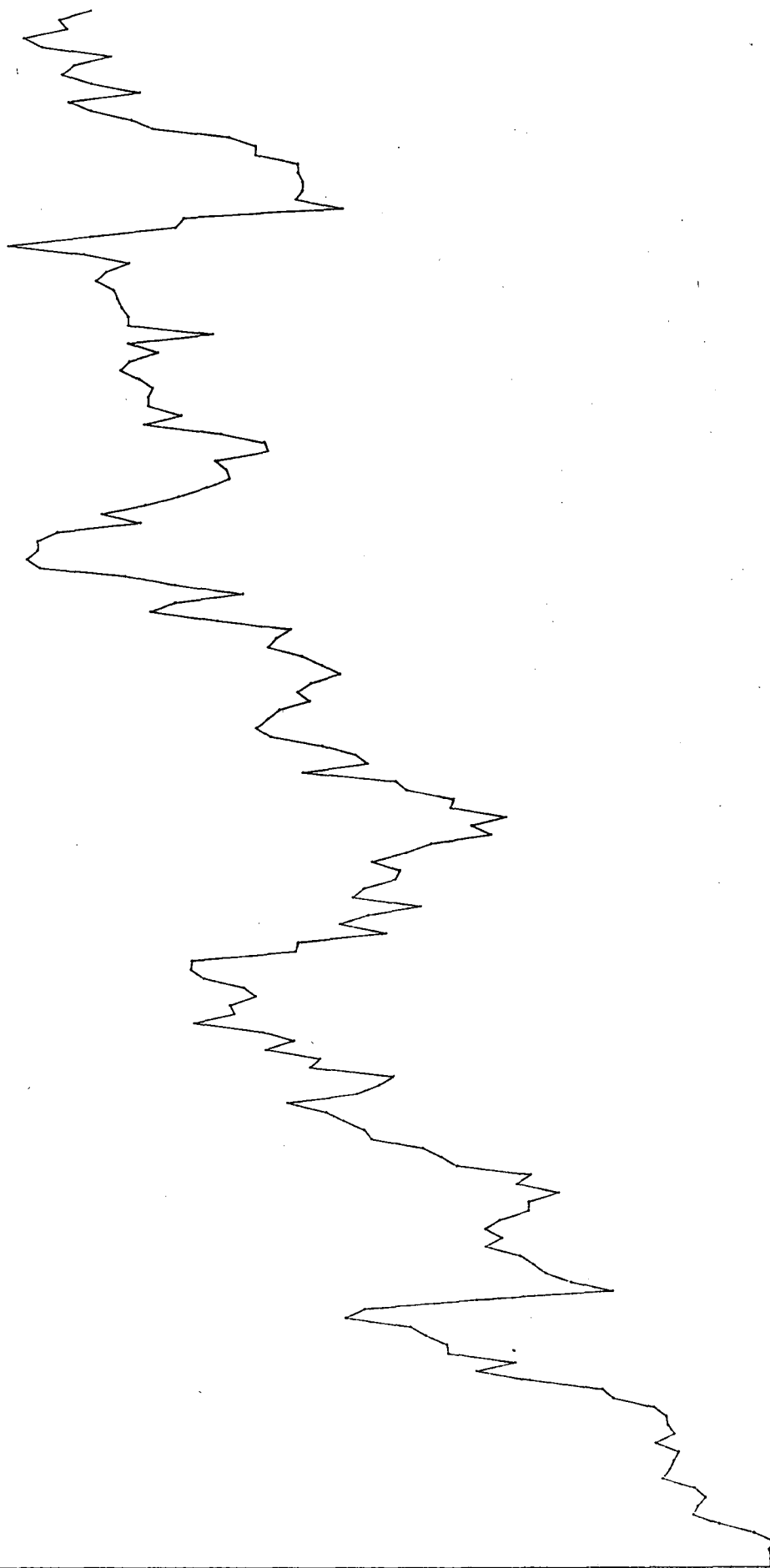


Figure 3 : Sugar

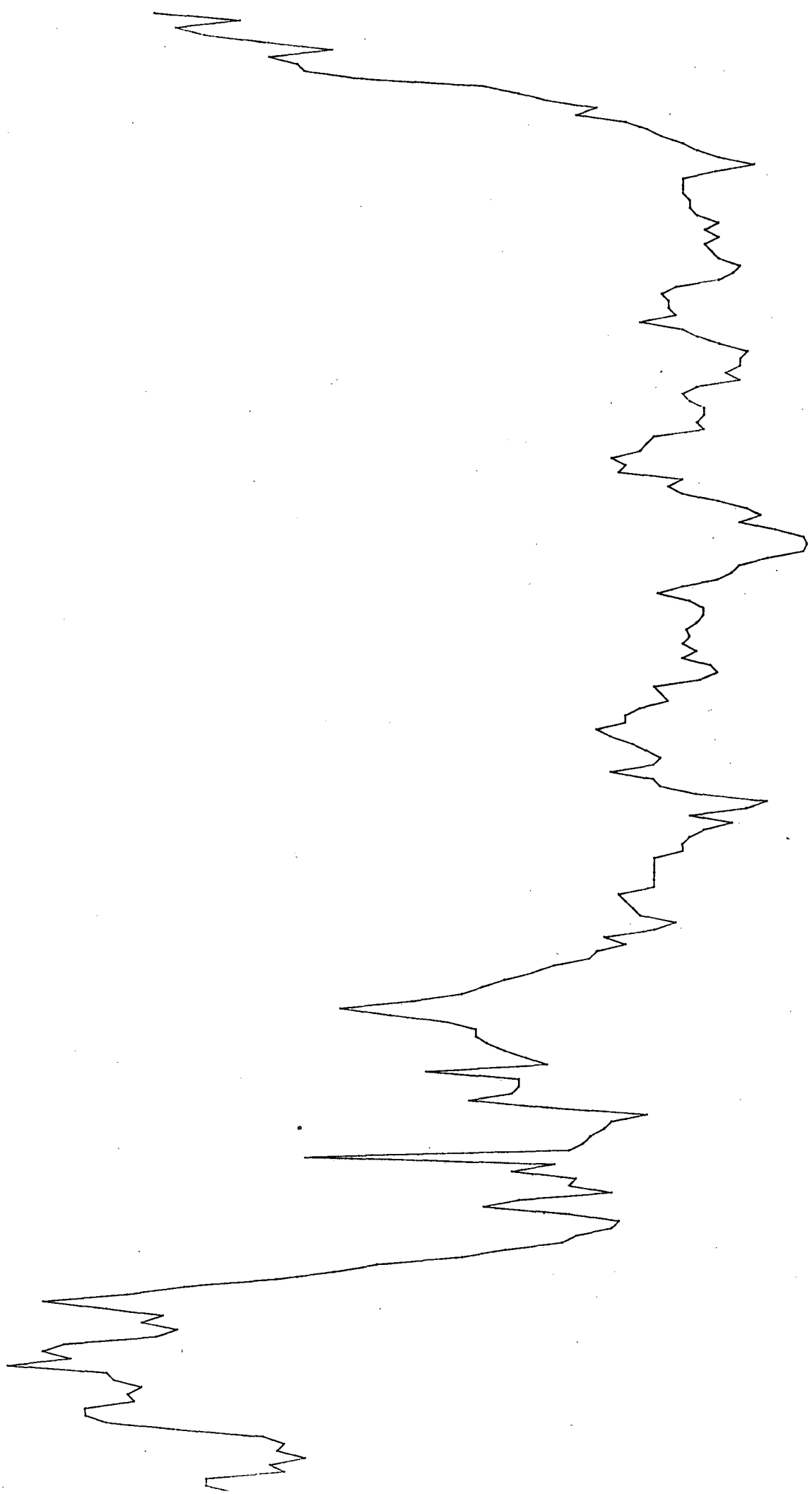


Figure 4 : Cocoa

- 17 -



Figure 5 : Colombian Mild Arabica Coffee

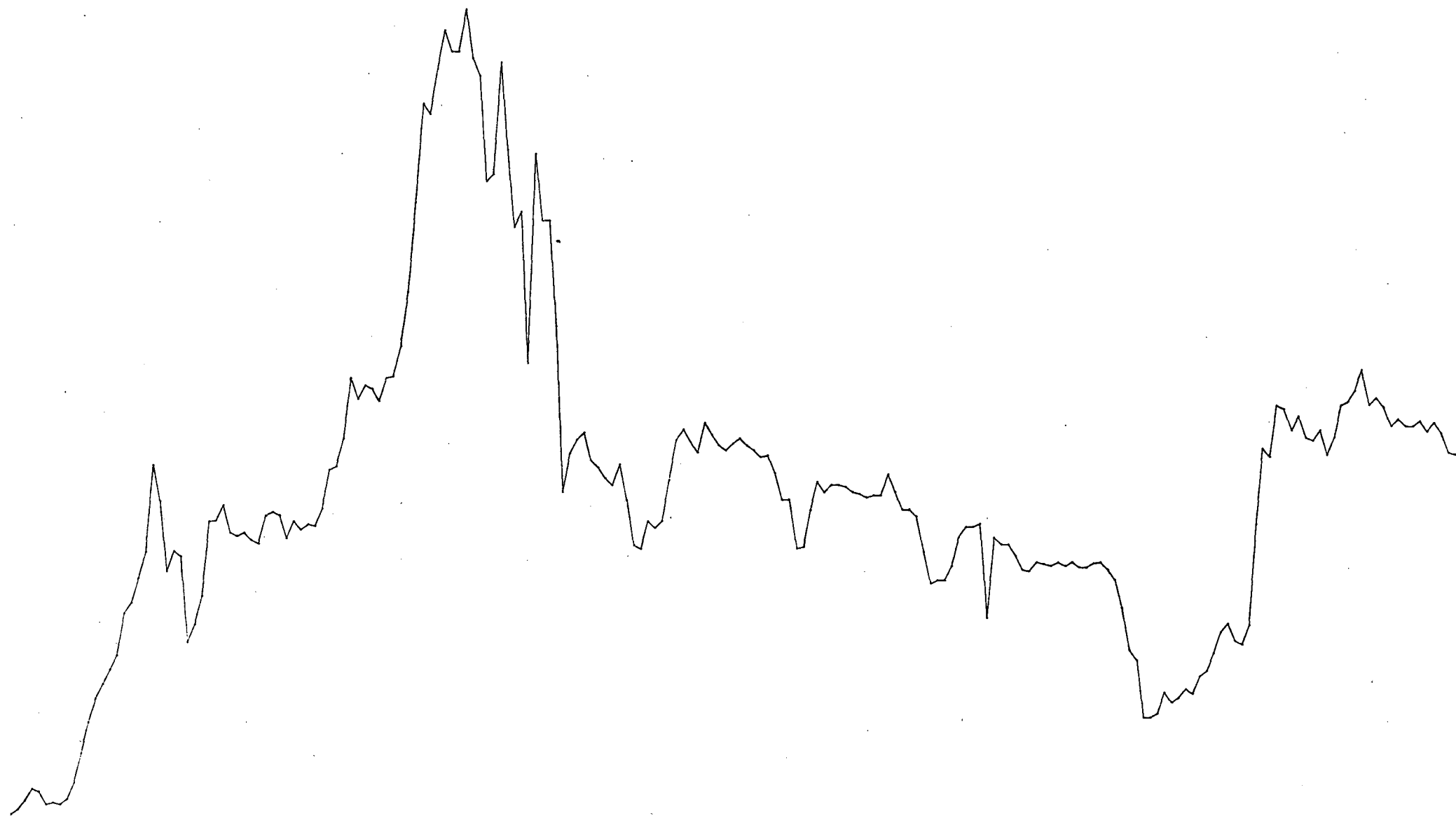
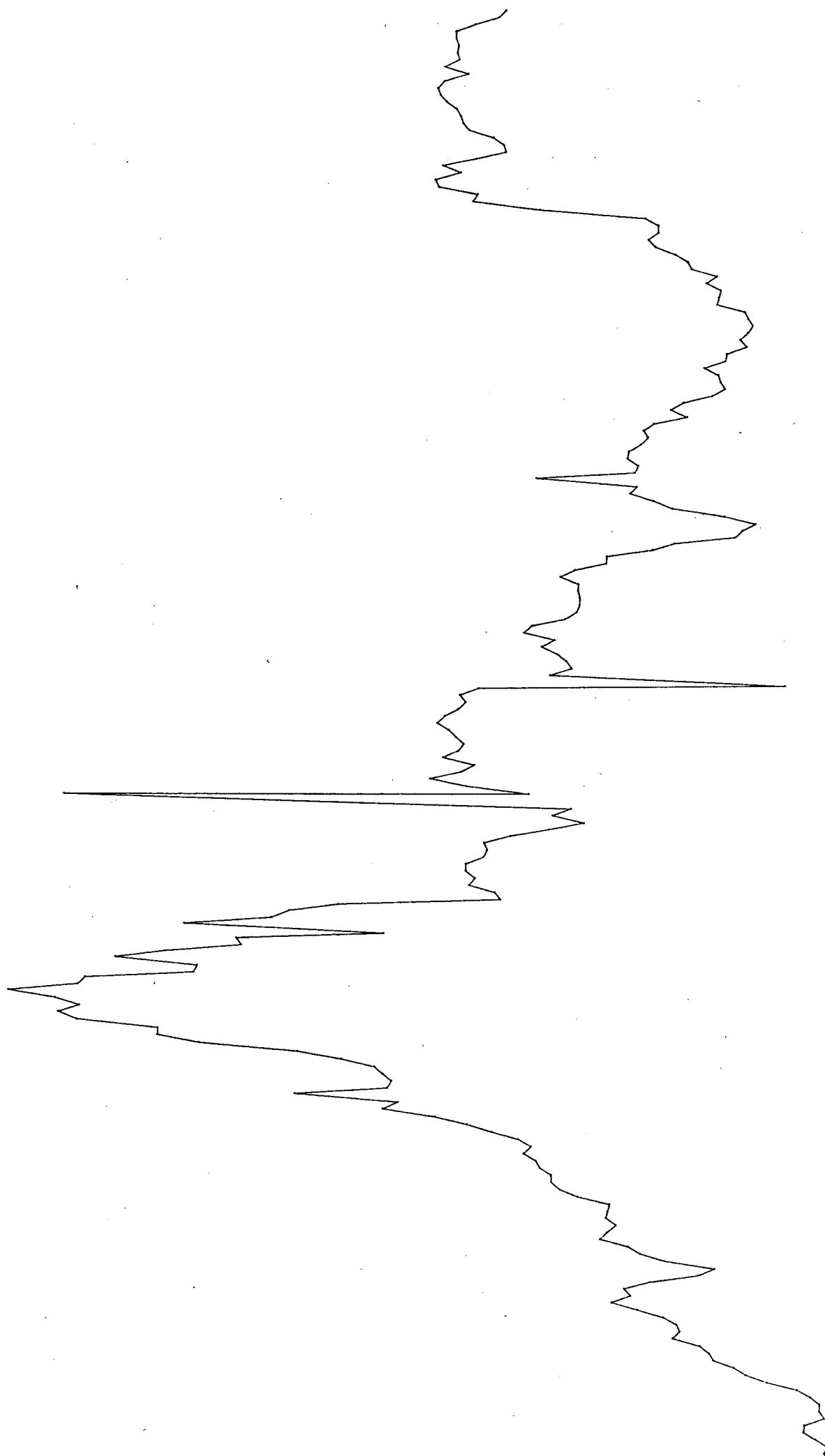


Figure 6: Other Mild Arabica Coffee



References

1. BILSON, J.F.O. and R.M. LEVICH. "A Test of the Forecasting Efficiency of the Forward Exchange Rate." New York University, Graduate School of Business Administration, Working Paper Series, No. 77-61, 1977.
2. BOX, G.E.P. and C. JENKINS. Time Series Analysis: Forecasting and Control, Holden-Day, San Francisco, 1976.
3. CARGILL, T.F. and G.C. RAUSSER. "Future Price Behaviour as a stochastic Process." American Statistical Association Proceedings, Business and Economic Statistics Section, August 1969, pp. 438-445.
4. _____. "Temporal Price Behaviour in Commodity Futures Markets." Journal of Finance 30 (1975), 1043-53.
5. DANTHINE, J.P. "Information, Futures Prices and Stabilising Speculation." Journal of Economic Theory, 17 (1978), 79-98.
6. DONGES, J.B. "UNCTAD's Integrated Programme for Commodities: Economic Implications and Europe's Response." Resources Policy, 5 (1979), 2-15.
7. DOWER, R.C. and R.C. ANDERSON. "Futures Markets: An Alternative for Stabilising Secondary Materials Markets?" Resources Policy, 3 (1977), 230-236.
8. FAMA, E.F. "Efficient Capital Markets: A Review of Theory and Empirical Work." Journal of Finance, 25 (1970), 383-417.
9. HOUTHAKKER, H.S. "Systematic and Random Elements in Short-term Price Movements." American Economic Review, Papers and Proceedings, 51 (1961), 164-172.
10. KOFI, T.A. "A Framework for Comparing the Efficiency of Futures Markets." American Journal of Agricultural Economics, 55 (1973), 584-94.

11. LABYS, W.C. and C.W.T. GRANGER. Speculation, Hedging and Commodity Price Forecasts, Heath Lexington Books, Massachusetts, 1970.
12. LEUTHOLD, R.M. "Random Walk and Price Trends: The Live Cattle Futures Market." Journal of Finance, 27 (1972), 879-889.
13. _____ and Peter A. HARTMANN. "A Semi-Strong Form Evaluation of the Efficiency of the Hog Futures Market." American Journal of Agricultural Economics, 61 (1979), 482-489.
14. NELSON, C.R. Applied Time Series Analysis. Holden-Day, San Francisco, 1973.
15. REIDY, B. and JOHN EDWARDS (ed.), Guide to World Commodity Markets, Kogan Page, London, 1977.
16. SMIDT, S. "A Test of the Serial Independence of Price Changes in Soybean Futures." Food Research Institute Studies, 5 (1965), 117-136.
17. STEVENSON, R.A. and R.M. BEAR. "Commodity Futures: Trends or Random Walks?" The Journal of Finance, 25 (1970), 65-81.
18. STREIT, M.E. "On the Use of Futures Markets for Stabilisation Purposes." Weltwirtschaftliches Archiv, 116 (1980), 493-513.
19. TOMEK, W.G., and R.W. GRAY. "Temporal Relationship among Prices on Commodity Futures Markets: Their Allocative and Stabilising Roles." American Journal of Agricultural Economics, 52 (1970), 372-380.