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Industry-specific conditional variances of inflation and stock returns

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INDUSTRY-SPECIFIC CONDITIONAL VARIANCES of INFLATION and STOCK RETURNS

by

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A dissertation submitted to the Graduate Faculty in Economics in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

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Dedicated to My Parents and to My Wife, Hae Woon

Abstract

INDUSTRY-SPECIFIC CONDITIONAL VARIANCES
of INFLATION and STOCK RETURNS

by

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Adviser: Professor Salih N. Neftci

The symmetry between variance *over time* (volatility) and variance *across markets* (variability) is proposed by exploring the variance decomposition, alternative to Barro's (1976), within the context of Lucas's model (1973).

A posterior variance (the RSS of linear projection) *over time* is identical with a posterior variance *across markets*, which a priori identity between variance *over time* and variance *across markets* implies that both variances are not dichotomous but complementary. In that sense, volatility is, in operation, accompanied by variability and further that both variances, in alternation, become each the source of the other.

This thesis proposes, as a *combined* measure, the industry-specific conditional variance of inflation, which is estimated by autoregressing on both economy-wide and within-industry variabilities with the absolute residuals

from a preliminary fit (of industry inflation regressed on general inflation as well as both economy-wide and within-industry variabilities, which function is implied by the SOS decomposition.)

The term *combined*, in the sense that the variance of inflation (recognized as the efficient operation of an economy) is induced not only on *over time* but also on *across markets*, embodies the idea that inflation (recognized as an outcome of economic processes) should be analyzed in order to view volatility upon variability.

Both economy-wide and within-industry variabilities as well as the industry-specific conditional variance of inflation are estimated using the most disaggregated monthly data in PPI for the period of 1970-88. Likewise, those of stock returns are also estimated using the monthly stock returns of individual firms in CRSP.

To gauge the extent of symmetry between volatility and variability, the elasticity of industry-specific conditional variance with respect to within-industry variability is estimated. The relation between inflation and stock returns in terms of variance is examined. Also, this thesis presents a striking evidence, contrary to the earlier literature, that the association between within-industry relative price variability and industry-average rate of inflation in the seventies in the United States is *not* dominated by Food and Petroleum-related industries.

Acknowledgements

At sight of the breach of the Berlin Wall in Germany, a question struck me: "does volatility accompany variability?"

Quoting historian's viewpoint: "history should be analyzed in order to view diachronic stream upon synchronic structure."

I see an analogy: inflation should be analyzed in order to view volatility upon variability, in the sense that volatility is, in operation, accompanied by variability and further that both variances, in alternation, become each the source of the other.

I would like to acknowledge that History side of the analogy is up to Kim, Yong Ok, Korean Philosopher, whom I meet through his about fifteen books.

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I. INTRODUCTION

Macroeconomic theory often suggests that economic agents respond not only to the mean but also to the variance of inflation. In the financial theory, the variance as well as the mean of the rate of stock return are determinants for portfolio decisions.

"The more volatile the rate of general inflation, the harder it becomes to extract the signal about relative prices from the absolute prices" [Friedman (1977, p.467)]. Friedman further conjectures in his Nobel lecture that this reduction in the efficiency of market prices as coordinators of economic activity may reduce output and increase unemployment, which implies a positively sloped Phillips curve.

In Friedman's statement, variability of relative prices as of one market relative to another is correlated with volatility of relative prices as of prices now relative to prices in the future. Two concepts of variance, variance across markets and variance over time was first formalized probabilistically by Lucas (1973), where the variances of inflation are determinants of the response to various shocks. Lucas's innovation triggers the variance approach for the analysis of the behavior of price movements.

The previous empirical variance approaches, however, are likely to be bifurcated exclusively into variability and volatility, in the sense that two concepts of variance are considered as dichotomous, not complementary.

This thesis proposes the symmetry between variance *over time* (volatiliy) and variance *across markes* (variability) by exploring the variance decomposition, which is an alternative to Barro's variance decomposition (1976), within the context of Lucas's model (1973).

A posterior variance (the residual sum of squares of linear projection) *over time* is identical with a posterior variance *across markets*, which a priori identity between variance *over time* and variance *across markets* implies that both variances are not dichotomous but complementary in the efficient operation of the price system of an economy. In that sense, volatility is, in operation, accompanied by variability and further that both variances, in alternation, become each the source of the other.

This thesis proposes, as a *combined* measure, the industry-specific conditional variance of inflation, which is estimated by autoregressing on both economy-wide and within-industry variabilities with the absolute residuals from a preliminary fit (of industry inflation regressed on general inflation as well as both economy-wide and within-industry variabilities, which function is implied by the sum of squares decomposition.)

The term *combined*, in the sense that the variance of inflation (recognized as the efficient operation of an economy) is induced not only on *over time* but also on *across markets*, embodies the idea that inflation (recognized as an outcome of economic processes) should be analyzed in order to view volatility upon variability. Quoting historian's viewpoint as an analogy, history should be analyzed in order to view diachronic stream upon synchronic structure.

Both economy-wide and within-industry variabilities as well as the industry-specific conditional variance of inflation are estimated using the most disaggregated monthly data in the Producer Price Index (PPI) File for the period of 1970-1988.

Likewise, with the rationale that an a priori identity between variance *over time* and variance *across markets* coincides with the a priori concept of risk in the financial theory that ex ante volatility *over time* is symmetric to covariance *across stocks*, those of stock returns are also estimated using the monthly stock returns of individual firms in the Center for Research in Security Prices (CRSP) File.

To gauge the extent of symmetry between volatility and variability, the elasticity of the industry-specific conditional variance with respect to the within-industry variability is estimated. Also, the relation between inflation and stock returns in terms of variance is examined.

On the other hand, this thesis presents a striking evidence, contrary to the earlier literature, that the association between the within-industry relative price variability and the industry-average rate of inflation in the seventies in the United States is *not* dominated by Food and Petroleum-related industries.

Yet, there is the strong evidence, supporting the earlier literature, that the industry-average rate of stock returns is positively related to the industry-specific conditional variance of stock returns as well as the within-industry relative return variability.

II. LITERATURE REVIEW

The two forms of variation, one of the general price level over time and the other of individual prices relative to each other at a point in time, were first specified probabilistically by Lucas (1973). Lucas's innovation triggers the variance approach for the analysis of the behavior of price movements. Barro (1976) extends Lucas's model by developing the variance decomposition, where the distribution of prices both across markets and over time is focused on the problem of predicting the future price.

The previous empirical variance approaches, however, are likely to be bifurcated exclusively into variability and volatility, in the sense that two concepts of variance are considered as dichotomous, not complementary.

On the one branch, the positive relationship between (unexpected) inflation and its variability (measured as of relative price dispersions) has been widely documented by, for example, Vining and Elwertowski (1976), Parks (1978), Blejer and Leiderman (1980), Herkowitz (1981), Fischer (1981), Domberger(1987), Van Hoomissen (1988), and recently Kaul and Seyhun (1990).

On the other branch, Engle (1983) tests the relationship between inflation and its volatility by estimating the conditional variance of inflation using ARCH model. Recently, volatility approach has prevailed especially in the field of financial economics. For example, Pindyck (1984), and Schwert

(1989) analyze the relation of stock return volatility with inflation volatility. Poterba and Summers (1986), and French, Schwert, and Stambaugh (1987) attempt to relate changes in stock return volatility to changes in expected stock returns.

2.1 Theory

2.1.1 Lucas's Model of the Phillips Curve

Lucas (1973) specifies the two forms of variation of the price movements in the language of probability theory within the framework of imperfect information. It is presumed that rational agents (placed in a formulation of the natural rate theory), whose decisions depend on relative prices only, do not have enough information to distinguish relative from general price movements.

Lucas postulates the supply function for market *i*, which embodies the idea that suppliers (located in a large number of scattered, competitive markets) increase supply only in response to what they perceive to be relative price movements:

$$y_{it} = \gamma \; (P_{it} - E[P_t | I_{it}]) \tag{2.1}$$

where y_{it} and P_{it} are the logarithm of output and actual price in market *i* at *t* and $E[P_t | I_{it}]$ is the mean current, general price level, conditioned on information available in i at t, I_{it}.

Suppliers do not observe the current general price level directly but have a "prior" distribution for P_t, that is assumed to be known to be normal, with mean $\bar{P}_t$ and a constant variance σ^2:

$$(2.2) \qquad P_t \sim N(\bar{P}_t, \sigma^2)$$

where P_t is the logarithm of the general price level at t.

They then observe P_{it}, which is supposed to deviate from the (geometric) economy-wide average P_t by the relative disturbance z_{it}, where z_{it} is normally distributed, independent of P_t, with mean zero and variance τ^2:

$$(2.3) \qquad P_{it} - P_t = z_{it} \sim N(0, \tau^2)$$

P_{it} can therefore be thought of as a realization from a distribution with mean P_t so that suppliers estimate a "posterior" mean for P_t conditional on I_{it}:

$$(2.4) \qquad E[P_t | I_{it}] = E(P_t | P_{it}, \bar{P}_t) = (1-\theta) P_{it} + \theta \bar{P}_t$$

where $\theta = \tau^2/(\sigma^2 + \tau^2)$, and variance $\theta\sigma^2$.

Substituting *(2.4)* into *(2.1)* yields the supply function for market *i*:

(2.5)
$$y_{it} = \gamma \, (P_{it} - ((1-\theta)P_{it} + \theta \, \bar{P}_t))$$
$$= \gamma\theta \, (P_{it} - \bar{P}_t)$$

Averaging over markets gives the aggregate supply function:

(2.6)
$$y_t = \gamma\theta \, (P_t - \bar{P}_t)$$

which shows output as an increasing function of the price surprise, the unanticipated increase in the aggregate price level. This is Lucas's version of the Phillips curve. "The slope of the aggregate supply function thus varies with the fraction θ of total individual price variance, $\sigma^2 + \tau^2$, which is due to relative price variation. In cases where τ^2 is relatively small, so that individual price changes are virtually certain to reflect general price changes, the supply curve is nearly vertical. At the other extreme when general prices are stable (σ^2 is relatively small) the slope of the supply curve approaches the limiting value of γ" (p.328).

Vining and Elwertowski (1976) interpret Lucas's model as: "thus, the variance (τ^2) in individual prices P_{it} around their mean P_t is a constant, and is therefore independent of the degree of variability (σ^2) in the general price level P_t around its trend $\bar{P}_t$. ... In short, the familiar constancy of relative prices in neoclassical economics is translated into a constancy in the mode of variation in these prices" (p.700-701).

They translate Lucas's assumption into a statement about the changes in relative and general prices from one period to the next by proceeding with a simple transformation of equation *(2.3)*:

$$(2.7) \qquad \pi_{it} = \pi_t + z_{it} - z_{it-1}$$

where $\pi_{it} = P_{it} - P_{it-1}$, and $\pi_t = P_t - P_{t-1}$

$$\begin{aligned}(2.8) \qquad Var\ \pi_{it} &= E(\pi_{it} - \pi_t)^2 \\ &= E(z_{it} - z_{it-1})^2 \\ &= 2\tau^2, \text{ since } E(z_{it}, z_{it-1}) = 0 \\ &= \delta^2\end{aligned}$$

That is, the variance in π_{it} around their mean π_t should be roughly constant, and therefore unrelated to the degree of variability (σ^2) in the mean change. *(2.8)* in effect says that δ^2 is invariant under shifts in the parameter σ^2.

However, they provide an empirical evidence that reveals changes in δ^2 which are obviously in close association with the degree of general price change instability (σ^2).

Cukierman (1979) disagrees with Vining and Elwertowski's interpretation of Lucas's model as the independence between σ^2 and τ^2. He rather argues that both σ^2 and τ^2 are determined endogeneously by some common exogeneous variances like the variance of aggregate excess demand shocks and the variance of relative excess demand shocks. If either of those exogeneous variances or both of them change over time, the variances of general price level change and the variance of relative price change will also change over time causing a definite systematic relationship to emerge between them.

He argues that a positive association between σ^2 and τ^2 as found empirically by Vining and Elwertowski is perfectly consistent with the Lucas's model.

2.1.2 Barro's Variance Decomposition

Barro (1976) extends Lucas's model by developing the variance decomposition. It is assumed that participants in market *i*, possessing the differential information structure, cannot tell what fraction of the observed movement in P_{it} reflects a relative price shift rather than an absolute shift.

The discussion of distributions of prices both across markets and over time is focused on the problem of predicting the future price in a (randomly-selected) market *j*, based on information currently possessed by participants in market *i*. That is, the gap between P_{jt+1} and $E[P_{t+1}|I_{it}]$, where it is assumed that $EP_{jt+1} = EP_{t+1}$ for all j, is broken down into three independent components:

$$(2.9) \quad P_{jt+1} - E[P_{t+1}|I_{it}] \equiv [P_{jt+1} - P_{t+1}] + [P_{t+1} - E[P_{t+1}|I_t]] + [E[P_{t+1}|I_t] - E[P_{t+1}|I_{it}]]$$

where I_t denotes full current information, whereas I_{it} denotes the information possessed at time *t* by participants in market *i*. The first component refers to the distribution of relative prices at a point in time, the second refers to the future price net of the price that is predictable based on full current information, and the third refers to the distribution of relative information in terms of its implications for EP_{t+1}.

The three components in *(2.9)* are assumed to be independently, normally distributed with zero mean, so that the variances of each component fully specifies its distribution. The full variance of P_{jt+1} about $E[P_{t+1}|I_{it}]$ is therefore the sum of the three component variances:

$$(2.10) \qquad \begin{aligned} V &\equiv E(P_{jt+1}-E[P_{t+1}|I_{it}])^2|I_{it} \\ &= E(P_{jt+1}-P_{t+1})^2|I_{it} + E(P_{t+1}-E[P_{t+1}|I_t])^2|I_{it} \\ &\quad + E(E[P_{t+1}|I_t]-E[P_{t+1}|I_{it}])^2|I_{it} \\ &\equiv \tau_1^2 + \sigma^2 + \tau_2^2 \end{aligned}$$

where V amounts to the variance of future prices about their currently predictable values, and τ_1^2 amounts to the variance of relative prices, and σ^2 amounts to the variance of the future absolute price level, and τ_2^2 amounts to the variance of relative information.

Barro then calculates the variance of three components in terms of the parameters of the exogeneous variables: [refer to Barro (1976, p.13-14)]

$$(2.11) \qquad \begin{aligned} \tau_1^2 &= (\theta_1+\theta_2)^2 \sigma_\varepsilon^2 \\ \sigma^2 &= (\theta_1+\theta_2)^2 \sigma_A^2 \\ \tau_2^2 &= (\theta_1/\beta) \sigma_\varepsilon^2 \end{aligned}$$

$$\text{where} \quad \Theta_1 = \frac{\sigma_A^2}{\beta\ (\sigma_A^2 + \sigma_\varepsilon^2)}, \quad \Theta_2 = \frac{\sigma_\varepsilon^2}{\alpha\ (\sigma_A^2 + \sigma_\varepsilon^2)}$$

where σ_ε^2 and σ_A^2 refer to the variances of relative and aggregate shifts, and α and β are the price and wealth elasticities of excess demand, where $\alpha > \beta$ is assumed.

Then a simple summation yields:

$$(2.12) \qquad V = (\Theta_1 + \Theta_2)^2\ (\sigma_\varepsilon^2 + \sigma_A^2) + (\Theta_1 / \beta)\ \sigma_\varepsilon^2$$

V is shown by straightforward differentiation to be unambiguously increasing in not only σ_ε^2 but also σ_A^2.

Barro then analyzes the impact of monetary policy on the predictability of future prices, as measured inversely by V, upon the underlying assumption that the existence of an effect of unperceived monetary expansion on output depends entirely on the inability of market participants to distinguish immediately between relative and absolute price shifts. Note that the variance V in *(2.12)* is an increasing function of the variance of money, which is part of σ_A^2. That is to say, as the money variance increases, the predictability of prices reduces.

He argues that the higher the variance of the monetary growth rate, since individuals attribute a larger fraction of observed price movements to monetary causes, the smaller the effect of a given size of monetary disturbance on output—that is, the smaller the magnitude of the Phillips curve slope.

Cukierman (1979) claims that it is wrong to interpret the Barro model as providing a rationale for "a chain of causality running from general price level change instability to relative price change instability" (Vining and Elwertowski, p.707). Rather a correct interpretation is that "both types of price change instability are causally dependent on the variances of (exogeneous) aggregate and relative excess demands shocks" (Cukierman, p.446).

2.2 Empirical Approaches

2.2.1 Variability Approach

Vining and Elwertowski (1976) report that an analysis of the behavior of both wholesale and retail prices over the period 1948-74 reveals changes in τ^2. They provide a strong statistical evidence that as σ^2 increases (as the general price level become more unstable or less predictable relative to its trend value $\bar{P}_t$), so does τ^2 (the dispersion in relative prices increases), and vice versa. They also note that σ^2 is correlated with the rate of inflation.

Parks (1978) claims that Vining and Elwertowski "fail to provide a precise definition of their notion of general price change instability (σ^2) or to provide a microeconomic link to explain the transmission of σ^2 into the relative price variance (τ^2)" [p.80]. He instead interprets σ^2 as the notion of variance in the price level around its anticipated level. He also notes that a measure similar to that proposed by Klein (1975), a multiyear moving standard deviation, might serve the purposes of Vining and Elwertowski.

He uses the 12-commodity breakdown annually for the period 1929-75. He interprets the variance τ_t^2 as a measure of nonproportionality of the price movements, for if all prices change by the same rate, the common π_t, then the variance measure will be zero; the measure will be larger the more nonproportional the price changes become:

$$\tau_t^2 = \sum w_{it} (\pi_{it} - \pi_t)^2 \qquad (2.13)$$

where $\pi_t = \sum w_{it}\pi_{it}$, and $\pi_{it} = log(P_{it}/P_{it-1})$, and w_{it} is the average expenditure share on the *i*th good at time $t-1$ and t.

He reports that there is a fairly weak but statistically significant association between the measure of price variability and the squared rate of price change, suggesting that the amount of relative price change increases when the rate of price change increases. He argues that a measure of "surprise" (measured as the difference between the actual rate and a time-series predictor) is a more important determinant of relative price variability than the rate of inflation, therefore, although fully anticipated price changes are neutral in their effect, unanticipated changes in the rate of inflation have a significant effect on the amount of relative price change in the economy and result in nonneutral real effects:

$$\tau_t^2 = \alpha_0 + \alpha_1 (\pi_t - \pi_t^*)^2 + v_t \qquad (2.14)$$

where π_t^* is the anticipated general inflation rate.

He finds a linear relationship between the variance of relative price change and the squared measure of surprise or unanticipated inflation. "If we were to average over the observations of a particular subperiod or over observations for a particular country, we would have a linear relationship between the variance of relative changes for the period or country and the variance of price changes around their expected rate" [p.93]. He asserts that this latter variance is a more precise representation of the Vining and Elwertowski notion of general price change instability and also corresponds with Lucas's notion of the variance of the prior distribution of the (changes in) price level (σ^2).

Blejer and Leiderman (1980) present empirical evidence concerning the effects of relative price variability on real economic variables within the framework of the natural rate hypothesis, embodying the view that inflation will have real effects when it is unanticipated by economic agents:

$$(2.15) \qquad X_t = \beta_1 + \beta_2\, t + \beta_3\, X_{t-1} + \beta_4\, (\pi_t - \pi_t^*) + \beta_5\, V_t + e_t$$

where X_t is either the log of real output or the unemployment rate, and t is a time trend, and $(\pi_t - \pi_t^*)$ is the unanticipated inflation, and V_t is a measure of variability, which has three alternative formulation: τ_t^2 [taken from Parks (1978)]; $s\tau = \tau_t^2 + \tau_{t-1}^2$; and $ss\tau = \tau_t^2 + \tau_{t-1}^2 + \tau_{t-2}^2$.

They report the evidence that increased relative price variability leads to a decrease in the level of output and to an increase in the rate of unemployment. They also provide evidence that unanticipated inflation has a significantly positive effect on output and a negative effect on unemployment.

Hercowitz (1981) generates price dispersion equation by modifying Barro's model, which links price change dispersion to the exogeneous shocks affecting the economy such as the magnitude of the unperceived money growth and the variance of money shocks.

He postulates the following relation:

$$m_t = \bar{m}_t + \mu_t \tag{2.16}$$

where m_t is the rate of growth of the money stock, and $\bar{m}_t$ is a prior expectation about money growth formed from all the economy-wide shared information, and the quantity μ_t is the unperceived part of money growth, which is a random variable with zero mean and variance $\sigma^2_{\mu t}$.

The prior conditional expectation $\hat{m}_t$ and the variance of money are estimated:

$$m_t = \sum \beta_i \, x_{it} + \varepsilon_t \tag{2.17}$$

$$\hat{\varepsilon}^2_t = \sum \rho_i \, x_{it} + \rho \, \hat{\varepsilon}^2_{t-1} + \upsilon_t \tag{2.18}$$

where the x_{it}'s are the exogeneous variables, and $\hat{\varepsilon}_t = m_t - \hat{m}_t$ are the residuals from *(2.17)*. The fitted values from *(2.18)* $\tilde{\varepsilon}_t^2$ account for a measure of variance of money shocks, $\sigma_{\mu t}^2$.

He also computes a measure of price change dispersion τ_t^2 for the hyperinflation in Germany during the period of 1921:1- 1923:7 using 68 series of monthly averages of wholesale commodity prices:

$$(2.19) \qquad \tau_t^2 = \frac{1}{n} \sum (\pi_{it} - \pi_t)^2$$

where $\pi_t = \frac{1}{n} \sum \pi_{it}$, and $\pi_{it} = log(P_{it}/P_{it-1})$, and P_{it} is the price of market *i* of a specific commodity.

Then, the price dispersion equation is estimated:

$$(2.20) \quad \tau_t^2 = \beta_0 + \beta_1(\mu_t - \mu_{t-1})^2 + \beta_2\sigma_{\mu t}^2 + \beta_3(\pi_t - \pi_{t-1})^2 + \beta_4\pi_t^2 + v_t$$

where $(\mu_t - \mu_{t-1})^2$ refers to the unperceived monetary shocks, $\sigma_{\mu t}^2$ refers to the variance of the money shocks, and $(\pi_t - \pi_{t-1})^2$ refers to the acceleration/deceleration in inflation.

Hercowitz provides an evidence that there is a statistically significant correlation between price change dispersion and the magnitude of changes in the inflation rate as well as the unperceived money.

Fischer (1981) makes a comprehensive survey of the theoretical and empirical literature about relative price variability. He also provides evidence that the association between inflation and relative price variability in post-1956 in the United States is dominated by food and energy shocks, suggesting an implication that there are the different degrees of price adjustment to the inflationary shocks across markets as well as the different magnitude of dispersion of relative prices across markets.

In his comments to Fischer's paper, Hall remarks that inflation, which is recognized as an outcome of economic processes, not an exogeneous causal influence, is good, not bad, because it helps achieve desirable shifts in relative prices. Supply shocks as well as changes in macro policy change the rate of inflation and relative prices at the same time. The shifts in relative prices are simply the efficient operation of the economy and are not in any case a cost of inflation. He draws two conclusions from the paper: First, the motivation of macro policy for ending inflation cannot be elimination of excess variability of relative prices. Variability has indeed been higher in time of inflation, but good microeconomic reasons. Second, anti-inflation policy- at least monetary restriction and high interest rates- has adverse effects on real output.

Recently, Domberger (1987) and Van Hoomissen (1988) investigate the impact of inflationary shocks on the intramarket relative price variability within a microeconomic framework of optimally imperfect decision making theory implying that each market, which has a specific structural characteristic, will have a different speed of price adjustment to the inflationary shocks.

Domberger finds evidence, using quarterly price data for 80 disaggregated commodity groups in the United Kingdom from 1974 to 1984, that intramarket variability is positively related to the average market rate of price change, but the strength of this relationship is inversely related to the level of industry concentration. He argues that the findings generally support the search theory.

Van Hoomissen finds evidence, using monthly price data for 13 uniquely defined goods sold in Israel between 1971 and 1984, that the price dispersion of individual goods is positively related to the rate of market price inflation. He argues that the findings support price dispersion theories based on optimally imperfect decision making, since inflation is an unlikely proxy for changes in perceived differences in quality, service agreements, or location.

More recently, Kaul and Seyhun (1990) construct an annual measure of the variance of the overall inflation rate using twelve nonoverlapping monthly observations per annual estimate of the variable:

(2.21) $$\sigma_T^2 = \sum_{t=1}^{12} (\pi_t^u - \frac{1}{12} \sum_{t=1}^{12} \pi_t^u)^2,$$

where π_t^u is the monthly unexpected component of the inflation rate (based on ARIMA model) calculated using PPI.

They also calculate a common unweighted measure of relative price variability using PPI at the item/product level for 1947-85 period, because "the use of such disaggregated data is suggested by the absolute-relative price confusion models" (p.481) of the Lucas (1973) type. They also construct a variability measure of fuel/oil-related products only by averaging the squared deviations of oil and fuel prices around the overall PPI. This variable serves as their measure of real supply shocks in order to gauge the importance of supply shocks in the determination of relative price variability and its relation with output and stock returns. They argue that "relative price variability in post-war U.S. may be a reflection of real supply shocks (in particular, the oil shocks witnessed in the seventies and eighties), rather than monetary shocks." (p.482)

They present evdence that the three price volatility measures are highly correlated with each other and that each is positively correlated with (unexpected) inflation. They also provide evidence that the negative relations between stock returns and expected and unexpected inflation proxy for the negative effects of relative price variability on the stock returns. They argue that the adverse effects of relative price variability on output and stock market are largely a reflection of the supply shocks witnessed in the seventies.

2.2.2 Volatility Approach

Engle (1983) interprets σ^2 in Lucas's model as the unconditional variance , which is constant over time. He also claims that the estimates of variance by Klein (1977) by constructing the five-period moving variance about the ten-period moving mean of annual inflation rate is biased. He rather estimates the conditional mean and variance from U.S. time series data based on the autoregressive conditional heteroscedasticity (ARCH) model, where the variance of regression in one period is allowed to change over time and to depend upon variables known from previous periods including the disturbances.

The model as formulated in terms of an information set ψ_{t-1} is:

$$\pi_t | \psi_{t-1} \sim N\ (x_t\beta,\ h_t) \qquad (2.22)$$

$$h_t = \alpha_0 + \alpha_1\varepsilon^2_{t-1} + \alpha_2\varepsilon^2_{t-2} + \cdots\cdots + \alpha_p\varepsilon^2_{t-p} \qquad (2.23)$$

where $\varepsilon_t = \pi_t - x_t\hat{\beta}$, and x_t is a vector of explanatory variables included in ψ_{t-1}.

He tests whether the variance of inflation is high when the level is high:

$$(2.24) \qquad h_t = \alpha_0 + \alpha_1 \pi_{t-1}$$

He argues, contrary to Friedman's statement, that a high rate of inflation does not necessarily imply a high variance of inflation.

Recently, volatility approach has prevailed especially in the field of financial economics, where as a measure of risk the covariance between its returns and return on a market portfolio is replaced by ex ante volaility over time. For example, Pindyck (1984), and Schwert (1989) analyze the relation between stock return volatility and inflation volatility. Poterba and Summers (1986), and French, Schwert, and Stambaugh (1987) attempt to relate changes in stock return volatility to changes in expected stock returns.

Pindyck (1984) computes a monthly sample variance using the CPI:

$$(2.25) \qquad \sigma_t^2 = \sum_{i=-6}^{6} (\pi_{t+i} - \bar{\pi}_t)^2 / 12$$

where $\bar{\pi}_t = \sum_{i=-6}^{6} \pi_{t+i} \;/\; 13$, and $\pi_t = log(P_t/P_{t-1})$

He provides the evidence that increases in σ_t^2 are roughly confined to the oil shocks and recessions of 1973-75 and 1979-82. He argues that increases in the expected rate of inflation is concurrent with increases in the volatility of inflation, which can affect the volatility of stock returns.

Schwert (1989) characterizes the changes in stock market volatility through time and relates stock market volatility to the time-varying volatility of a variety of economic variables. The method to estimate volatility is a generalized 12-month rolling standard deviation estimator, which is similar to ARCH model:

$$(2.26) \qquad R_t = \sum_{j=1}^{12} \alpha_j \, D_{jt} + \sum_{i=1}^{12} \beta_i \, R_{t-i} + \varepsilon_t$$

$$(2.27) \qquad |\hat{\varepsilon}_t| = \sum_{j=1}^{12} \gamma_j \, D_{jt} + \sum_{i=1}^{12} \rho_i \, |\hat{\varepsilon}_{t-i}| + \upsilon_t$$

where D_{jt} are the monthly dummy variables, and $\hat{\varepsilon}_t = R_t - \hat{R}_t$ are the residuals from *(2.26)*. The fitted values from *(2.27)* $|\tilde{\varepsilon}_t|$ estimate the conditional deviation of R_t, given information available before month *t*.

He also estimates monthly inflation volatility using the same procedure. He finds evidence that inflation is more volatile during recessions, but little evidence that financial asset volatility helps to predict future inflation volatility and vice versa.

Poterba and Summers (1986) calculate a measure of volatility for month t as follows:

$$(2.28) \qquad \hat{\sigma}_t^2 = \sum_{i=1}^{K_t} \delta_{t,i}^2 \; / \; k_t$$

where $\delta_{t,i}^2$ is the market return on the ith day of month t, measured by the percentage change in the S&P Composite Index, and k_t is the number of trading days in month t.

They then estimate the elasticity of share prices P_t with respect to stock return volatility, $d \log P_t \; / \; d \log \sigma_t^2$, to evaluate the impact of volatility shocks on share prices. However, extremely small elasticity resulted casts serious doubt on the view (shared by Pindyck) that changes in volatility, through their influence on investor's risk premia, have a substantial effect on stock market values.

French, Schwert, and Stambaugh (1987) examine the intertemporal relation (opposed to the cross-sectional relation, where risk is measured as of the covariance between its return and market return) between risk and expected returns on commom stocks. They estimate the variance of the monthly return to the S&P portfolio as the sum of the squared daily returns plus twice the sum of the product of adjacent returns:

$$\sigma_t^2 = \sum_{i=1}^{N_t} r_{it}^2 + 2 \sum_{i=1}^{N_t-1} r_{it} r_{i+1,t} \qquad (2.29)$$

where there are N_t daily returns, r_{it}, in month t.

They argue that the expected market risk premium (defined as the expected return on a stock market portfolio minus risk-free interest rate) is positively related to risk (as measured by the volatility of stock returns).

III. MODEL

3.1 Variance Decomposition within the Context of Lucas's Model

Lucas (1973) postulates the supply function for market *i*, which embodies the idea that suppliers increase supply only in response to what they perceive to be relative price movements:

$$y_{it} = \gamma\ (P_{it} - E[P_t | I_{it}]) \tag{3.1}$$

where y_{it} and P_{it} are the logarithm of output and actual price in market *i* at *t*.

Suppliers do not observe the current general price level directly but have a "prior" distribution for P_t, that is assumed to be known to be normal, with mean $\bar{P}_t$ and a constant variance σ^2. They then observe P_{it}, which is supposed to deviate from the economy-wide average P_t by the relative disturbance z_{it}, where z_{it} is normally distributed, independent of P_t, with mean zero and variance τ^2.

P_{it} can therefore be thought of as a realization from a distribution with mean P_t so that suppliers estimate a "posterior" mean for P_t conditional on I_{it}:

$$(3.2) \qquad E[P_t | I_{it}] = E(P_t \mid P_{it}, \bar{P}_t) = (1-\theta) P_{it} + \theta \bar{P}_t$$

where $\theta = \tau^2/(\sigma^2 + \tau^2)$, and variance $\theta\sigma^2$.

Substituting *(3.2)* into *(3.1)* yields the supply function for market *i*:

$$(3.3) \qquad y_{it} = \gamma \, (P_{it} - ((1-\theta)P_{it} + \theta \bar{P}_t)) = \gamma \, \theta \, (P_{it} - \bar{P}_t)$$

Averaging over markets gives the aggregate supply function:

$$(3.4) \qquad y_t = \gamma \, \theta \, (P_t - \bar{P}_t)$$

which shows output as an increasing function of the price surprise. This is the Lucas's version of Phillips curve. "The slope of the aggregate supply function thus varies with the fraction θ of total individual price variance, $\sigma^2 + \tau^2$, which is due to relative price variation. In cases where τ^2 is relatively small, so that individual price changes are virtually certain to reflect general price changes, the supply curve is nearly vertical. At the other extreme when general prices are stable (σ^2 is relatively small) the slope of the supply curve approaches the limiting value of γ" (p.328).

Vining and Elwertowski (1976) interpret Lucas's model as: "thus, the variance (τ^2) in individual prices P_{it} around their mean P_t is a constant, and is therefore independent of the degree of variability (σ^2) in the general price level P_t around its trend $\bar{P}_t$. ... In short, the familiar constancy of relative prices in neoclassical economics is translated into a constancy in the mode of variation in these prices."

Cukierman (1979) disagrees with Vining and Elwertowski's interpretation of Lucas's model as the independence between σ^2 and τ^2. He rather argues that both σ^2 and τ^2 are determined endogeneously by some common exogeneous variances like the variance of aggregate excess demand shocks and the variance of relative excess demand shocks. If either of those exogeneous variances or both of them change over time, the variances of general price level change and the variance of relative price change will also change over time causing a definite systematic relationship to emerge between them.

In Lucas's model, each of P_t and z_{it} is assumed to be distributed normally, and independently each other:

$$(3.5) \qquad P_t \sim N\ (\bar{P}_t,\ \sigma^2), \qquad z_{it} \sim N\ (0,\ \tau^2)$$

The sum of two normal random variables P_{it} ($=P_t+z_{it}$) is thus normally distributed:

$$(3.6) \qquad P_{it} \sim N\,(\bar{P}_t,\ \sigma^2{+}\tau^2)$$

The joint distribution of P_t and P_{it} is bivariate normal, which is fully described by five numbers: two means, two variances and one correlation coefficient:

$$(3.7) \qquad (P_t,\ P_{it}) \sim (\bar{P}_t,\ \bar{P}_t,\ \sigma^2,\ \sigma^2{+}\tau^2,\ \rho)$$

where $\rho = \dfrac{\sigma}{(\sigma^2{+}\tau^2)^{1/2}}$

In a bivariate normal distribution, given $P_{it}{=}p_{it}$ a conditional distribution is induced on P_t, which is univariate normal:

$$(3.8) \qquad (P_t|P_{it}{=}p_{it}) \sim N\,(\,(1{-}\theta)p_{it}{+}\theta\bar{P}_t,\ \theta\sigma^2\,)$$

where $\theta = \dfrac{\tau^2}{\sigma^2{+}\tau^2}$

Note that the mean of $(P_t|P_{it}{=}p_{it})$ is the expectation of P_t given $P_{it}{=}p_{it}$, denoted $E(P_t|P_{it}{=}p_{it})$, called a posterior mean for P_t, which is a constant. We can apply the formular for $E(P_t|P_{it}{=}p_{it})$ to a misperceived random variable P_{it} instead of a realization of $P_{it}{=}p_{it}$. The result is a random variable and it is called the regression curve of P_t on P_{it}, denoted $E(P_t|P_{it})$, which is normally distributed:

$$(3.9) \qquad E(P_t|P_{it}) \equiv [\,(1{-}\theta)P_{it}{+}\theta\bar{P}_t\,] \sim N\,(\,\bar{P}_t,\ (1{-}\theta)\sigma^2\,)$$

where $Var(E(P_t|P_{it})$ amounts to the explained sum of squares (ESS) of the regression P_t on P_{it}, $Cov^2(P_t,P_{it}) / Var(P_{it})$.

Note that the consideration of P_{it} as a misperceived random variable is based on the underlying assumption in Barro's model that participants in market i cannot distinguish immediately what fraction of the observed movements in P_{it} reflects a relative price shifts rather than an absolute shifts. Rewriting *(3.9)* gives:

$$(3.10) \qquad E(P_t|P_{it}) = P_{it} - \theta\ (P_{it} - \bar{P}_t) = P_{it} - \theta\ (z_{it} + \zeta_t)$$

where $\zeta_t = (P_t - \bar{P}_t) \sim N\ (0,\ \sigma^2)$.

The gap between two normal random variables P_{it} and $E[P_t|P_{it}]$ becomes the sum of two normal random variables, which is normally distributed:

$$(3.11) \qquad P_{it} - E(P_t|P_{it}) = \theta\ (z_{it} + \zeta_t) \sim N\ (0,\ \theta\tau^2)$$

where $P_{it} - E(P_t|P_{it}) = E(z_{it}|P_{it})$, and thus $Var(P_{it} - E(P_t|P_{it})) = Var(E(z_{it}|P_{it}))$, which amounts to the ESS of the regression of z_{it} on P_{it}, $Cov^2(z_{it},P_{it}) / Var(P_{it})$.

Then, the following variance decomposition can be explored by using *(3.5)*, *(3.9)* and *(3.11)*:

$$(3.12)\quad Var(P_{it}-E[P_t|P_{it}]) = \theta\tau^2$$
$$= \tau^2 - \sigma^2 + (1-\theta)\sigma^2$$
$$= Var(z_{it}) - Var(P_t) + Var(E[P_t|P_{it}])$$

Note that the variance decomposition in *(3.12)* still holds statistically after relaxing Lucas's assumption of independence between P_t and z_{it}.[1]

---

1 In cases where $\rho(P_t,z_{it})\neq 0$, *(3.12)* can be derived as

$$\tau^2\ \frac{(\tau+\rho\sigma)^2}{\sigma^2+\tau^2+2\rho\sigma\tau} = \tau^2 - \sigma^2 + \sigma^2\ \frac{(\sigma+\rho\tau)^2}{\sigma^2+\tau^2+2\rho\sigma\tau}$$

where $\rho = \rho(P_t,z_{it})$

Statistical Proof

Let X and Z be two independent normal random variables.

$$(1) \qquad X \sim N\left(\mu_x, \sigma_x^2 \right) \qquad\qquad Z \sim N\left(\mu_z, \sigma_z^2 \right)$$

The sum of two normal random variables $Y=X+Z$ is thus normal.

$$(2) \qquad Y \sim N\left(\mu_y, \sigma_y^2 \right)$$

where $\mu_y = \mu_x + \mu_z$, and $\sigma_y^2 = \sigma_x^2 + \sigma_z^2$

The joint distribution of X and Y is bivariate normal. Given $y=\mathrm{Y}$, a conditional distribution is induced on X, which is univariate normal.

$$(3) \qquad (X|\,Y=\mathrm{Y}) \sim N\left(\mu_x + \rho_{xy} \frac{\sigma_x}{\sigma_y} (\mathrm{Y}-\mu_y),\ (1-\rho_{xy}^2)\sigma_x^2 \right)$$

likewise, $(Z|\,Y=\mathrm{Y}) \sim N\left(\mu_z + \rho_{zy} \frac{\sigma_z}{\sigma_y} (\mathrm{Y}-\mu_y),\ (1-\rho_{zy}^2)\sigma_z^2 \right)$

where $\rho_{xy} = \frac{\sigma_{xy}}{\sigma_x \sigma_y} = \frac{\sigma_x^2}{\sigma_x \sigma_y} = \frac{\sigma_x}{\sigma_y}$, and $\rho_{zy} = \frac{\sigma_{zy}}{\sigma_z \sigma_y} = \frac{\sigma_z^2}{\sigma_z \sigma_y} = \frac{\sigma_z}{\sigma_y}$

Note that the mean of $(X|\,Y=\mathrm{Y})$ is the expectation of X given $Y=\mathrm{Y}$, denoted $E(X|\,Y=\mathrm{Y})$, which is a constant. We can apply the formular for $E(X|\,Y=\mathrm{Y})$ to a random variable Y instead of a realization of $y=\mathrm{Y}$. The result is a random variable, and it is called the regression curve of X on Y, denoted $E(X|Y)$, which is normally distributed.

$$(4) \qquad E(X|Y) \equiv [\ \mu_X + \rho_{Xy} \frac{\sigma_X}{\sigma_y} (Y-\mu_y)\ ] \sim N(\ \mu_X,\ \rho_{Xy}^2 \sigma_X^2\ )$$

likewise, $E(Z|Y) \equiv [\ \mu_Z + \rho_{Zy} \frac{\sigma_Z}{\sigma_y} (Y-\mu_y)\ ] \sim N(\ \mu_Z,\ \rho_{Zy}^2 \sigma_Z^2\ )$

[Proposition I] $\qquad Var(X|Y=y) = Var(X) - Var(E(X|Y))$

likewise, $\qquad Var(Z|Y=y) = Var(Z) - Var(E(Z|Y))$

Proof

from (3), $Var(X|Y=y) = (1-\rho_{Xy}^2)\sigma_X^2$, *which is homoskedastic*

$= E(Var(X|Y))$

$= Var(X) - Var(E(X|Y))$, *by theorem*

$= \sigma_X^2 - \rho_{Xy}^2\ \sigma_X^2$, *by (1) and (4)*

[Proposition II] $\qquad Var(X|Y=y) = Var(Z|Y=y)$

Proof

$$(1-\rho_{Xy}^2)\sigma_X^2 = (1- \frac{\sigma_X^2}{\sigma_y^2})\sigma_X^2 = \frac{\sigma_Z^2\ \sigma_X^2}{\sigma_X^2 + \sigma_Z^2} = (1- \frac{\sigma_Z^2}{\sigma_y^2})\sigma_Z^2 = (1-\rho_{Zy}^2)\sigma_Z^2$$

[Proposition III] $Y - E(X|Y) = E(Z|Y)$

Proof

$$Y - E(X|Y) = Y - [\ \mu_X + \rho_{XY} \frac{\sigma_X}{\sigma_y} (Y-\mu_y)\ ]$$
$$= \mu_y - \mu_X + (1- \rho_{XY} \frac{\sigma_X}{\sigma_y}) (Y-\mu_y)$$
$$= \mu_Z + \rho_{Zy} \frac{\sigma_Z}{\sigma_y} (Y-\mu_y)$$
$$= E(Z|Y)$$

where, $1- \rho_{Xy} \frac{\sigma_X}{\sigma_y} = 1- \rho^2_{Xy} = \rho^2_{Zy} = \rho_{Zy} \frac{\sigma_Z}{\sigma_y}$

By Proposition I and II:

(5) $Var(X) - Var(E(X|Y)) = Var(Z) - Var(E(Z|Y))$

By Proposition III:

(6) $Var(Y-E(X|Y)) = Var(Z) - Var(X) + Var(E(X|Y))$

QED

3.2 Alternative to Barro's Variance Decomposition

Barro (1976) extends Lucas's model by developing the variance decomposition. It is assumed that participants in market *i*, possessing the differential information structure, cannot tell what fraction of the observed movement in P_{it} reflects a relative price shift rather than an absolute shift.

The discussion of distributions of prices both across markets and over time is focused on the problem of predicting the future price in a (randomly-selected) market *j*, based on information currently possessed by participants in market *i*. That is, the gap between P_{jt+1} and $E[P_{t+1}|I_{it}]$, where it is assumed that $EP_{jt+1} = EP_{t+1}$ for all j, is broken down into three independent components:

$$(3.13) \quad P_{jt+1} - E[P_{t+1}|I_{it}] \equiv [P_{jt+1} - P_{t+1}] + [P_{t+1} - E[P_{t+1}|I_t]] + [E[P_{t+1}|I_t] - E[P_{t+1}|I_{it}]]$$

where I_t denotes full current information, whereas I_{it} denotes the information possessed at time *t* by participants in market *i*. The first component refers to the distribution of relative prices at a point in time, the second refers to the future price net of the price that is predictable based on full current information, and the third refers to the distribution of relative information in terms of its implications for EP_{t+1}.

The three components in *(3.13)* are assumed to be independently, normally distributed with zero mean, so that the variances of each component fully specifies its distribution. The full variance of P_{jt+1} about $E[P_{t+1}|I_{it}]$ is therefore the sum of the three component variances:

$$
\begin{aligned}
(3.14)\qquad V &\equiv E(P_{jt+1}-E[P_{t+1}|I_{it}])^2|I_{it} \\
&= E(P_{jt+1}-P_{t+1})^2|I_{it} + E(P_{t+1}-E[P_{t+1}|I_t])^2|I_{it} \\
&\quad + E(E[P_{t+1}|I_t]-E[P_{t+1}|I_{it}])^2|I_{it} \\
&\equiv \tau_1^2 + \sigma^2 + \tau_2^2
\end{aligned}
$$

where V amounts to the variance of future prices about their currently predictable values, and τ_1^2 amounts to the variance of relative prices, and σ^2 amounts to the variance of the future absolute price level, and τ_2^2 amounts to the variance of relative information.

We claim that Barro's independence assumption may not hold within the context of Lucas's model. The third component $E[P_{t+1}|I_t] - E[P_{t+1}|I_{it}]$ is, in Lucas's context, nothing but the difference between prior and posterior mean for the general price at time $t+1$:

$$
\begin{aligned}
(3.15)\qquad E(P_{t+1}|I_t) - E(P_{t+1}|I_{it}) &= \bar{P}_{t+1} - [(1-\theta)P_{it+1}+\bar{P}_{t+1}] \\
&= (\theta-1)(P_{it+1}-\bar{P}_{t+1}) \\
&= (\theta-1)(z_{it+1}+\zeta_{t+1})
\end{aligned}
$$

where $z_{it+1} = (P_{it+1} - P_{t+1}) \sim N(\emptyset, \tau^2)$

$\zeta_{t+1} = (P_{t+1} - \bar{P}_{t+1}) \sim N(\emptyset, \sigma^2)$

If P_{it} (sum of two independent normal random variables) is independent of P_t (a component of the sum), the posterior mean of P_t turns out to be equal to the prior mean, that is, $E[P_t | I_{it}] = \bar{P}_t$. Eventually, Lucas's supply function for market i becomes invariant, that is, $y_{it} = \gamma(P_{it} - \bar{P}_t)$. There is no shift (noise) term.

Substituting *(3.15)* into *(3.13)* yields:

$$(3.16) \quad P_{jt+1} - E[P_{t+1} | I_{it}] \equiv z_{jt+1} + \zeta_{t+1} + (\theta - 1)(z_{it+1} + \zeta_{t+1})$$

Then, the full variance in *(3.14)* can be derived using *(3.16)*:

$$
\begin{aligned}
(3.17) \qquad V &\equiv E(P_{jt+1} - E[P_{t+1} | I_{it}])^2 | I_{it} \\
&= E[\ z_{jt+1} + \zeta_{t+1} + (\theta-1)(z_{it+1} + \zeta_{t+1})\ ]^2 | I_{it} \\
&= \tau^2 + \sigma^2 + (\theta-1)^2(\tau^2 + \sigma^2) + 2(\theta-1)\tau^2 + 2(\theta-1)\sigma^2 \\
&= \tau^2 + [\ \sigma^2 + 2(\theta-1)(\tau^2 + \sigma^2)\ ] + (\theta-1)^2(\tau^2 + \sigma^2) \\
&= \tau^2 - \sigma^2 + (\theta-1)^2(\tau^2 + \sigma^2) \\
&= \tau^2 - \sigma^2 + (1-\theta)\sigma^2 \\
&= Var(z_{it}) - Var(P_t) + Var(E[P_t | P_{it}])
\end{aligned}
$$

where $Var(E[P_t | P_{it}])$ amounts to what Barro calls the variance of relative information, $\tau_2^2 \equiv E\{E[P_{t+1}|I_t]-E[P_{t+1}|I_{it}]\}^2|I_{it}$. Besides, $Var(z_{it})$ and $Var(P_t)$, respectively, are equivalent to τ_1^2 and σ^2 in Barro's variance decomposition.

It turns out that Barro's variance decomposition may be misleading within the context of Lucas's model, rather a correct variance decomposition in his terms is:

$$V = \tau_1^2 - \sigma^2 + \tau_2^2 \tag{3.18}$$

In Barro's model, the variances of each component are expressed in terms of the parameters of the exogeneous variables, for example, the monetary shock, and then simply summed to V:

$$\begin{aligned} \tau_1^2 &= (\Theta_1+\Theta_2)^2\,\sigma_\varepsilon^2 \\ \sigma^2 &= (\Theta_1+\Theta_2)^2\,\sigma_A^2 \\ \tau_2^2 &= (\Theta_1/\,\beta)\,\sigma_\varepsilon^2 \end{aligned} \tag{3.19}$$

where $\Theta_1 = \dfrac{\sigma_A^2}{\beta\,(\sigma_A^2+\sigma_\varepsilon^2)}$, $\quad \Theta_2 = \dfrac{\sigma_\varepsilon^2}{\alpha\,(\sigma_A^2+\sigma_\varepsilon^2)}$

Substituting *(3.19)* into a correct variance decomposition in *(3.18)* gives:

$$V = (\Theta_1+\Theta_2)^2\,(\sigma_\varepsilon^2 - \sigma_A^2) + (\Theta_1/\,\beta)\,\sigma_\varepsilon^2 \tag{3.20}$$

It can be shown by straightforward differentiation that V is "no more necessarily" [contrary to "unambiguously" in Barro (1976, p.14-15)] increasing in σ_{ε}^2 than σ_A^2. That is to say, as the variance of monetary growth rate (which is one component of the variance of aggregate excess demand, σ_A^2) increases, neither the predictability of future prices (as measured inversely by V) nor thereby the responsiveness of output to a given monetary disturbances (as measured by minimizing the variance of output) does necessarily reduce.

3.3 Implication of the Variance Decomposition

A simple transposition of the variance decomposition in *(3.12)* gives:

(3.21)

$$Var(P_t) - Var(E[P_t|P_{it}]) = Var(z_{it}) - Var(P_{it} - E[P_t|P_{it}])$$

$$\equiv \quad Var(P_t) - Var(E[P_t|P_{it}]) = Var(z_{it}) - Var(E[z_{it}|P_{it}])$$

$$\equiv \quad Var(P_t) - \frac{Cov^2(P_t, P_{it})}{Var(P_{it})} = Var(z_{it}) - \frac{Cov^2(z_{it}, P_{it})}{Var(P_{it})}$$

$$\equiv \quad Var(P_t)\ [1 - \rho^2(P_t, P_{it})] = Var(z_{it})\ [1 - \rho^2(z_{it}, P_{it})]$$

$$\equiv \quad Var(P_t|P_{it} = p_{it}) = Var(z_{it}|P_{it} = p_{it})$$

$$Var(P_t|P_{it} = p_{it}) = Var(z_{it}|P_{it} = p_{it})$$

It turns out that a posterior variance for P_t is identical with a posterior variance for z_{it}. In the sense that a distribution that is a posterior distribution in relation to some past sample can be regarded as a prior distribution when viewed in relation to a future sample, it can be inferred that variance *over time* is a priori identical with variance *across markets.*

Specifically, $Cov^2(P_t, P_{it}) / Var(P_{it})$ in *(3.21)* amounts to the ESS in the linear regression of P_t on P_{it}. In that sense, $Var(P_t)$ represents the total sum of squares. Then a posterior variance for P_t, $Var(P_t|P_{it} = p_{it})$, turns out to be the residual sum of squares (RSS) of the regression curve at given point $P_{it}=p_{it}$. Similarly, the right side of equality in *(3.21)* can be analogously interpreted in the linear regression of z_{it} on P_{it}. Hence, it can be inferred that the RSS of linear projection *over time* is a priori identical with the RSS of linear projection *across markets*.

This inferrence of the a priori identity implies that two concepts of variance, variance *over time* and variance *across markets*, are complementary, not dichotomous, in the efficient operation of the system of an economy. Then, this complementary relationship supports the idea that volatility is, in operation, accompanied by variability, and further that both variances, in alternation, become each the source of the other.

In that sense, inflation, recognized as an outcome of economic processes, should be analyzed in order to view volatility upon variability. Quoting historian's viewpoint, history should be analyzed in order to view diachronic stream upon synchronic structure.

It is worth noting that the a priori identity between variance *over time* and variance *across markets* coincides with the concept of risk in financial theory that ex ante volatility *over time*, which proxies for a measure of risk, is symmetric to ex post covariance *across stocks*.

Back to the Lucas's supply function for market *i* in *(3.3)*:

$$(3.22) \qquad \begin{aligned} y_{it} &= \gamma\ (P_{it} - E[P_t | I_{it}]) \\ &= \gamma\ (P_{it} - E[P_t | P_{it} = p_{it}]) \\ &= \gamma\ \theta\ (p_{it} - \bar{P}_t) \end{aligned}$$

where $\theta = \frac{\tau^2}{\sigma^2 + \tau^2}$, and p_{it} is a realization of P_{it}.

If P_{it} is considered as a misperceived random variable, the supply function for market *i* becomes:

$$(3.23) \qquad \begin{aligned} y_{it} &= \gamma\ (P_{it} - E[P_t | P_{it}]) \\ &= \gamma\ \theta\ (P_{it} - \bar{P}_t) \end{aligned}$$

Then, the variance of output for market *i* is:

$$(3.24) \qquad \begin{aligned} Var(y_{it}) &= \gamma^2\ Var\ (P_{it} - E[P_t | P_{it}]) \\ &= \gamma^2\ \theta^2\ Var\ (P_{it} - \bar{P}_t) \\ &= \gamma^2 \left\{ \frac{\tau^2}{\sigma^2 + \tau^2} \right\}^2 (\tau^2 + \sigma^2) \\ &= \gamma^2\ \frac{\tau^4}{\sigma^2 + \tau^2} \end{aligned}$$

On the other hand, the variance of aggregate output using the aggregate supply function in *(3.4)* is:

$$(3.25) \qquad Var\ (y_t) = \gamma^2\ \theta^2\ Var\ (P_t - \bar{P}_t)$$

$$= \gamma^2 \left\{ \frac{\tau^2}{\sigma^2+\tau^2} \right\}^2 \sigma^2$$

It can be shown by straightforward differentiation that the variances of both output for market i and aggregate output are unambiguously increasing in τ^2.

What is striking is that, given τ^2, $Var(y_{it})$ is unambiguously decreasing in σ^2, yet $Var(y_t)$ is ambiguous:

$$\frac{\partial\ Var(y_t)}{\partial\ \sigma^2} = \frac{(\tau^2-\sigma^2)\ \tau^4}{\{\tau^2+\sigma^2\}^3} \tag{3.26}$$

If $\tau^2 < \sigma^2$, that is, in cases where τ^2 is relatively small, so that individual price changes are virtually certain to reflect general price changes (the supply curve is nearly vertical), then the variance of aggregate output is decreasing in σ^2. It is implied that the steeper the supply curve, the lower the variance of output, which conforms to Hall's argument in his comment to Fischer (1981) that "Phillips curves in individual markets are curves, not lines. A steeper Phillips curve means a market is working better. With higher average inflation, the typical market is at a steeper point on its Phillips curve and so is functioning more efficiently. Inflation is good, not bad, because it helps achieve desirable shifts in relative prices."

If $\tau^2 > \sigma^2$, that is, at the other extreme when σ^2 is relatively small, so that general prices are stable (the slope of the supply curve approaches the limiting value of

γ), then the variance of aggregate output is increasing in σ^2. However, the variance of output for market i is still decreasing in σ^2.

In that sense, with higher general inflation (in the seventies in the United States), increases in volatility of general inflation reflect in both an economy and typical market working better.

On the other hand, with lower general inflation (in the eighties in the United States), increases in volatility of general inflation reflect in an economy functioning inefficiently, yet typical market functioning efficiently.

3.4 Model Specification

An economy is assumed to be composed of many separate industries, indexed by *i*, each of which is characterized by a specific response not only to the micro supply shocks, but also to the macro demand shocks.

It is supposed that variance across markets (τ^2) is a manifestation of the efficient operation of an economy in response to the micro supply shocks, which move output and inflation in the opposite direction, while variance over time (σ^2) is a manifestation of the efficient operation of an economy in response to the macro demand shocks, which result in the positive output-inflation tradeoffs. This supposition is supported by the implication in *(3.24)* that the variance of output is increasing in τ^2 (implying that typical market is functioning inefficiently) and decreasing in σ^2 (implying that typical market is functioning efficiently).

Notice that the supply shock effects of a decreased supply of food and energy in 1970's, which would result in an unanticipated upward movement in inflation coupled with an output decline, has been widely documented, for example, by Fischer (1981). Recently, Kaul and Seyhun (1990) argue that "relative price variability in post-war U.S. may be a reflection of real supply shocks (in particular, the oil shocks witnessed in the seventies and eighties), rather than monetary shocks."

It is supposed, in particular, that industry inflation π_{it} reveals a specific conditional variance conditioned on the local supply shocks (which is reflected in within-industry relative price variability τ_i^2) as well as the global supply shocks (which is reflected in economy-wide relative price variability τ^2). The implicit difference between τ_i^2 and τ^2 seems best viewed as reflecting substantial difference in the vulnerability to the shocks across industries, rather than implying possible difference in the persistence of volatility over time.

As a statistical rationale for this supposition, the theorem of sum of squares (SOS) decomposition is considered: [see J.Johnson, *ECONOMETRIC METHODS*, 3rd Edition, p.522-24]

$$(3.27) \qquad \sum_i^k \sum_j^{n_i} \left[\pi_{ij} - \pi\right]^2 = \sum_i^k \sum_j^{n_i} \left[\pi_{ij} - \pi_i\right]^2 + \sum_i^k n_i \left[\pi_i - \pi\right]^2$$

where $i = 1,2,\dots,k;\ j = 1,2,\dots,n_i$, *and* $n = \sum_i n_i$

$$\pi_i = \frac{1}{n} \sum_{ij} \pi_{ij}, \text{ and } \pi = \frac{1}{n} \sum_i \sum_j \pi_{ij} \left[= \frac{1}{n} \sum_i n_i \pi_i \right]$$

This decomposition often written as:

Total SOS = within-group SOS + between-group SOS

Define economy-wide and within-industry relative price variabilities:

$$(3.28) \qquad \tau^2 = \frac{1}{n} \sum_i \sum_j \left[\pi_{ij} - \pi\right]^2$$

$$(3.29) \qquad \tau_i^2 = \frac{1}{n_i} \sum_j \left[\pi_{ij} - \pi_i\right]^2$$

Substitution of *(3.28)* and *(3.29)* into *(3.27)* yields:

$$(3.30) \qquad n\,\tau^2 = \sum_i n_i\,\tau_i^2 + \sum_i n_i \left[\pi_i - \pi\right]^2$$
$$= \sum_i n_i\,\tau_i^2 + \sum_i n_i\,\pi_i^2 - 2\,\pi \sum_i n_i\,\pi_i + n\,\pi^2$$
$$= \sum_i n_i\,\tau_i^2 + \sum_i n_i\,\pi_i^2 - n\,\pi^2$$

Under the condition that n_i is same for all i,

$$(3.31) \qquad \pi_i^2 = \tau^2 - \tau_i^2 + \pi^2$$

It turns out that the square of industry-average rate of inflation is a linear combination of the square of general inflation and both economy-wide and within-industry variabilities. This functional relationship supports the supposition that industry inflation reveals a specific conditional variance conditioned on both local and global supply shocks.

However, the previous empirical variance approaches for the analysis of the behavior of inflation are likely to be bifurcated exclusively into variability and volatility, in the sense that two concepts of variance, variance *across markets* and variance *over time*, are considered as dichotomous, not complementary. On the one branch, the positive correlation between relative price variability and the rate of (unexpected) inflation has been widely documented by, for example, Vining and Elwertowski (1976), Parks (1978), Blejer and Leiderman (1980), Hercowitz (1981), Fischer (1981), Domberger (1987), Van Hoomissen (1988), and Kaul and Seyhun (1990).

Vining and Elwertowski (1976) first attempted to justify Lucas's innovation: the two forms of variation, one of the general price level over time (σ^2) and the other of individual prices relative to each other at a particular time (τ^2). They provide strong statistical evidence that the two parameters σ^2 and τ^2 move together.

Parks (1978) claims that Vining and Elwertowski "fail to provide a precise definition of their notion of general price change instability (σ^2) or to provide a microeconomic link to explain the transmission of σ^2 into the relative price variance (τ^2)" [p.80]. He instead interprets σ^2 as the notion of variance in the price level around its anticipated level. He argues that the amount of unanticipated inflation is a more important determinant of relative price variability than the rate of inflation.

On the other branch, Engel (1983) who points out the variance measures in Lucas as an unconditional variance, constant over time, instead estimates a conditional variance of inflation using the autoregressive conditional heteroscedasticity (ARCH) model which embodies the idea that "assuming that inflation is a random variable, it has a nonstochastic mean and variance at each point in time. Of more relevance to economic agents planning their behavior are the conditional densities of inflation given all past information. From these densities, conditional moments can be defined that in general will depend upon the conditioning information set" (p.287). He argues that a high rate of inflation, if predictable, does not necessarily imply a high variance of inflation.

Recently, volatility approach has prevailed especially in the field of financial economics, where ex ante volatility over time, as a measure of risk, proxies for covariance between its return and the return on a market portfolio, where volaility is estimated as of, for example, the 12-month moving average [Pindyck (1984)], the generalized 12-month rolling standard deviation [Schwert (1989)], the sum of the squared daily returns [Poterba and Summers (1986), French, Schwert, and Stambaugh (1987)].

This paper proposes, as a *combined* measure, an industry-specific conditional variance of inflation, which is estimated by autoregressing on both economy-wide and within-industry variabilities with the absolute residuals from a preliminary fit (of the industry-average rate of inflation regressed on general inflation as well as both economy-wide and within-indusry variabilities).

The term *combined*, in the sense that variance of inflation is induced on *over time* as well as *across markets*, embodies the idea that inflation should be analyzed in order to view volatility upon variability.

Specifically, the industry-specific conditional mean and variance of π_{it} are defined as:

$$(3.32) \qquad \pi_{it} = f\ (\ \tau_t,\ \tau_{it},\ \pi_t)$$

$$(3.33) \qquad |\hat{\varepsilon}_{it}| = g\ (\ \tau_t,\ \tau_{it},\ |\hat{\varepsilon}_{it-1}|\ )$$

where $\hat{\varepsilon}_{it}$ $(= \pi_{it}-\hat{\pi}_{it})$ are the estimate of residuals from regression in *(3.32)*, and τ_t and τ_{it} amount to the economy-wide and within-industry relative price variability. The fitted values from *(3.33)* $\tilde{\varepsilon}_{it}$ account for the industry-specific conditional standard deviation of π_{it}.

The industry-specific conditional mean equation in *(3.32)* is specified following the functional relationship inferred from a linear combination in *(3.31)* drived from the SOS decomposition, where the explanatory variables do not include, contrary to the earlier literature, the exogeneous variables, like money supply or wages.

While, the industry-specific conditional variance equation in *(3.33)* is specified following the complementary relationship between volatility and variability inferred from the a priori indentity in *(3.21)* derived from the variance decomposition.

This specification also follows the Davidian and Carroll (1987)'s argument that "most variance function estimation procedures can be looked upon as regressions with responses being transformations of absolute residuals from a preliminary fit or sample standard deviations from replicates at a design point." Following their argument, Schwert (1989) applies to the generalized 12-month rolling standard deviation estimator, which is similar to the ARCH model of Engle (1983).

We also estimate the industry-specific conditional variance of stock returns using the same procedures as in *(3.32)* and *(3.33)*, because the a priori identity between variance *over time* and variance *across markets* coincides with the concept of risk in financial theory that ex ante volatility *over time*, which proxies for a measure of risk, is symmetric to ex post covariance *across stocks*.

IV. VARIANCE MEASURES

4.1 Measure of Variability

An economy as a whole is divided arbitrarily, but based on two digit Standard Industrial Classification (SIC), into 19 broad industry categories such as mining, food, machinery, transportation, wholesale, finance, and the like. [refer to TABLE 1]

A common measure of the relative price variability is given by the unweighted sum of squared deviations of the individual market inflation rate π_{ijt} around the average. The economy-wide and within-industry variabilities of inflation are defined as:

$$(4.1) \qquad \tau_t^2 = \frac{1}{n_t} \sum_i \sum_j \left[\pi_{ijt} - \pi_t\right]^2$$

$$(4.2) \qquad \tau_{it}^2 = \frac{1}{n_{it}} \sum_j \left[\pi_{ijt} - \pi_{it}\right]^2$$

where $i=1,2,\ldots,k;\quad j=1,2,\ldots,n_{it}$

$$\pi_{ijt} = \log\,(PPI_{ijt}/\,PPI_{ijt-12})$$

$$\pi_{it} = \frac{1}{n_{it}} \sum_j \pi_{ijt}$$

$$\pi_t = \frac{1}{n_t} \sum_i \sum_j \pi_{ijt}$$

$$n_t = \sum_i n_{it}$$

where PPI_{ijt}, the Producer Price Index (PPI) of market j in industry i at time t, accounts for the monthly PPI of four-digit SIC categories available under PPI Revision File covering a period of 20 years from 1969 to 1988. An economy as a whole in PPI File belonging to SIC 1000-1499 and 2000-3999 consists of between 77 to 478 four-digit SIC categories, with smaller sample size at the beginning of the period of study and the larger at the end.

The economy-wide and within-industry variabilities of stock returns, τ_t^{2R} and τ_{it}^{2R}, are also measured as in *(4.1)* and *(4.2)*, where $i=1,2,..,k;$ $j=1,2,..,m_i;$ $R_{it}=\frac{1}{m_i}\sum_j R_{ijt};$ $R_t=\frac{1}{m}\sum_i \sum_j R_{ijt};$ $m=\sum_i m_i$ and where R_{ijt}, the rate of stock return of firm j in industry i at t, accounts for the monthly stock returns of individual firms available under the Center for Research in Security Price (CRSP) Stock Returns File. Among about 3500 firms in CRSP File, 584 firms selected for this study all have the first entry on the NYSE before January, 1969 and keep on trading their securities until December, 1988.

The measures of within-industry variability of inflation are illustrated in FIGURE I.1 to I.12 by the dotted line labelled VINF1 to VINF12. Also, those of stock returns are illustrated in FIGURE II.1 to II.19 by the dotted line labelled VRET1 to VRET19.

4.2 Estimation of Industry-Specific Conditional Variance

The industry-specific conditional mean and variance of inflation are estimated as defined in *(3.32)* and *(3.33)*:

$$(4.3) \qquad \pi_{it} = \alpha_{\emptyset} + \alpha_{1}\,\tau_{t} + \alpha_{2}\,\tau_{it} + \alpha_{3}\,\pi_{t} + \varepsilon_{it}$$

$$(4.4) \qquad |\hat{\varepsilon}_{it}| = \beta_{\emptyset} + \beta_{1}\,\tau_{t} + \beta_{2}\,\tau_{it} + \beta_{3}\,|\hat{\varepsilon}_{it-1}| + \upsilon_{it}$$

where $\hat{\varepsilon}_{it}$ $(= \pi_{it} - \hat{\pi}_{it})$ are the estimate of residuals from regression in *(4.3)*, and τ_{t} and τ_{it} amount to the economy-wide and within-industry variabilities of inflation. The fitted values from *(4.4)* $\tilde{\varepsilon}_{it}$ account for the industry-specific conditional standard deviations of π_{it}.

Because of the serial correlation, π_{it-1} proxies for π_{t} in the estimation of industry-specific conditional mean in *(4.3)*. Ordinary Least Squares (OLS) estimation results, given in TABLE 2 and 3, are shown to be mostly significant in both economy-wide (τ_{t}) and within-industry (τ_{it}) relative price variabilities. The estimated measures of industry-specific conditional variance of inflation $\tilde{\varepsilon}_{it}$ are illustrated in FIGURE I.1 to I.12 by the solid line labelled CVINF1 to CVINF12.

The industry-specific conditional variances of stock returns $\tilde{\varepsilon}^{R}_{it}$ are also estimated using the same procedures. The estimation results, given in TABLE 4 and 5, are shown to be rather more significant in both economy-wide (τ_t^R) and within-industry (τ_{it}^R) relative return variabilities. Strikingly, the estimations of industry-specific conditional mean of stock returns show mostly greater than *0.800* of R^2, which is the best fitting compared to the earlier literature.

Of special interest is that industry stock returns are related adversely to τ_t^R and positively to τ_{it}^R, which is opposite in sign of the linear combination in *(3.31)*, which leaves a puzzle. The beta coefficients of market returns reveal mostly near to unity, but that of Electric and Gas (utilities) is much less than unity (*.604*), which coincides with the earlier literaure.

The estimated measures of industry-specific conditional variance of stock returns are illustrated in FIGURE II.1 to II.19 by the solid line labelled CVRET1 to CVRET19.

V. HYPOTHESES

5.1 Is Really the Association between Inflation and Relative Price Variability Dominated by Food and Oil Supply Shocks?

The generally agreed argument in the earlier literature that the association between relative price variability and inflation in the post-war period in the U.S. is dominated by food and energy shocks is tested:

$$\tau_{it} = a_{\emptyset} + a_{1}\,\pi_{it} + u_{it} \tag{5.1}$$

OLS estimation results, given in TABLE 6, provide the striking evidence contrary to the earlier literature. Besides Food and Petroleum-related industries, the other industries, especially Electronic, reveal even more strong positive association between the within-industry relative price variability and the industry-average rate of inflation.

Also, the positive relationship between industry inflation and its industry-specific conditional variance, also given in TABLE 6, is shown to be rather more significant.

The strong relationship between expected stock returns and volatility has been often documented in the finance literature. For example, Pindyck (1984) attributes much of the decline in share values to increases in risk premiums induced by increases in stock return volatility. Poterba and Summers (1986), on the other hand, cast serious doubt on the view that changes in volatility, through their influence on investor's risk premia, have a substantial effect on stock market values. French, Schwert, and Stambaugh (1987) argue that the expected market risk premium (the expected return on a stock market portfolio minus the risk-free interest rate) is positively related to risk (the volatility of stock returns).

OLS estimation results, given in TABLE 7, provide the strong evidence that the industry-average rate of stock returns is positively related to the industry-specific conditional variance of stock returns as well as the within-industry relative return variability, supporting the earlier literature.

5.2 Does Volaility Accompany Variability?

To gauge the extent of symmetry between volatility and variability, the elasticity of the industry-specific conditional variance with respect to the within-industry variability is estimated:

$$(5.2) \qquad \log \tilde{\varepsilon}_{it} = b_{\emptyset} + b_1 \log \tau_{it} + v_{it}$$

OLS estimation results, given in TABLE 8, show the different degrees of elasticity across industries ranging from *.314* (Mining) to *1.394* (Machinery).

In the sense that unit elasticity indicates the perfect symmetry between the industry-specific conditional variance and the within-industry variability, and that the conditional variance is induced on "over time" as well as both economy-wide and within-industry variability, it can be interpreted that the industry inflation which has greater than unit elasticity is likely to be either more volatile compared to general inflation or less variable compared to an economy as a whole.

In particular, Food, Metal, Machinery, and Electronic which have more than unit elasticity (ranging from *1.061* to *1.394*) reveal high coefficients of determination R^2 (ranging from *.363* to *.490*) in the estimation of industry-specific conditional variance of inflation, shown in TABLE 3. On the other hand, the other industries which have much less than unit elasticity (ranging from *.314* to *.653*) reveal the worst fitting R^2 (ranging from *.117* to *.304*).

The illustrations in FIGURE I.1 to I.12 reveal a likely symmetric trends between the industry-specific conditional variances of inflation labelled CVINF1 to CVINF12 and the within-industry relative price variabilities labelled VINF1 to VINF12.

The elasticity of industry-specific conditional variance of stock returns with respect to the within-industry relative return variability is also examined. The estimation results, given in TABLE 9, show that those are mostly less than unit (ranging from *.257* to *.769*) in 16 out of 19 industries, implying that the industry-average rates of stock returns are likely to be either less volatile compared to market returns or more variable compared to a stock market as a whole.

On the one extreme, Construction which has the least elasic (*.257*) symmetry reveals the worst fitting R^2 (*.058*) in the estimation of industry-specific conditional variance of stock returns, shown in TABLE 5. On the other extreme, Chemicals reveals the most elastic (*1.709*) with the best fitting R^2 (*.228*).

Of special interest is that Electric and Gas which has the lowest beta coefficient (*.604*) of market returns as well as the worst fitting R^2 (*.571*) in the estimation of industry-specific conditional mean of stock returns, shown in TABLE 4, reveals the perfect symmetry (unit elasticity *1.009*).

The illustrations in FIGURE II.1 to II.19 reveal a likely symmetric trends between the industry-specific conditional variances of stock returns labelled CVRET1 to CVRET19 and the within-industry relative return variabilities labelled VRET1 to VRET19.

5.3 Relation between Inflation and Stock Returns in Terms of Variance

In the field of financial economics, there have been many attempts to relate the aggregate stock market volatility to the volatility of macroeconomic variables. Pindyck (1984) documents that the volatility of inflation causes volatility of firm's gross marginal return on capital. Schwert (1989), however, provides little evidence that inflation volatility helps to predict future stock return volatility, and vice versa.

The relationship between inflation and stock returns is examined in terms of variances:

$$\tilde{\varepsilon}^{R}_{it} = c_{0} + c_{1}\,\tilde{\varepsilon}_{it} + w_{it} \qquad (5.3)$$

OLS estimation results, given in TABLE 10, provide evidence that the industry-specific conditional variance of stock returns is positively related to a large extent to those of inflation. The illustations in FIGURE III.1 to III.12 track a likely correlation.

However, the relationship between the within-industry variability of stock returns and those of inflation, also given in TABLE 10, is shown to be far less significant in some industries.

VI. CONCLUSION

To verify the complementary relation between variance over time and variance across markets, proposed by exploring, as a statistical rationale, an a priori identity of the variance decomposition, this thesis estimates the industry-specific conditional variances of inflation and stock returns, which are induced not only on over time but also on across markets.

To gauge the extent of symmetry between volatility and variability, the elasticities of the industry-specific conditional variance of inflation with respect to the within-industry relative variability are estimated, which are shown to vary across industries. Yet, those of stock returns are mostly less than unit, implying that the industry-average rates of stock returns are likely to be either less volatile compared to market returns or more variable compared to a stock market as a whole.

Also, this thesis presents the evidence that the industry-specific conditional variance of stock returns is positively related to a large extent to that of inflation. Yet, the relationship between the within-industry variability of stock returns and that of inflation is shown to be rather less significant in some industries.

On the other hand, there is the striking evidence, contrary to the earlier literature, that the association between the within-industry relative price variability and the rate of industry-average rate of inflation in the seventies in the United States is *not* dominated by Food and Petroleum-related industries.

Yet, there is the strong evidence, supporting the earlier literature, that the industry-average rate of stock returns is positively related to the industry-specific conditional variance of stock returns as well as the within-industry relative return variability.

TABLE 1

Industry Specification

i	*SIC*	*Specification*	n_{it}^{*}	m_i^{**}
1	10–14	Mining	3 – 35	32
2	20	Food	15 – 46	28
3	22	Textile	3 – 30	7
4	23	Apparel	5 – 33	8
5	24–25	Lumber, Paper	3 – 30	5
6	28	Chemicals	5 – 28	51
7	32	Stone, Glass	9 – 26	12
8	33	Primary Metal	6 – 24	26
9	34	Fabricated Metal	6 – 36	17
10	35	Machinery	8 – 44	36
11	36	Electronic	8 – 37	31
12	others***	Manufacturing	6 –109	99
13	15–17	Construction		4
14	40–48	Transportation		24
15	49	Electric, Gas		104
16	50–51	Wholesale		15
17	52–59	Retail		24
18	60–69	Finance		44
19	70–89	Services		17

** An economy as a whole in PPI Revision File belonging to SIC 1000–1499 and 2000–3999 consists of between 77 to 478 four-digit SIC categories, with the smaller sample size at the beginning of the period of study and the larger at the end (1969–88).*

*** Among about 3500 firms in CRSP File, 584 firms selected for this study all have the first entry on the NYSE before January, 1969 and keep on trading their securities until December, 1988.*

**** Others in Manufacturing consists of SIC 21, 26, 27, 29–31, 37–39, which individually does not include enough number of components especially at the beginning of the period of study.*

TABLE 2

Estimation of Industry-Specific Conditional Mean of Inflation; *1969:12–1988:12*

π_{it}	const.	τ_t	τ_{it}	π_{it-1}	R^2	SEE	D.W.
1	−.330 (-1.33)	.003 (.10)	.088 (3.65)	.956 (54.69)	.970	1.494	1.372
2	.599 (1.47)	−.253 (-1.47)	.119 (1.48)	.961 (40.16)	.906	2.475	2.235
3	.121 (.88)	.002 (.09)	−.011 (-.37)	.981 (59.17)	.960	.936	.987
4	−.236 (-1.73)	.001 (.09)	.145 (3.34)	.943 (45.31)	.950	.775	1.498
5	−.029 (-.22)	.021 (1.43)	.007 (.33)	.961 (48.37)	.956	.725	1.505
6	−.009 (-.04)	.031 (.92)	−.008 (-.23)	.974 (56.77)	.969	1.453	1.262
7	−.137 (-.91)	.047 (3.60)	.015 (.38)	.947 (57.18)	.970	.615	1.587
8	.161 (.61)	−.006 (-.22)	.000 (.00)	.983 (56.85)	.962	1.467	.918
9	−.133 (-.98)	.066 (3.56)	−.049 (-.84)	.954 (50.96)	.973	.798	.766
10	−.087 (-.90)	.080 (6.64)	−.171 (-2.52)	.966 (77.85)	.988	.502	.590
11	−.556 (-4.67)	.026 (1.96)	.211 (5.04)	.878 (43.14)	.977	.631	.680
12	−.227 (-1.90)	.045 (3.16)	.038 (1.69)	.938 (48.70)	.972	.727	1.045

Note: t-statistics given in parentheses.

TABLE 3

Estimation of Industry-Specific Conditional Variance of Inflation; *1970:1-1988:12*

$\lvert\hat{\varepsilon}_{it}\rvert$	*const.*	τ_t	τ_{it}	$\lvert\hat{\varepsilon}_{it-1}\rvert$	R^2	*SEE*	*D.W.*
1	.060	.085	.027	.050	.174	.999	2.010
	(.39)	(4.61)	(1.85)	(.74)			
2	-.289	.031	.092	.193	.391	1.479	1.976
	(-1.21)	(.32)	(1.94)	(3.00)			
3	-.114	.062	.022	.170	.304	.600	2.007
	(-1.30)	(4.59)	(1.14)	(2.48)			
4	-.079	.058	-.001	.200	.286	.504	2.065
	(-.90)	(5.71)	(-.04)	(3.11)			
5	.076	.023	.061	.060	.160	.449	1.955
	(.95)	(3.22)	(4.97)	(.91)			
6	-.295	.061	.093	.181	.381	.903	2.022
	(-2.17)	(3.01)	(4.34)	(2.72)			
7	.006	.033	.045	-.051	.117	.416	2.010
	(.06)	(4.81)	(1.82)	(-.77)			
8	-.359	.046	.114	.184	.363	.860	1.928
	(-2.42)	(2.88)	(5.19)	(2.77)			
9	-.152	.016	.113	.431	.443	.471	2.104
	(-2.00)	(1.74)	(3.59)	(7.20)			
10	-.104	.020	.049	.471	.490	.277	2.152
	(-2.06)	(3.02)	(1.56)	(7.98)			
11	-.074	.021	.035	.409	.414	.356	2.130
	(-1.29)	(2.73)	(2.26)	(6.73)			
12	-.097	.036	.044	.100	.250	.477	1.937
	(-1.28)	(4.29)	(3.91)	(1.49)			

Note: t-statistics given in parentheses.

TABLE 4

Estimation of Industry-Specific Conditional
Mean of Stock Returns; *1969:12–1988:12*

R_{it}	*const.*	τ_t^R	τ_{it}^R	R_t	R^2	*SEE*	*D.W.*
1	−2.887	−.537	.778	.934	.671	4.009	1.665
	(-1.99)	(-2.51)	(7.41)	(17.10)			
2	.832	−.326	.324	.869	.824	2.105	1.850
	(1.05)	(-3.01)	(3.42)	(30.41)			
3	.632	−.406	.325	1.095	.685	4.012	2.043
	(.43)	(-2.21)	(3.90)	(19.95)			
4	−.897	−.389	.464	1.182	.717	4.218	1.984
	(-.59)	(-1.91)	(5.24)	(20.37)			
5	−1.935	−.102	.292	1.204	.740	3.923	2.017
	(-1.36)	(-.55)	(3.58)	(22.52)			
6	.726	−.246	.190	.998	.892	1.827	2.013
	(1.10)	(-2.11)	(2.05)	(40.25)			
7	−1.820	−.304	.491	1.107	.836	2.786	1.930
	(-1.79)	(-2.30)	(8.12)	(29.10)			
8	−3.126	.025	.319	1.091	.714	3.855	1.854
	(-2.23)	(.13)	(2.91)	(20.78)			
9	.665	−.435	.338	1.138	.888	2.123	1.987
	(.86)	(-4.10)	(7.55)	(39.33)			
10	−.234	−.414	.389	1.177	.890	2.235	1.845
	(-.29)	(-3.21)	(4.19)	(38.16)			
11	−.645	−.146	.193	1.235	.889	2.332	1.958
	(-.74)	(-1.20)	(2.20)	(38.63)			
12	.842	−.289	.197	1.104	.964	1.121	2.045
	(2.02)	(-4.06)	(3.00)	(72.09)			
13	.099	−.343	.347	1.110	.632	4.638	1.834
	(.06)	(-1.60)	(3.79)	(17.50)			
14	−.392	−.536	.548	1.115	.854	2.488	1.994
	(-.43)	(-4.30)	(6.92)	(32.93)			
15	−.241	−.371	.786	.604	.571	2.779	1.728
	(-.24)	(-2.30)	(4.28)	(15.81)			
16	−1.745	−.033	.233	1.157	.874	2.368	2.081
	(-2.00)	(-.29)	(3.37)	(35.99)			
17	−1.361	−.235	.383	1.145	.825	2.910	1.788
	(-1.29)	(-1.55)	(4.70)	(28.88)			
18	.802	−.490	.450	.953	.905	1.637	1.989
	(1.35)	(-4.79)	(5.87)	(42.90)			
19	−.328	−.260	.257	1.294	.864	2.750	2.157
	(-.33)	(-1.78)	(3.52)	(34.61)			

Note: t–statistics given in parentheses.

TABLE 5

Estimation of Industry-Specific Conditional Variance of Stock Returns; *1970:1–1988:12*

$\lvert\hat{\varepsilon}^R_{it}\rvert$	*const.*	τ^R_t	τ^R_{it}	$\lvert\hat{\varepsilon}^R_{it-1}\rvert$	R^2	*SEE*	*D.W.*
1	−.934	.353	.082	.122	.120	2.370	2.021
	(−1.14)	(2.88)	(1.33)	(1.91)			
2	.293	.027	.160	.008	.052	1.307	2.000
	(.63)	(.42)	(2.70)	(.11)			
3	.245	.223	.182	−.076	.097	2.341	2.023
	(.30)	(2.19)	(3.44)	(−1.18)			
4	−.533	.353	.124	.002	.120	2.371	2.049
	(−.65)	(3.19)	(2.51)	(.02)			
5	.517	.143	.155	.060	.068	2.480	1.942
	(.58)	(1.30)	(3.00)	(.93)			
6	−1.318	.111	.232	.017	.228	1.129	1.941
	(−3.41)	(1.59)	(3.94)	(.27)			
7	.629	.132	.073	−.062	.053	1.685	2.029
	(1.07)	(1.73)	(2.01)	(−.94)			
8	−.935	.330	.154	.010	.133	2.161	1.949
	(−1.24)	(3.13)	(2.51)	(.15)			
9	.202	.168	.007	.028	.051	1.24	1.948
	(.46)	(2.91)	(.26)	(.43)			
10	.095	.073	.108	.099	.069	1.316	1.985
	(.20)	(.97)	(2.00)	(1.53)			
11	−.141	.103	.127	.043	.078	1.407	1.976
	(−.29)	(1.44)	(2.43)	(.67)			
12	−.356	.073	.077	.019	.111	.674	1.923
	(−1.49)	(1.74)	(1.96)	(.30)			
13	.431	.239	.119	.088	.058	2.942	1.982
	(.42)	(1.85)	(2.06)	(1.35)			
14	.752	−.025	.145	.094	.050	1.545	2.028
	(1.30)	(−.34)	(2.95)	(1.42)			
15	−.614	.150	.371	−.064	.157	1.567	1.936
	(−1.12)	(1.79)	(3.62)	(−1.04)			
16	.058	.145	.087	−.019	.077	1.353	1.989
	(.12)	(2.32)	(2.20)	(−.30)			
17	−.847	.317	.051	.026	.112	1.739	2.021
	(−1.42)	(3.62)	(1.05)	(.41)			
18	.330	.027	.092	.024	.048	1.031	2.003
	(.93)	(.42)	(1.89)	(.36)			
19	−.079	.116	.140	.030	.117	1.578	2.006
	(−.15)	(1.43)	(3.35)	(.47)			

Note: t-statistics given in parentheses.

TABLE 6

Relationship between Inflation and Its Variances

$\tilde{\varepsilon}_{it}$ / τ_{it}	constant / constant	π_{it} / π_{it}	R^2	SEE	D.W.
1	.680 (24.17)	.038 (16.74)	.553	.305	.242
	4.578 (12.31)	.337 (10.98)	.348	4.032	.179
2	1.226 (14.28)	.063 (7.27)	.189	1.062	.265
	11.750 (18.36)	.438 (6.72)	.166	7.915	.165
3	.411 (14.07)	.045 (9.67)	.292	.332	.263
	2.898 (12.71)	.331 (8.99)	.263	2.597	.126
4	.243 (9.10)	.056 (11.76)	.379	.250	.384
	2.253 (17.43)	.214 (9.31)	.277	1.208	.394
5	.358 (22.03)	.037 (13.24)	.436	.146	.260
	2.280 (8.83)	.313 (6.99)	.177	2.331	.138
6	.541 (13.49)	.060 (15.11)	.502	.497	.270
	3.826 (16.40)	.303 (13.00)	.428	2.892	.107
7	.239 (17.45)	.030 (15.49)	.515	.105	.269
	2.833 (20.68)	.115 (5.92)	.134	1.051	.290
8	.666 (14.99)	.051 (11.09)	.365	.515	.301
	5.513 (22.01)	.219 (8.61)	.247	2.903	.184
9	.154 (4.61)	.055 (12.84)	.422	.318	.611
	1.411 (14.38)	.198 (15.61)	.519	.934	.240
10	.057 (2.61)	.039 (14.43)	.479	.195	.626
	1.190 (20.14)	.141 (18.90)	.612	.530	.187
11	.211 (9.57)	.046 (13.08)	.429	.225	.602
	2.225 (23.63)	.444 (29.39)	.792	.960	.250
12	.187 (11.10)	.051 (21.43)	.670	.157	.345
	2.079 (9.08)	.544 (16.60)	.549	2.138	.144

Note: 1970:1–1988:12; t-statistics given in parentheses.

TABLE 7

Relationship between Stock Returns and Its Variances

$\tilde{\varepsilon}^R_{it}$ / τ^R_{it}	constant / constant	R_{it} / R_{it}	R^2	SEE	D.W.
1	3.036 (56.14)	.047 (6.16)	.143	.806	1.047
	9.031 (48.33)	.224 (8.44)	.239	2.786	1.437
2	1.587 (78.25)	.016 (4.33)	.076	.294	1.312
	6.686 (57.39)	.088 (3.92)	.063	1.689	1.401
3	3.099 (64.75)	.038 (5.81)	.130	.711	1.671
	7.139 (35.97)	.136 (4.93)	.097	2.950	1.772
4	3.301 (62.32)	.046 (6.95)	.176	.791	1.088
	7.856 (35.80)	.191 (6.92)	.174	3.281	1.524
5	2.992 (70.71)	.032 (5.94)	.135	.621	1.376
	6.894 (31.39)	.140 (4.90)	.096	3.300	1.710
6	1.236 (31.41)	.035 (5.06)	.101	.578	1.063
	7.055 (54.93)	.102 (4.53)	.083	1.888	1.150
7	2.141 (90.28)	.025 (7.50)	.199	.353	1.429
	7.993 (38.88)	.210 (7.06)	.181	3.064	1.564
8	3.009 (58.20)	.047 (6.62)	.162	.772	1.245
	8.106 (46.49)	.130 (5.40)	.114	2.604	1.367
9	1.652 (90.79)	.015 (5.46)	.116	.269	1.116
	8.048 (34.33)	.131 (3.59)	.054	3.469	1.895
10	1.738 (78.99)	.020 (6.39)	.153	.327	1.121
	8.203 (59.83)	.139 (5.52)	.172	2.043	1.267
11	1.777 (69.81)	.021 (5.98)	.136	.378	1.365
	7.961 (57.55)	.108 (5.52)	.119	2.057	1.656
12	.839 (55.89)	.014 (5.91)	.134	.220	1.028
	7.681 (69.29)	.103 (5.62)	.122	1.629	1.123
13	3.458 (76.08)	.034 (5.76)	.128	.680	1.253
	6.647 (29.12)	.149 (5.00)	.099	3.416	1.905
14	1.886 (84.58)	.018 (5.42)	.115	.332	1.707
	8.036 (52.83)	.134 (5.78)	.129	2.264	1.745
15	2.128 (48.46)	.048 (4.77)	.091	.641	1.122
	4.533 (51.59)	.078 (3.88)	.062	1.283	1.042
16	1.862 (76.13)	.020 (5.63)	.123	.363	1.238
	7.725 (46.32)	.087 (3.52)	.052	2.477	1.477
17	2.181 (56.75)	.035 (6.41)	.153	.568	1.036
	8.370 (45.99)	.158 (6.10)	.141	2.691	1.450
18	1.221 (82.64)	.015 (5.48)	.117	.217	1.273
	7.038 (53.01)	.130 (5.29)	.110	1.953	1.426
19	2.127 (59.06)	.027 (5.68)	.125	.534	1.220
	8.619 (43.39)	.130 (4.93)	.097	2.947	1.502

Note: 1970:1–1988:12; t-statistics given in parentheses.

TABLE 8

Elasticity of Conditional Variance of Inflation with Relative Price Variability

$\log \tilde{\varepsilon}_{it}$	constant	$\log \tau_{it}$	R^2	SEE	D.W.
1	−.623 (-12.29)	.314 (11.82)	.382	.319	.159
2	−2.803 (-56.32)	1.211 (62.21)	.944	.159	1.724
3	−1.443 (-30.66)	.621 (18.57)	.604	.370	.473
4	−1.578 (-17.17)	.647 (8.11)	.225	.501	.295
5	−1.087 (-44.11)	.372 (19.88)	.636	.230	.165
6	−1.863 (-25.36)	.981 (21.97)	.681	.415	.666
7	−1.574 (-21.84)	.540 (9.40)	.281	.286	.150
8	−2.456 (-36.15)	1.237 (34.25)	.838	.261	.716
9	−2.017 (-31.18)	1.235 (18.17)	.593	.409	1.058
10	−2.384 (-33.32)	1.394 (14.85)	.494	.530	.832
11	−2.482 (-28.95)	1.061 (17.57)	.577	.390	.918
12	−1.838 (-31.00)	.653 (17.30)	.569	.345	.211

Note: 1970:1–1988:12; t–statistics given in parentheses.

TABLE 9

Elasticity of Conditional Variance of Stock Returns with Relative Return Variability

$\log \tilde{\varepsilon}_{it}^{R}$	constant		$\log \tau_{it}^{R}$		R^2	SEE	D.W.
1	−.324	(- 3.82)	.650	(16.83)	.556	.176	1.409
2	−.910	(-67.16)	.726	(102.04)	.978	.025	1.600
3	.198	(5.07)	.482	(24.06)	.719	.119	1.915
4	.276	(5.64)	.451	(18.86)	.611	.145	1.443
5	.353	(14.53)	.384	(29.93)	.798	.095	1.351
6	−3.163	(-50.54)	1.709	(53.43)	.926	.116	1.783
7	−.005	(-.16)	.376	(22.41)	.689	.095	1.739
8	−.370	(-5.97)	.705	(23.72)	.713	.136	1.274
9	−.133	(-2.47)	.309	(11.86)	.383	.124	1.527
10	−.899	(-19.44)	.692	(31.48)	.814	.084	1.904
11	−1.017	(-23.61)	.769	(37.05)	.858	.080	1.253
12	−2.515	(-42.41)	1.145	(39.49)	.873	.090	1.469
13	.773	(25.55)	.257	(15.80)	.525	.134	1.355
14	−.509	(-12.53)	.552	(28.28)	.779	.082	1.827
15	−.770	(-19.41)	1.009	(38.60)	.868	.100	1.780
16	−.379	(-8.05)	.495	(21.38)	.669	.107	1.402
17	−.449	(-5.31)	.579	(14.56)	.484	.180	1.368
18	−1.032	(-58.21)	.635	(70.07)	.956	.035	1.764
19	−.769	(-22.57)	.712	(44.86)	.899	.075	1.405

Note: 1970:1–1988:12; t–statistics given in parentheses.

TABLE 10

Relationship between Inflation and Stock Returns in Terms of Variance

$\tilde{\varepsilon}^R_{it}$	constant	$\tilde{\varepsilon}_{it}$	R^2	SEE	D.W.
τ^R_{it}	constant	τ_{it}			
1	2.595 (19.12)	.489 (3.98)	.065	.842	1.217
	8.419 (22.51)	.115 (2.76)	.032	3.143	1.514
2	1.473 (45.98)	.087 (5.39)	.114	.288	1.671
	5.853 (27.89)	.067 (5.35)	.112	1.644	1.735
3	2.951 (32.67)	.329 (2.60)	.029	.751	1.841
	7.173 (20.20)	.032 (.47)	.001	3.103	1.837
4	3.009 (29.15)	.697 (3.95)	.064	.844	1.403
	7.521 (12.74)	.170 (1.01)	.004	3.604	1.497
5	2.874 (22.41)	.135 (.59)	.001	.667	1.332
	7.207 (17.7)	−.056 (−.62)	.001	3.468	1.653
6	.946 (16.15)	.378 (7.31)	.191	.549	1.562
	5.956 (28.55)	.221 (7.15)	.184	1.780	1.497
7	2.017 (26.12)	.362 (2.10)	.019	.391	1.624
	7.894 (10.68)	.093 (.46)	.001	3.384	1.592
8	2.796 (27.82)	.264 (3.10)	.041	.826	1.324
	7.960 (18.91)	.041 (.74)	.002	2.764	1.370
9	1.597 (56.07)	.154 (3.47)	.050	.279	1.353
	6.811 (13.49)	.539 (3.12)	.041	3.492	2.003
10	1.712 (47.94)	.154 (1.77)	.013	.354	1.249
	7.451 (19.08)	.431 (2.49)	.026	2.216	1.438
11	1.698 (36.74)	.249 (2.79)	.033	.400	1.548
	7.098 (22.17)	.234 (3.48)	.050	2.135	1.776
12	.699 (24.26)	.339 (6.42)	.154	.218	1.407
	7.317 (34.26)	.099 (2.79)	.033	1.710	1.290

Note: 1970:1–1988:12; t-statistics given in parentheses.

FIGURE I.1 : MINING

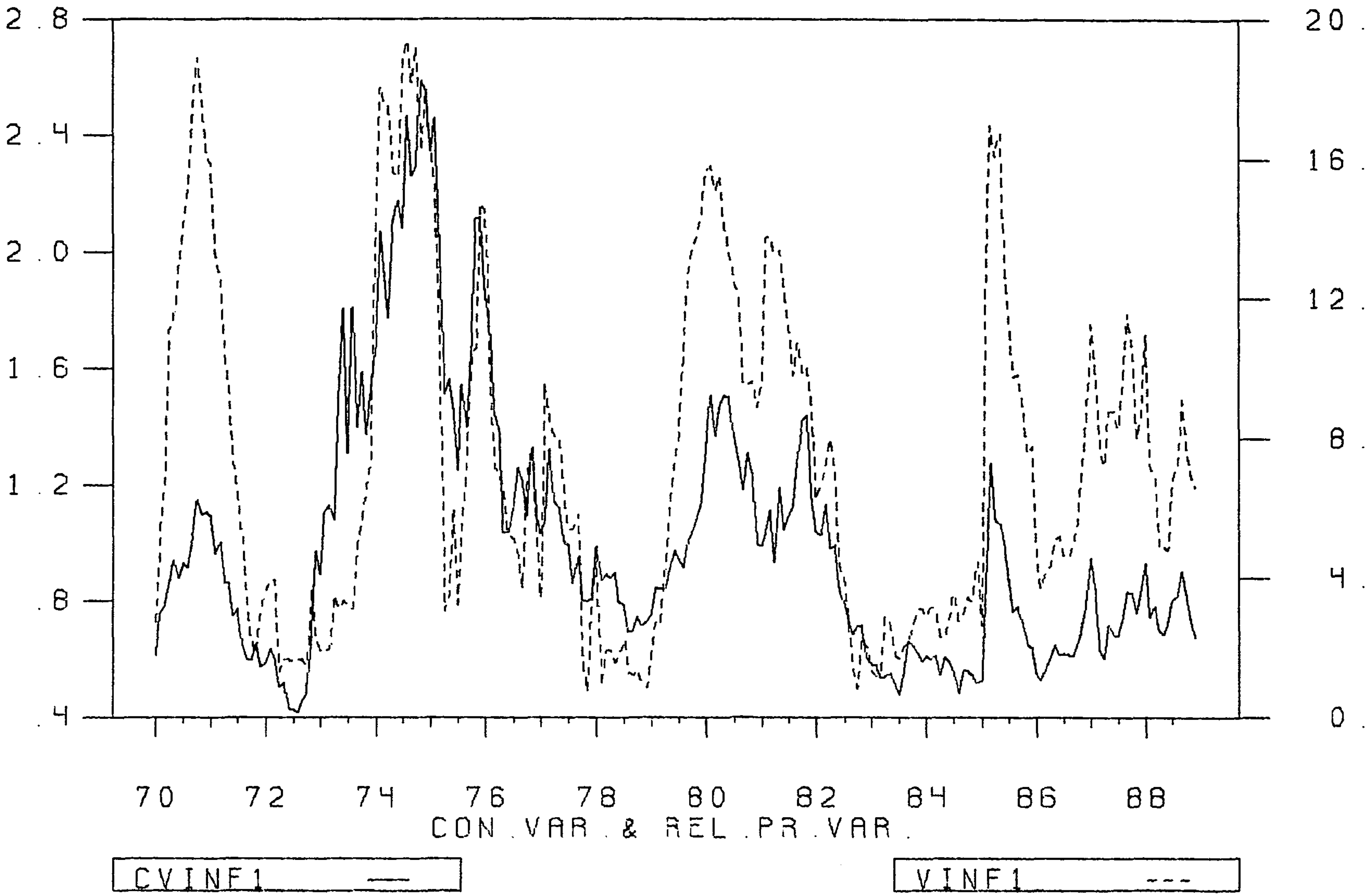


FIGURE I.2 : FOOD

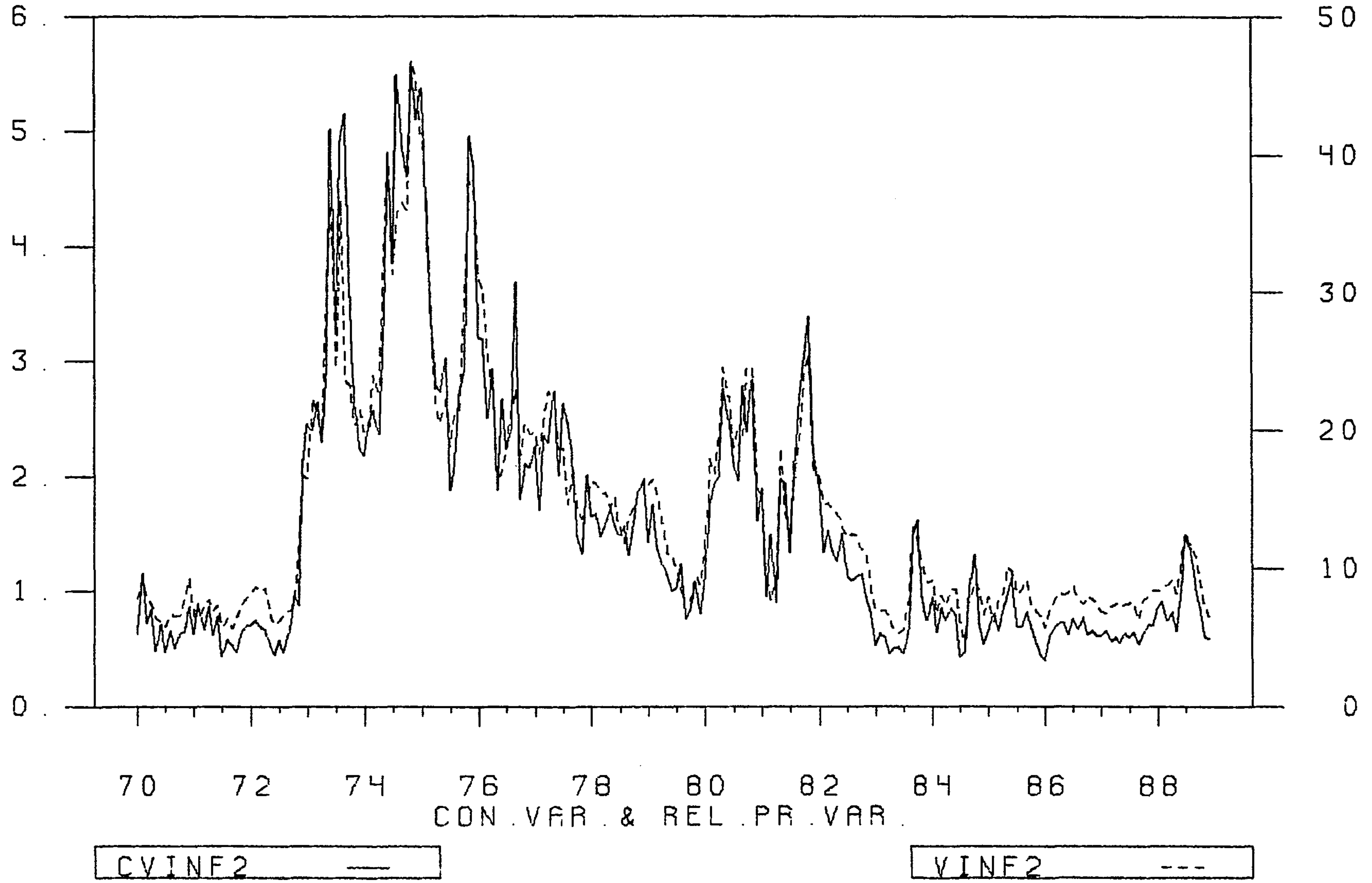


FIGURE I.3 : TEXTILE

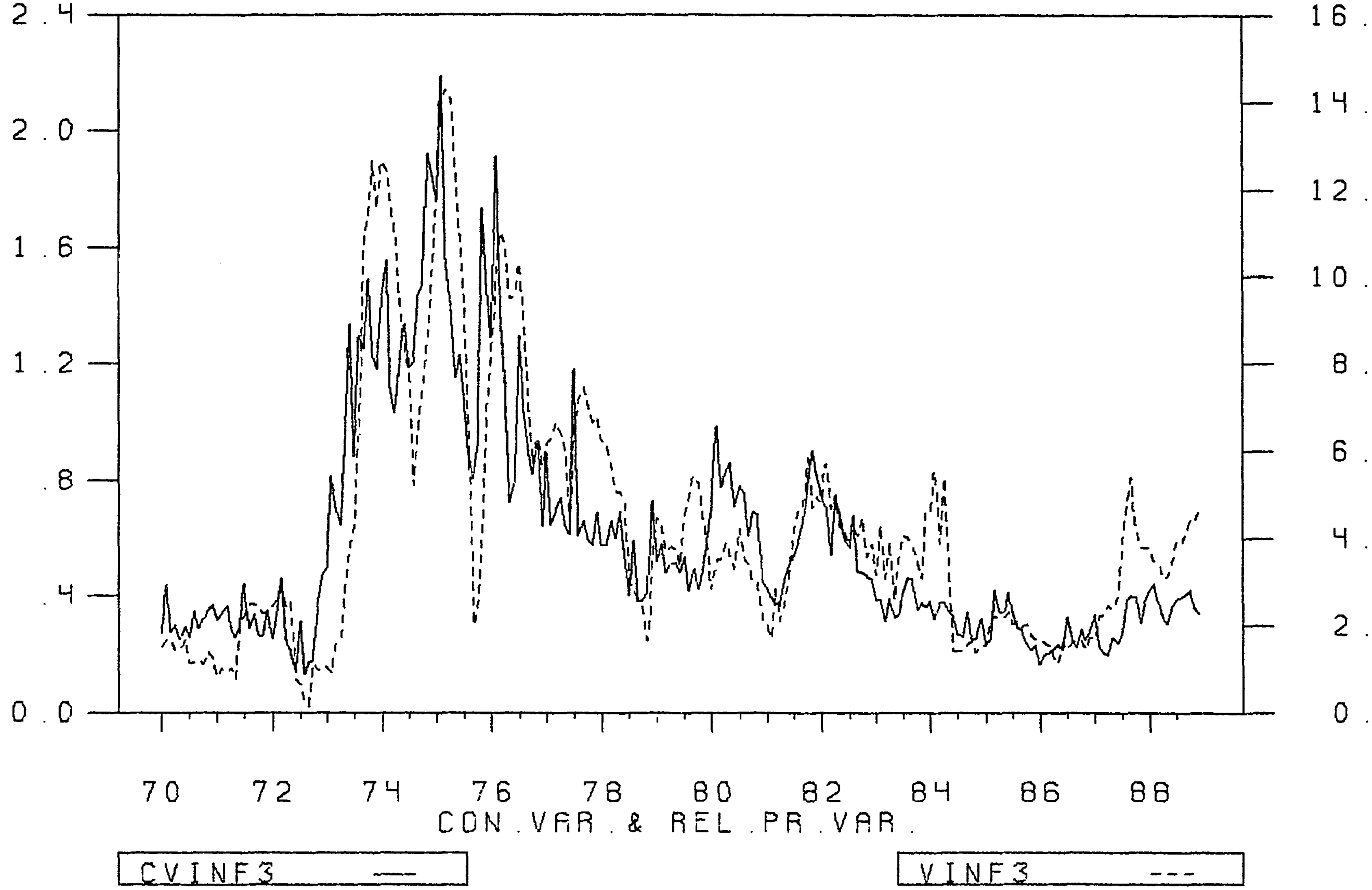


FIGURE I.4 : APPAREL

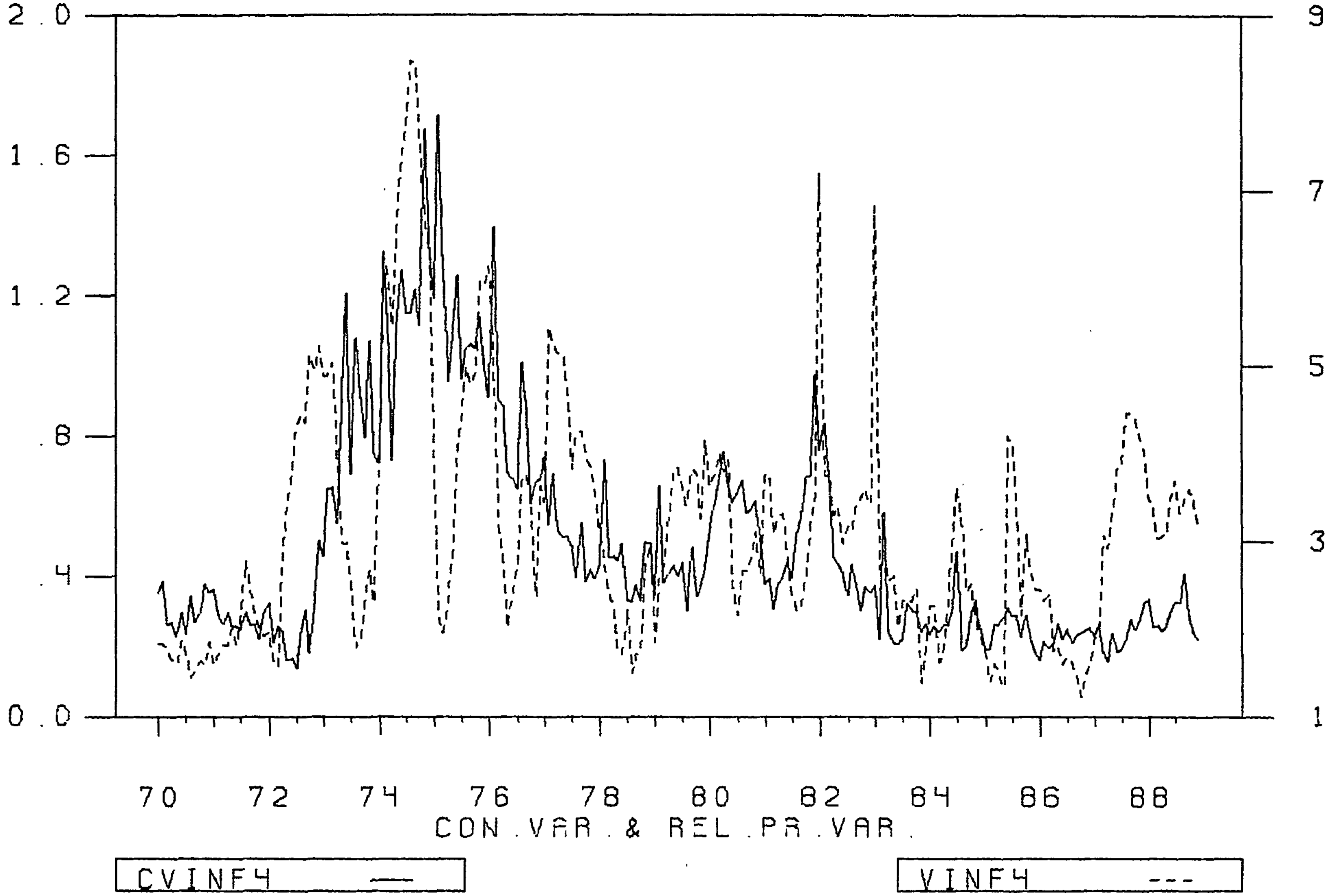


FIGURE I.5 : LUMBER

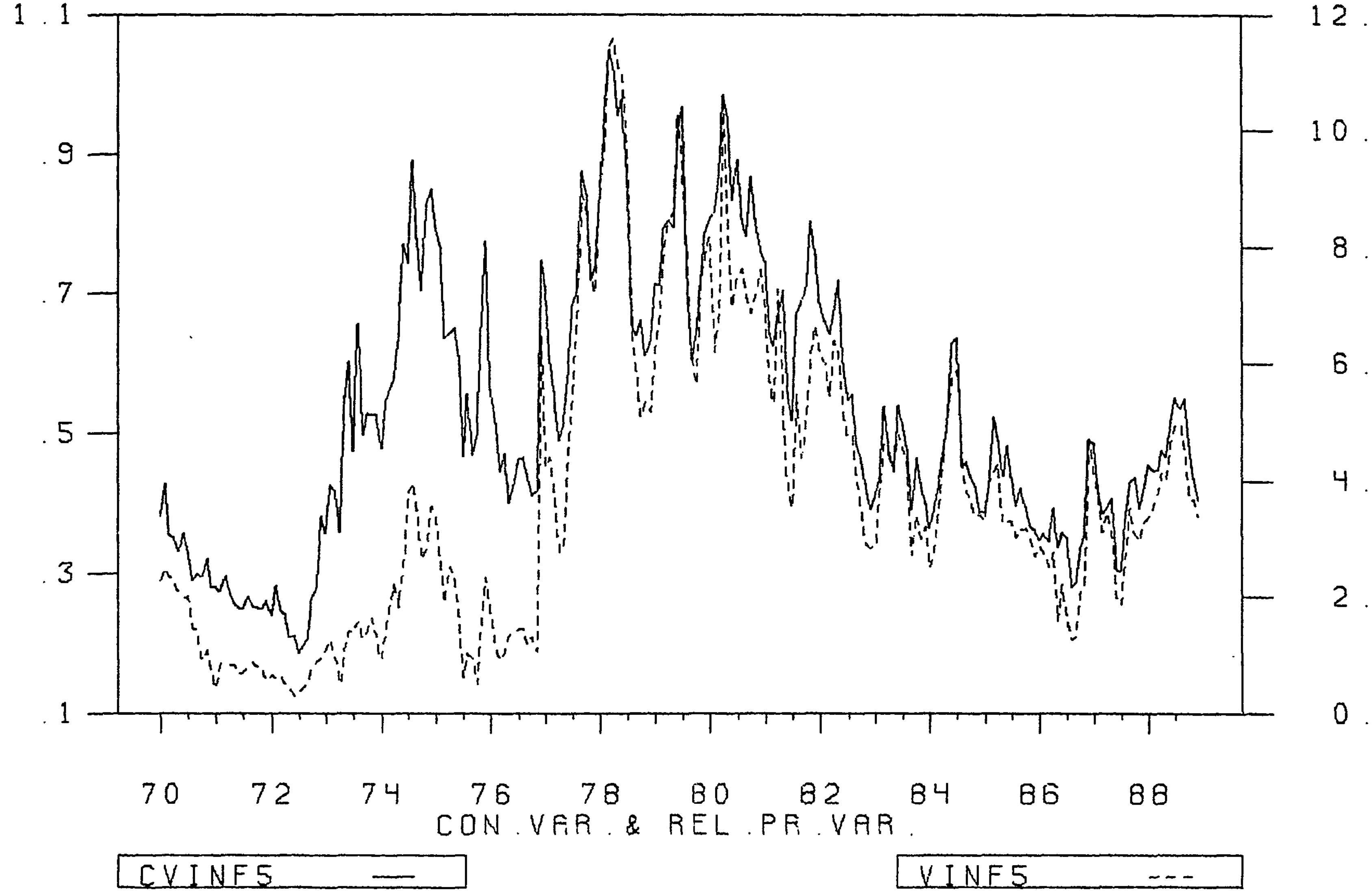


FIGURE I.6 : CHEMICALS

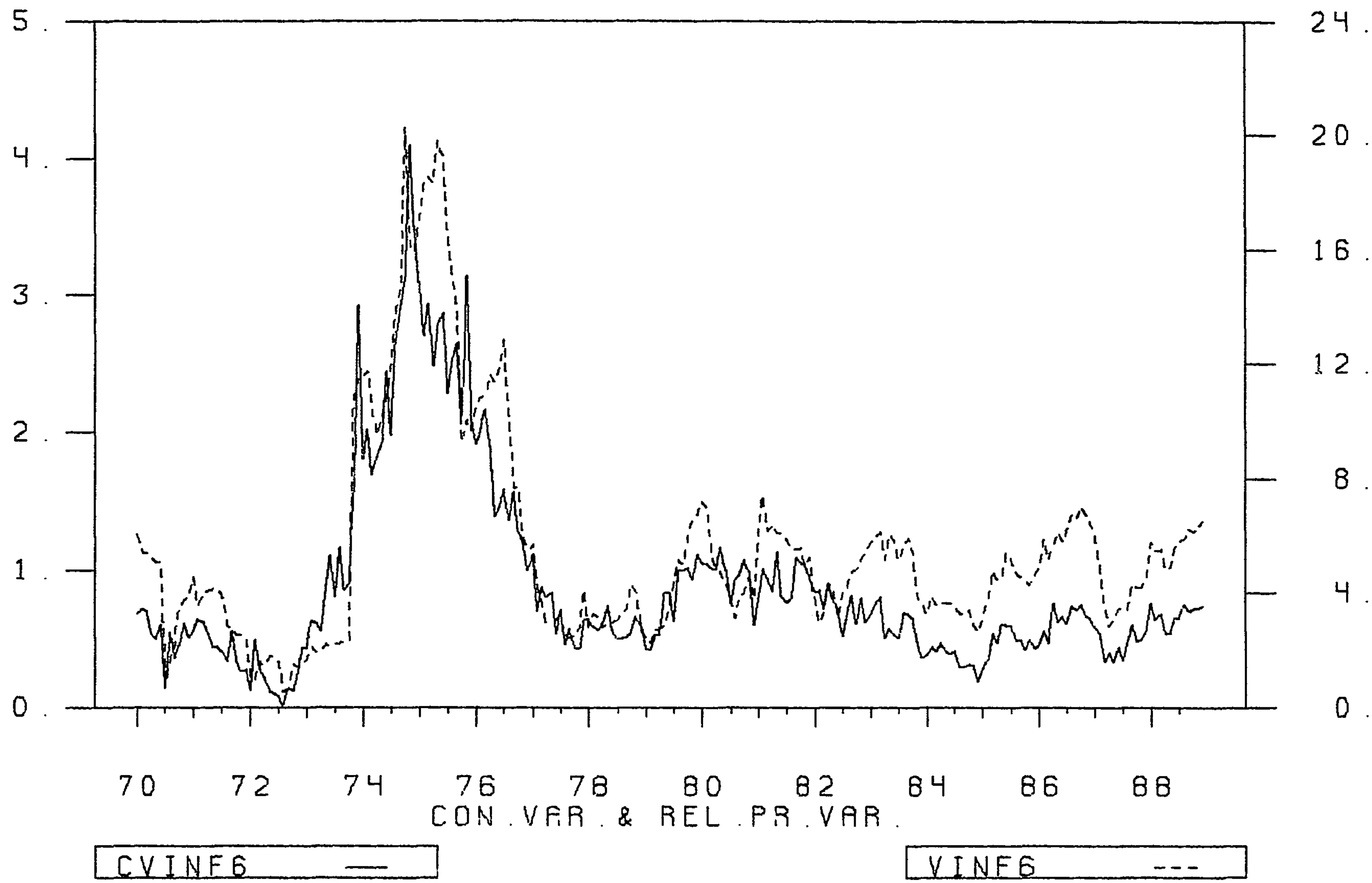


FIGURE I.7 : STONE

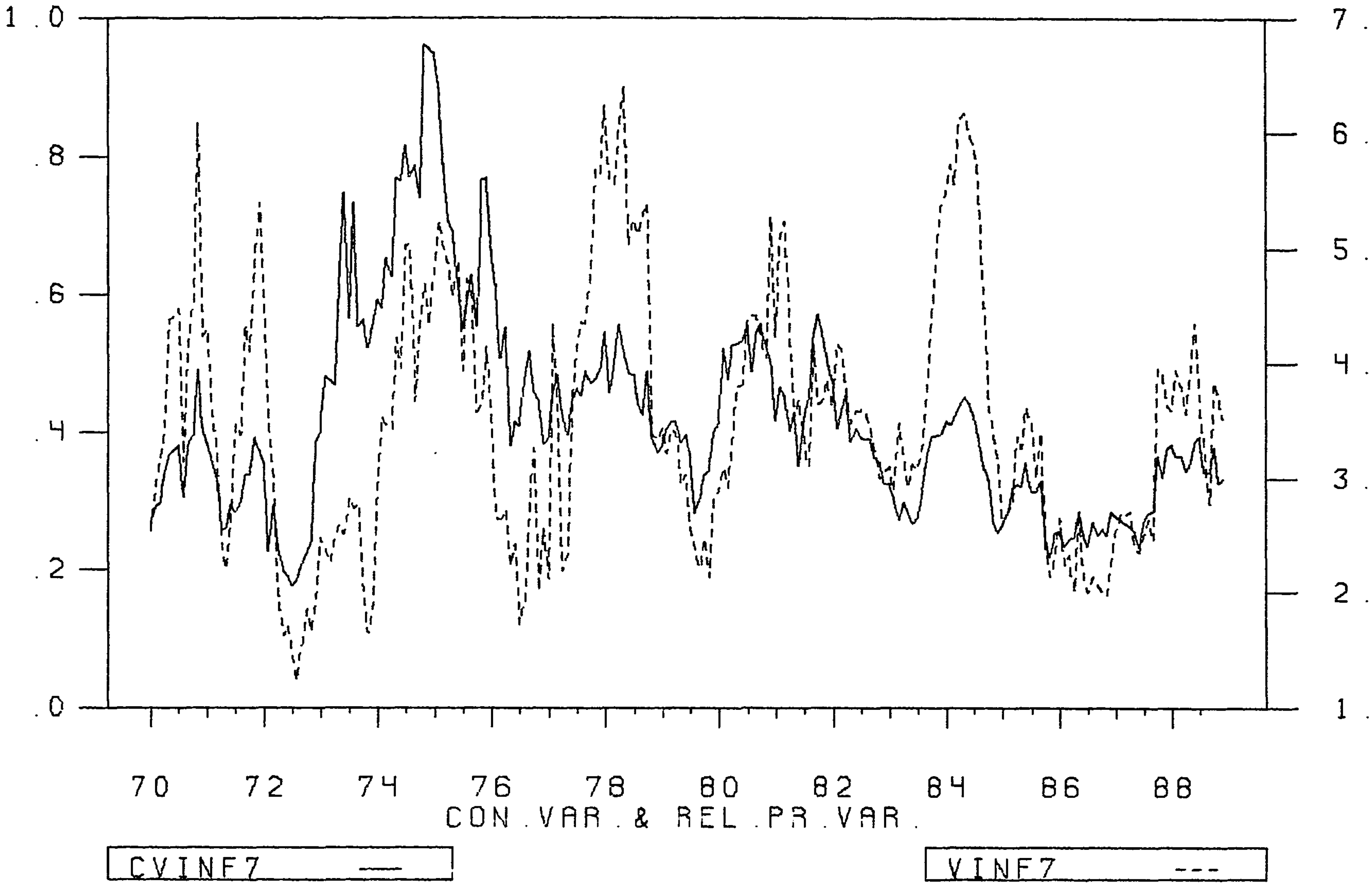


FIGURE I.8 : PRIMARY METAL

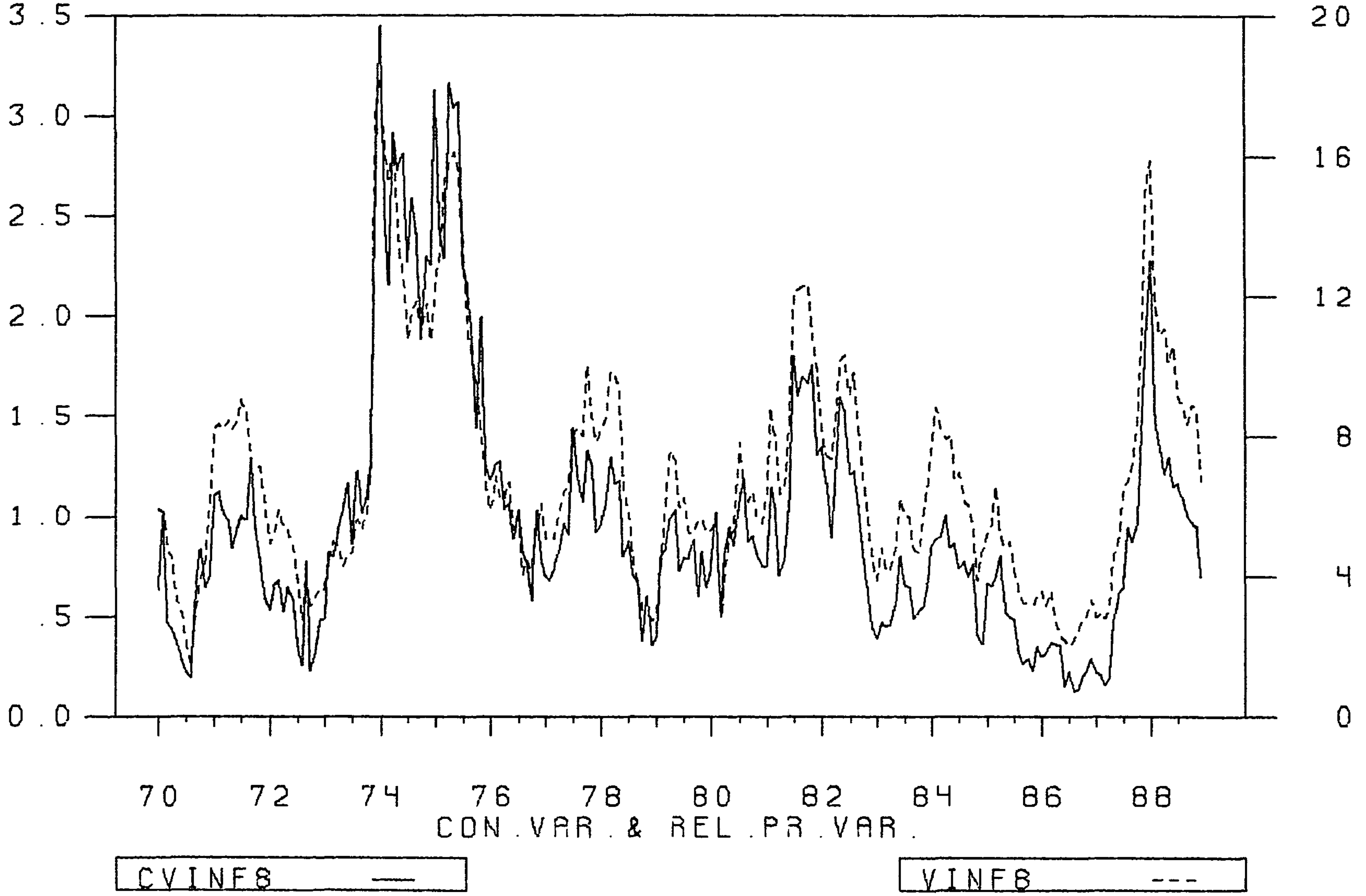


FIGURE I.9 : FABRICATED METAL

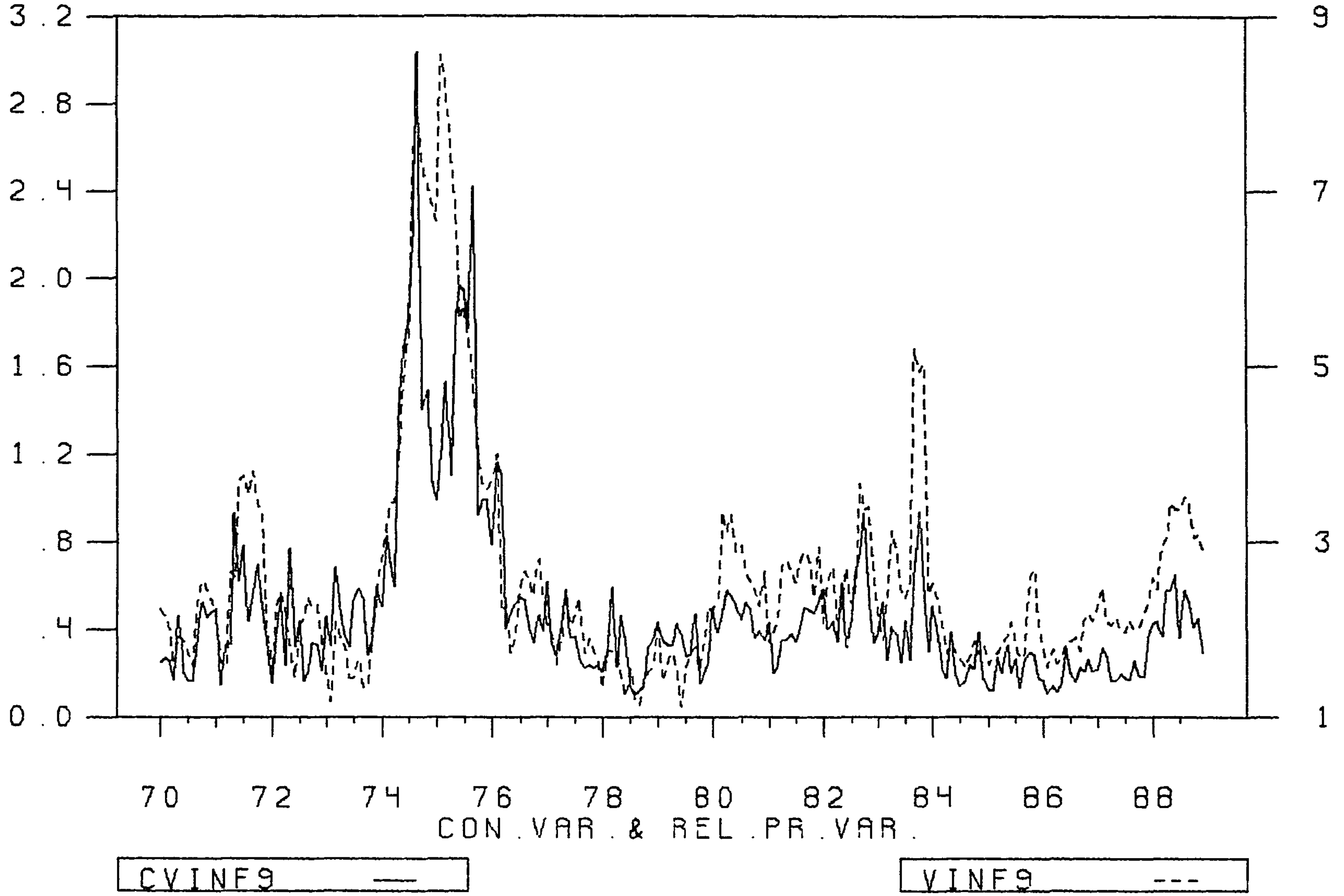


FIGURE I.10 : MACHINERY

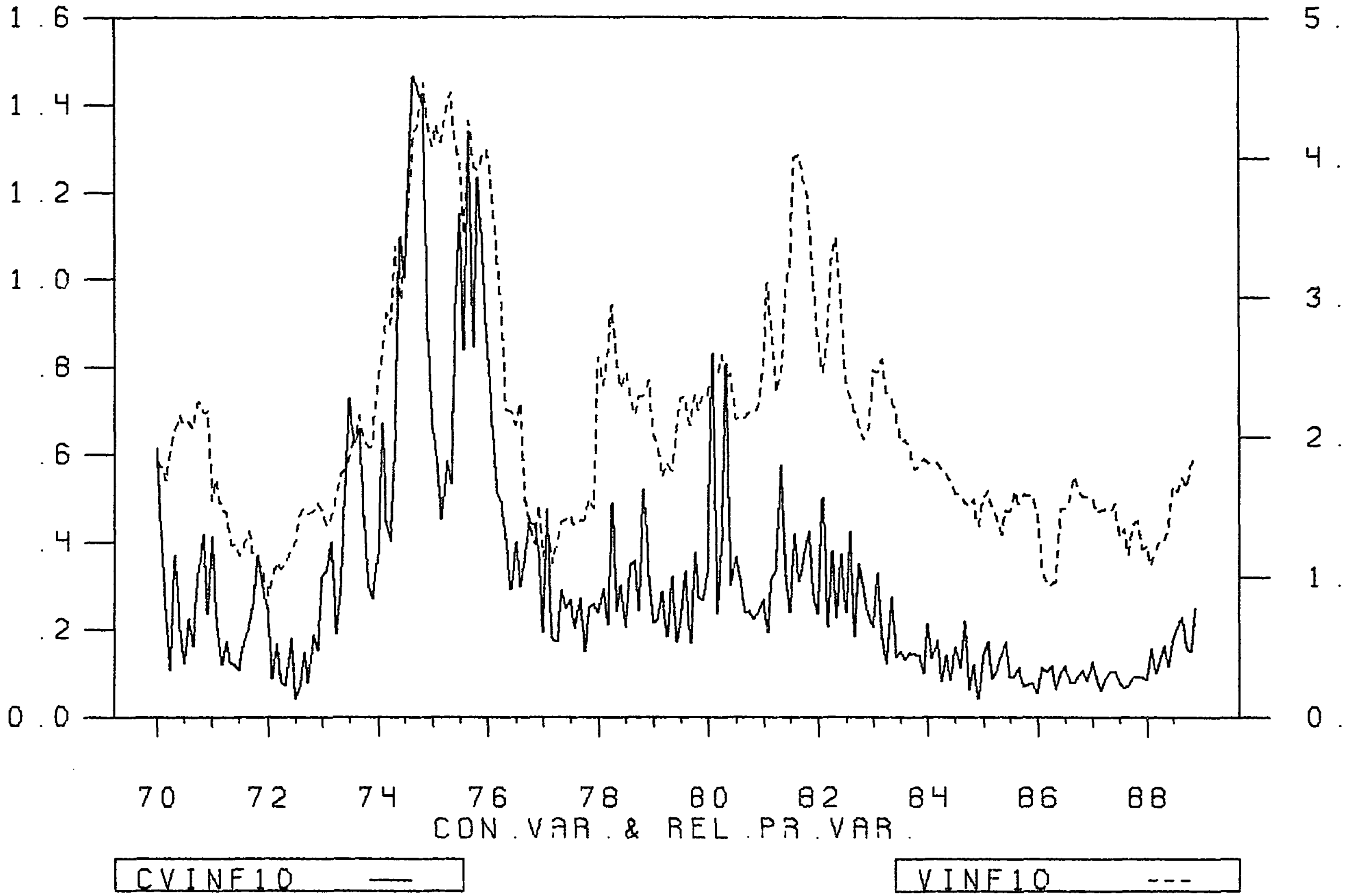


FIGURE I.11 : ELECTRONIC

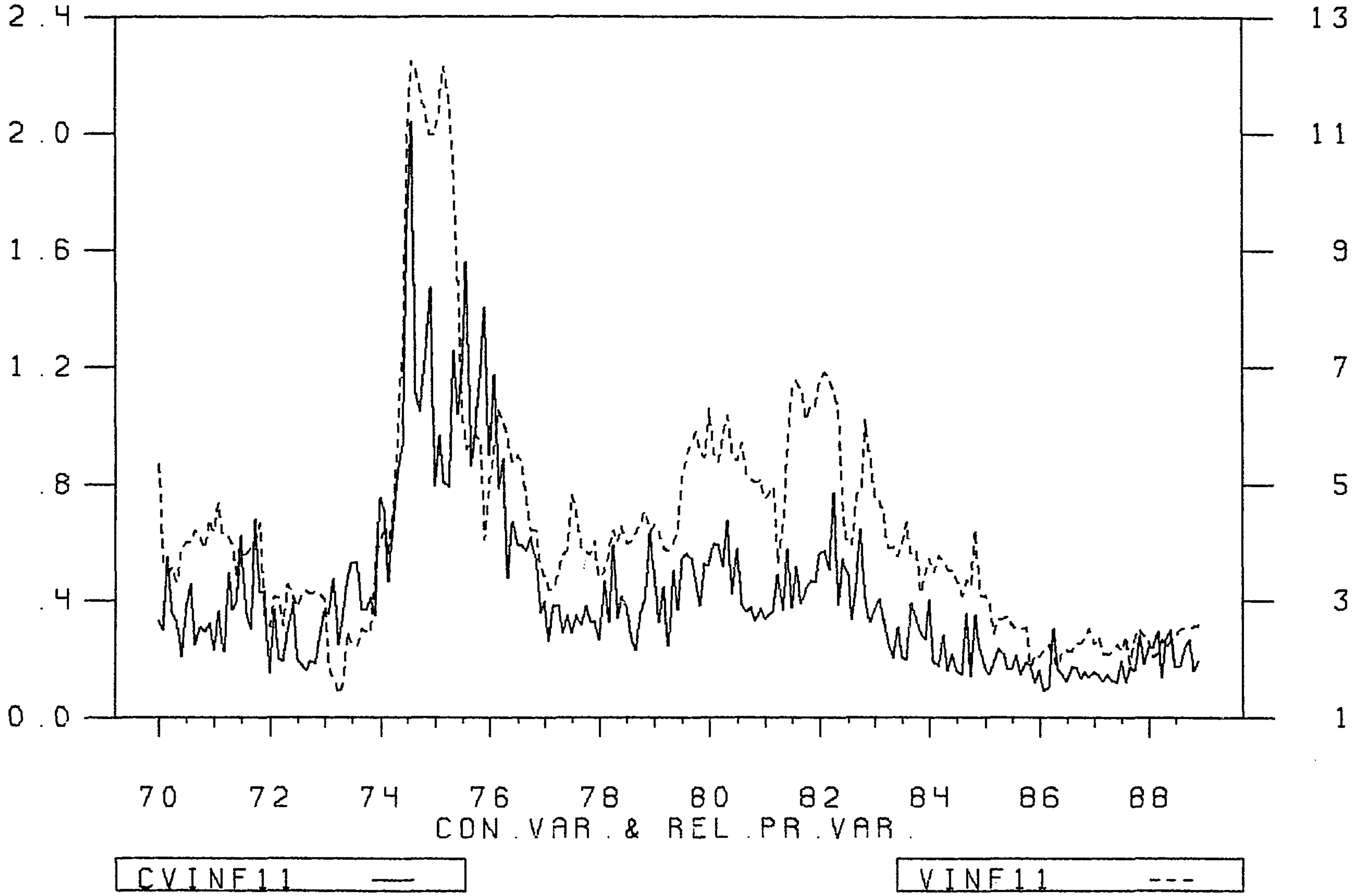


FIGURE I.12 : OTHERS IN MFG.

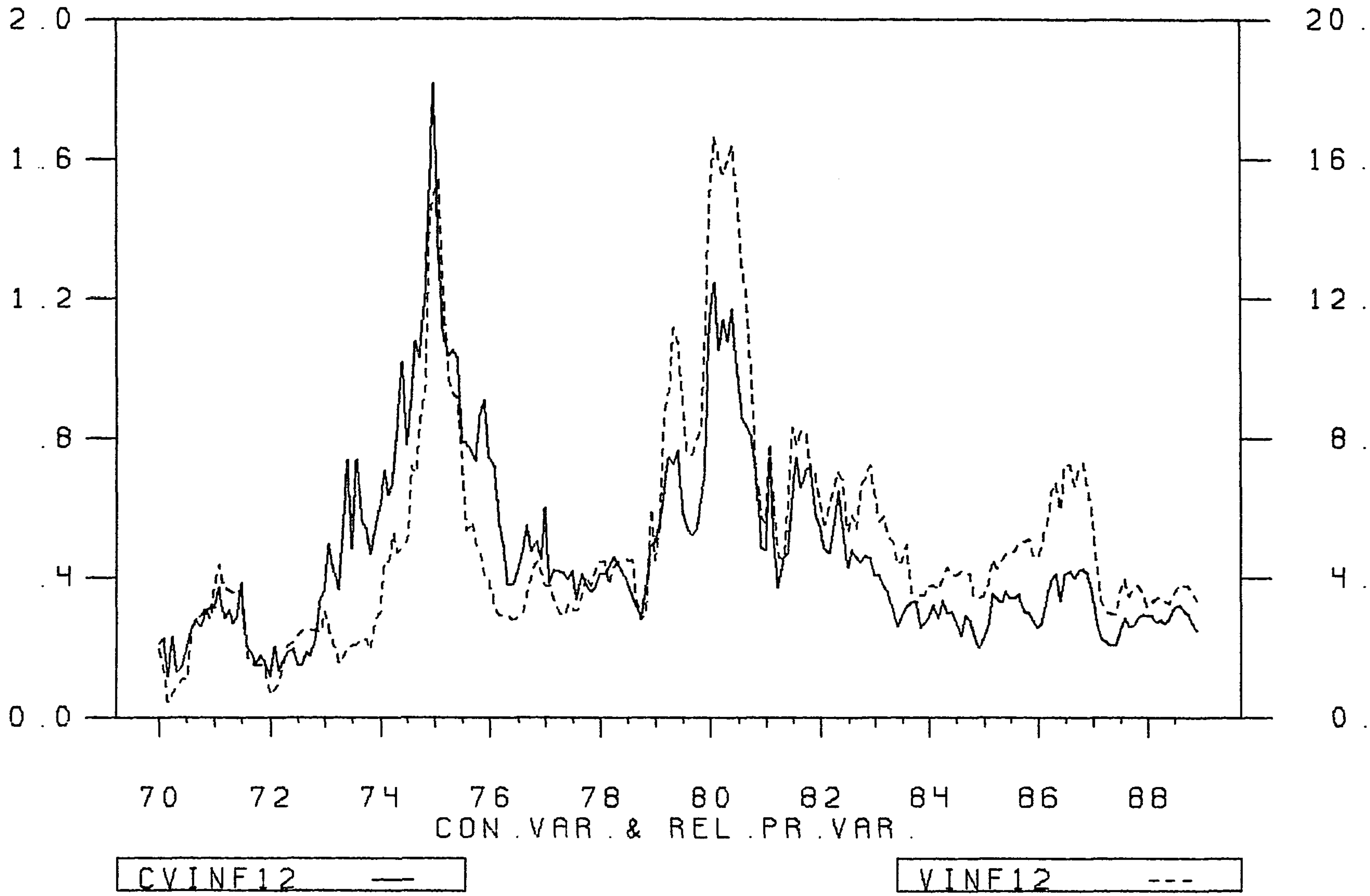


FIGURE II.1 : MINING

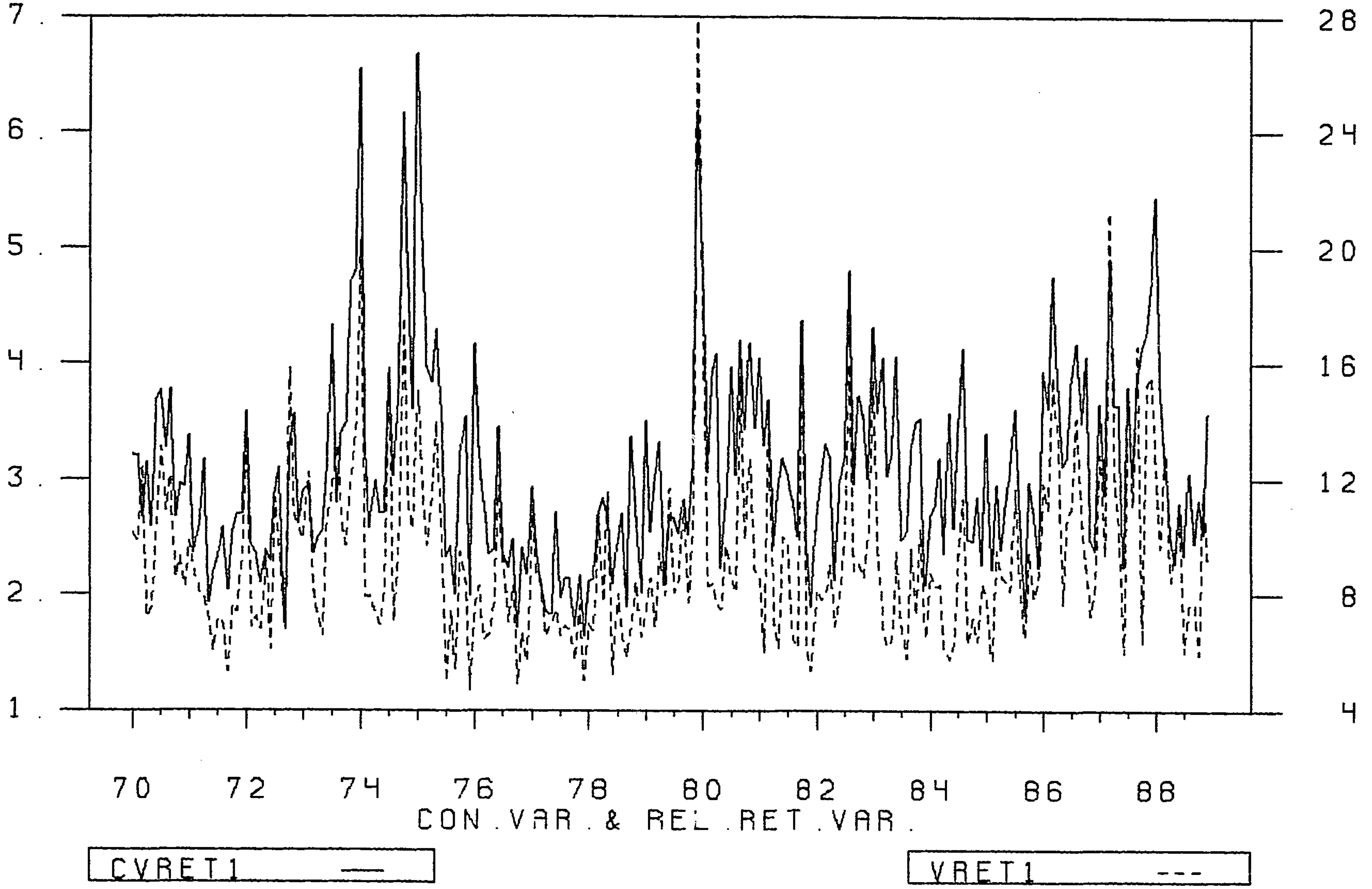


FIGURE II.2 : FOOD

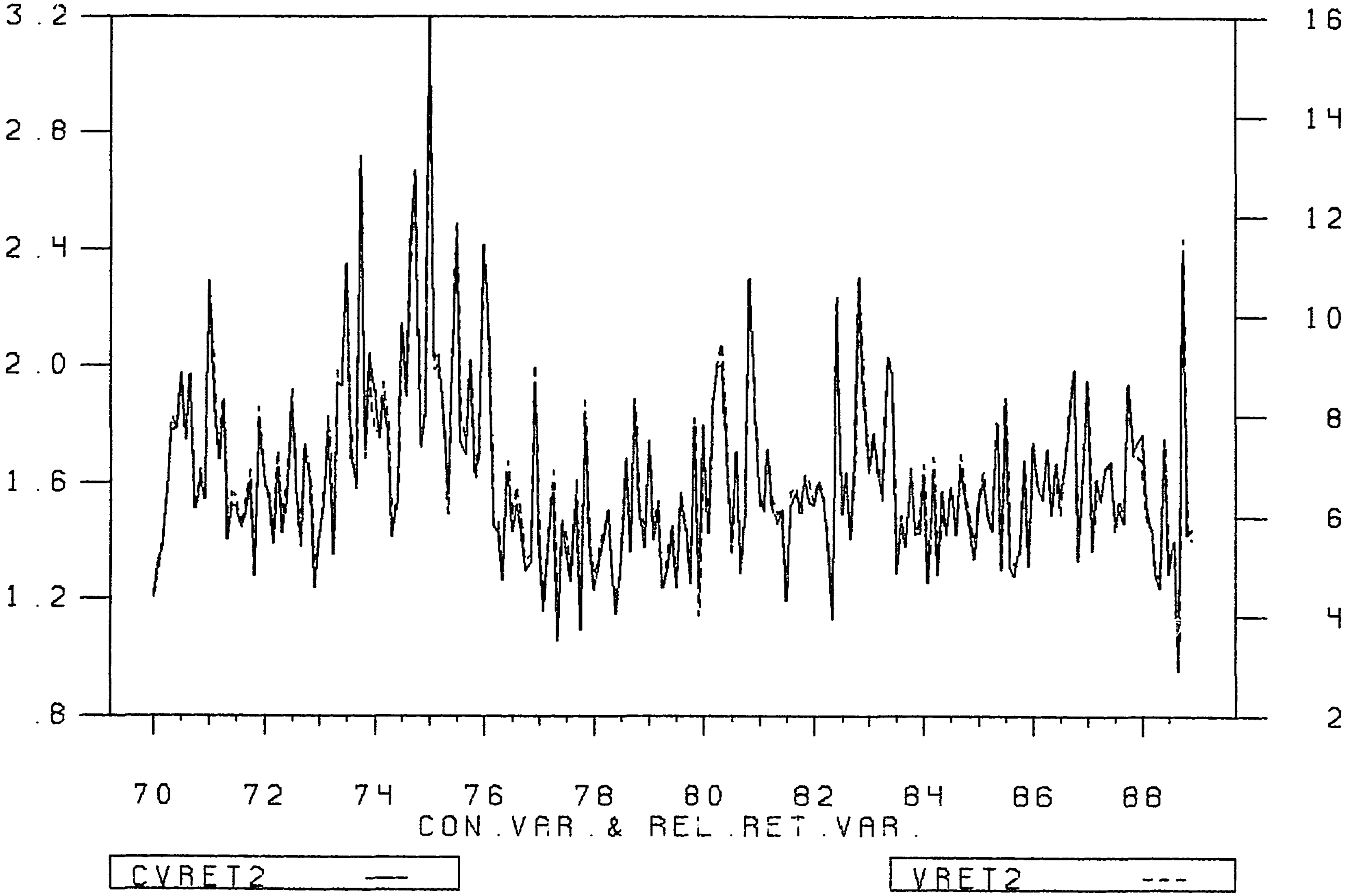


FIGURE II.3 : TEXTILE

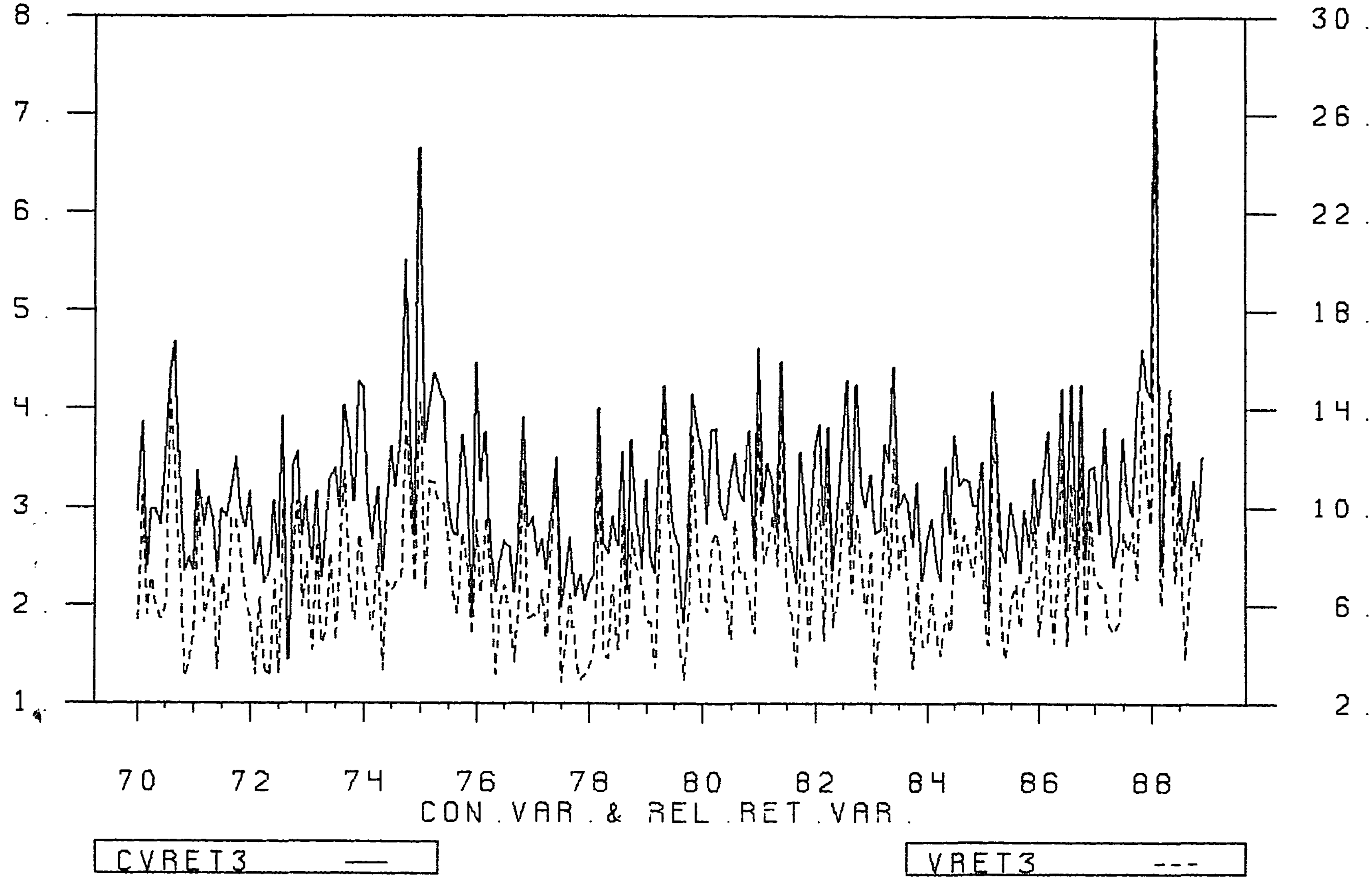


FIGURE II.4 : APPAREL

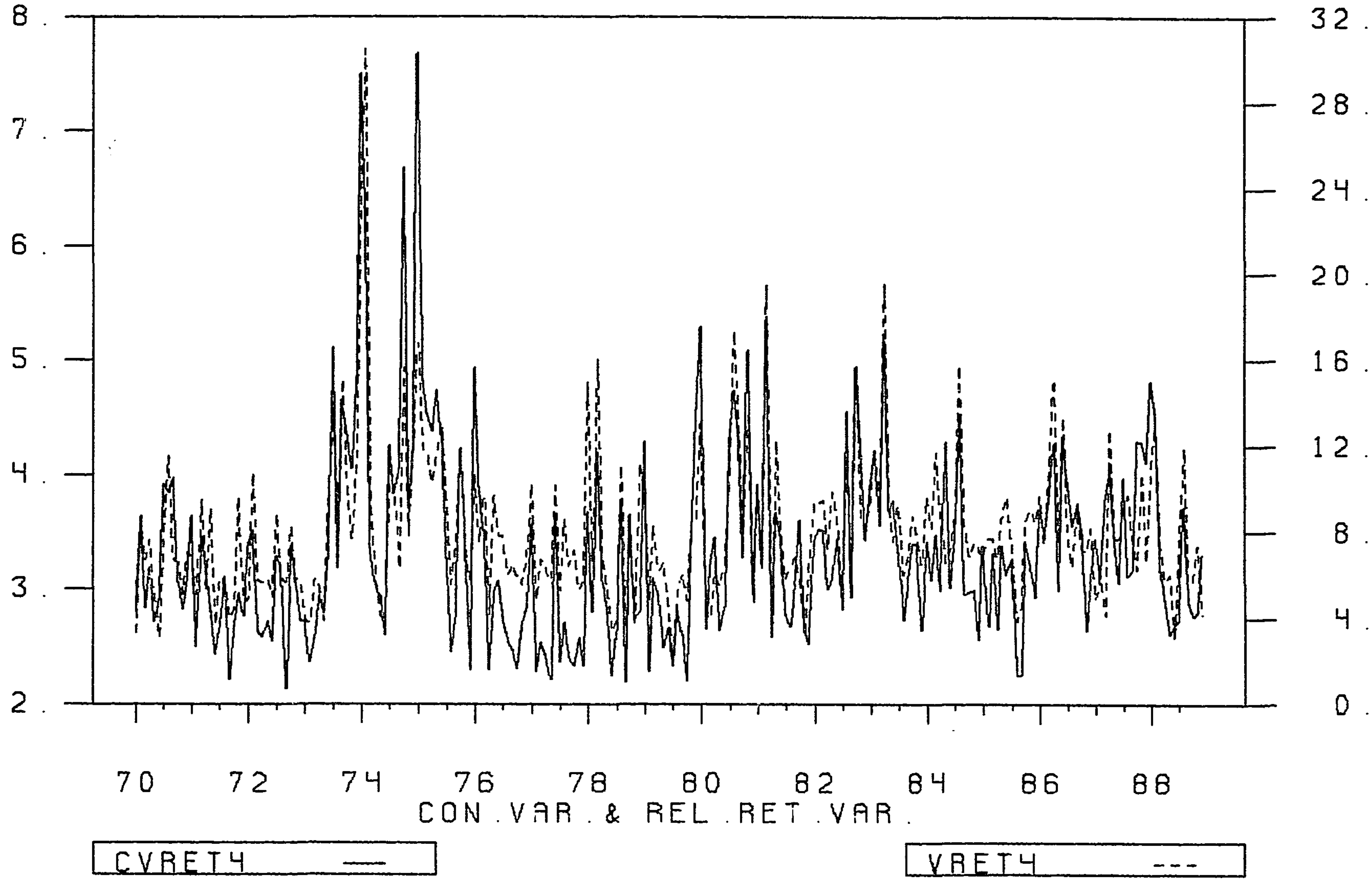


FIGURE II.5 : LUMBER

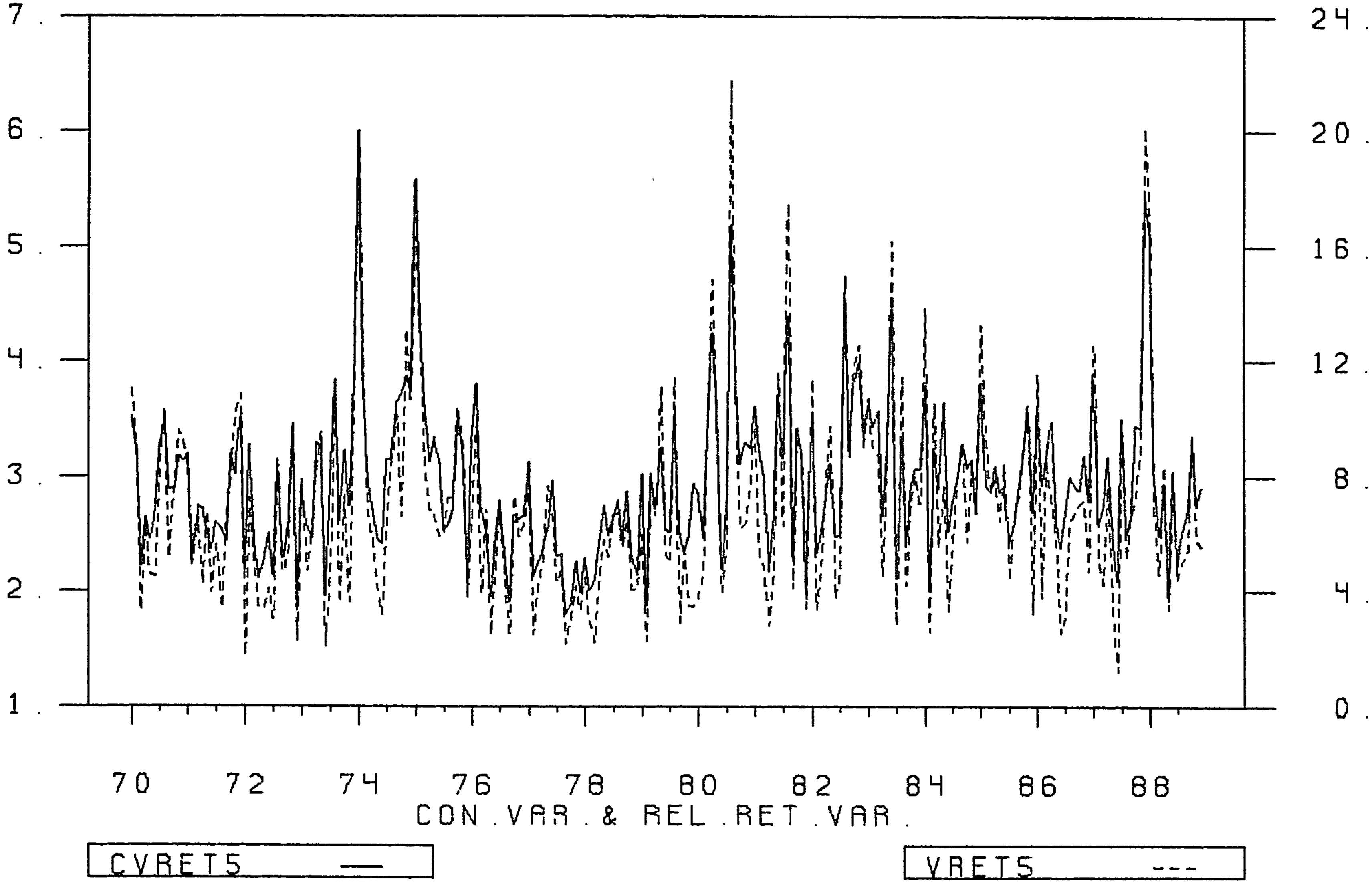


FIGURE II.6 : CHEMICALS

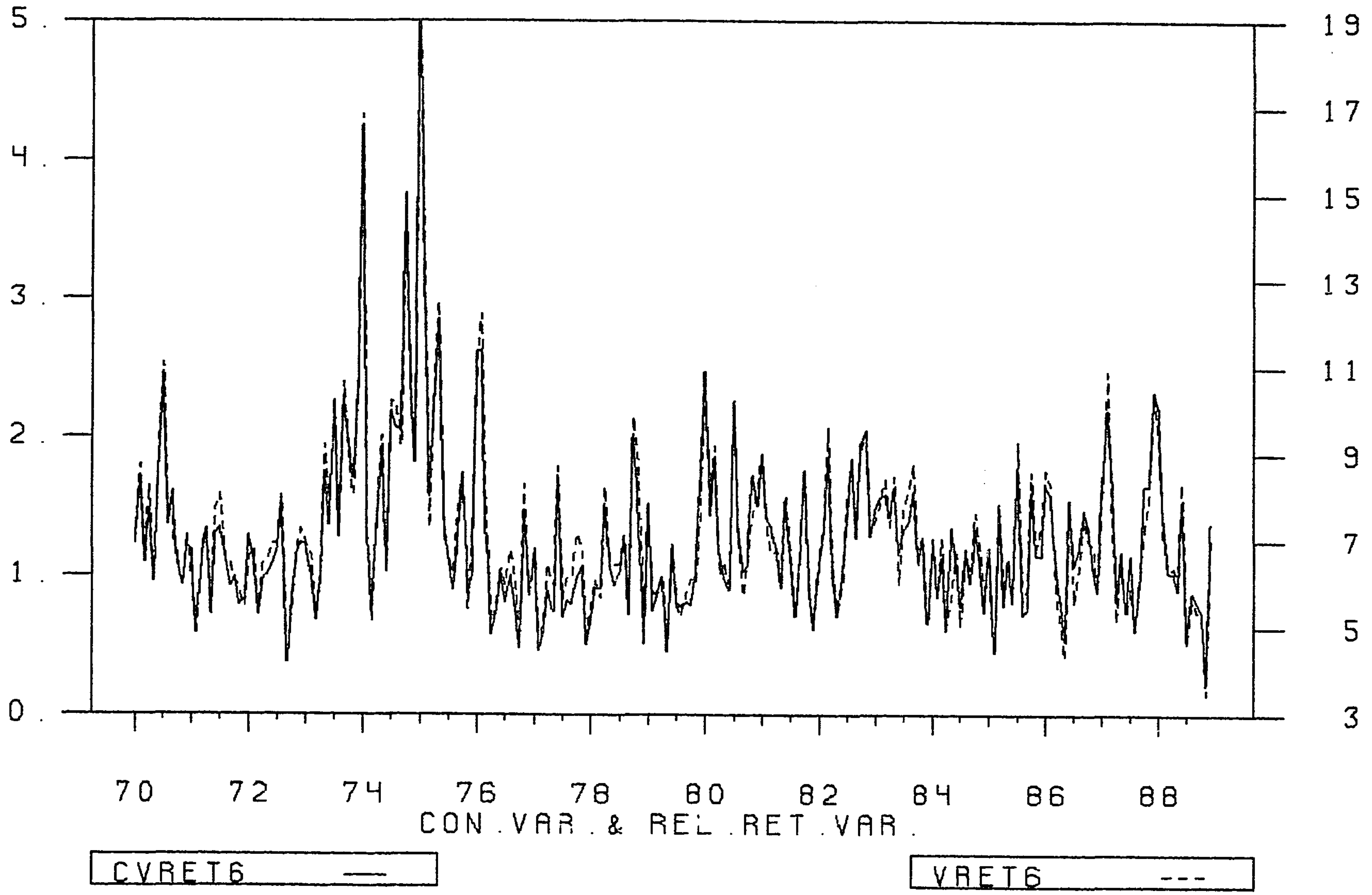


FIGURE II.7 : STONE

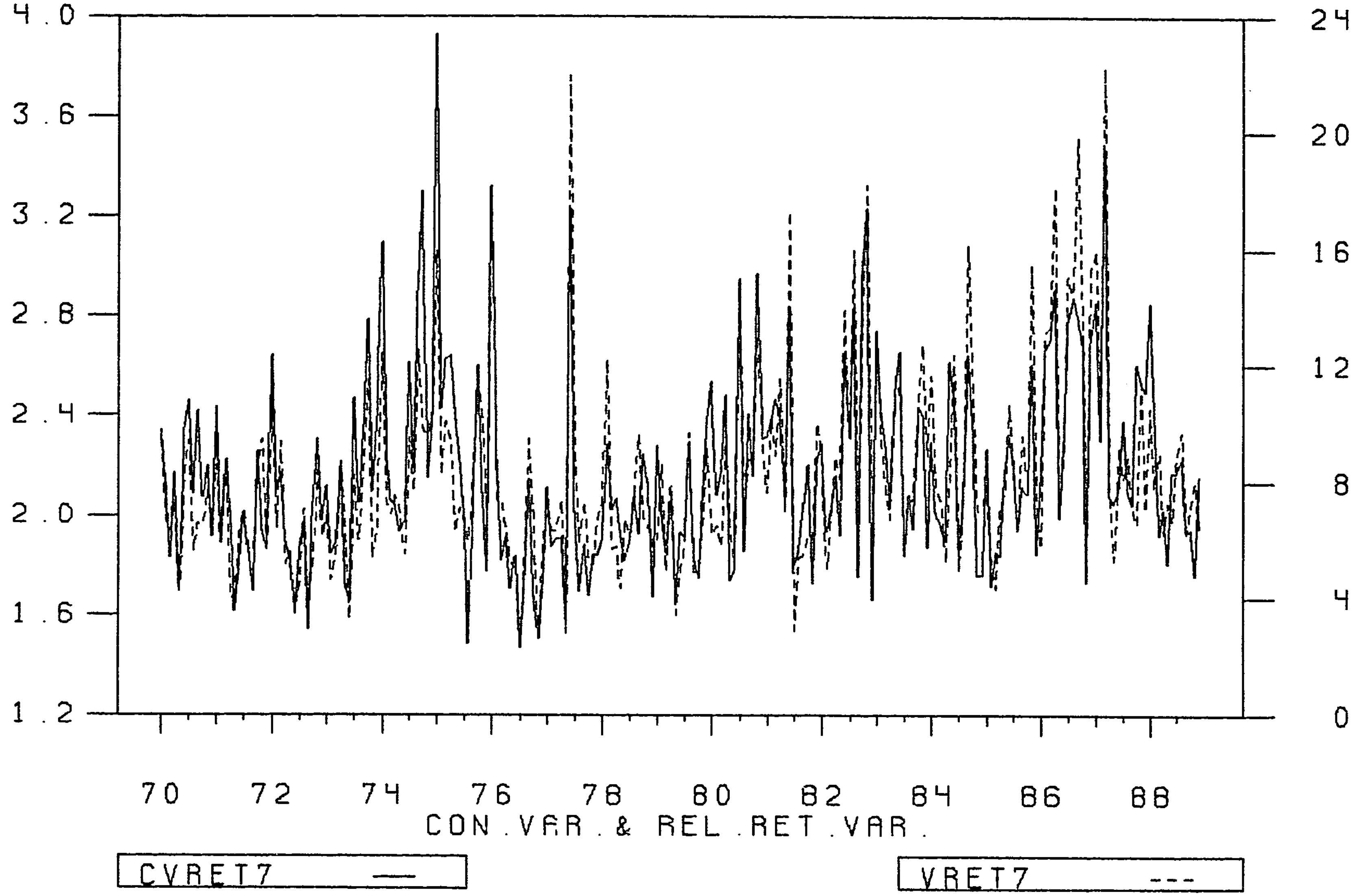


FIGURE II.8 : PRIMARY METAL

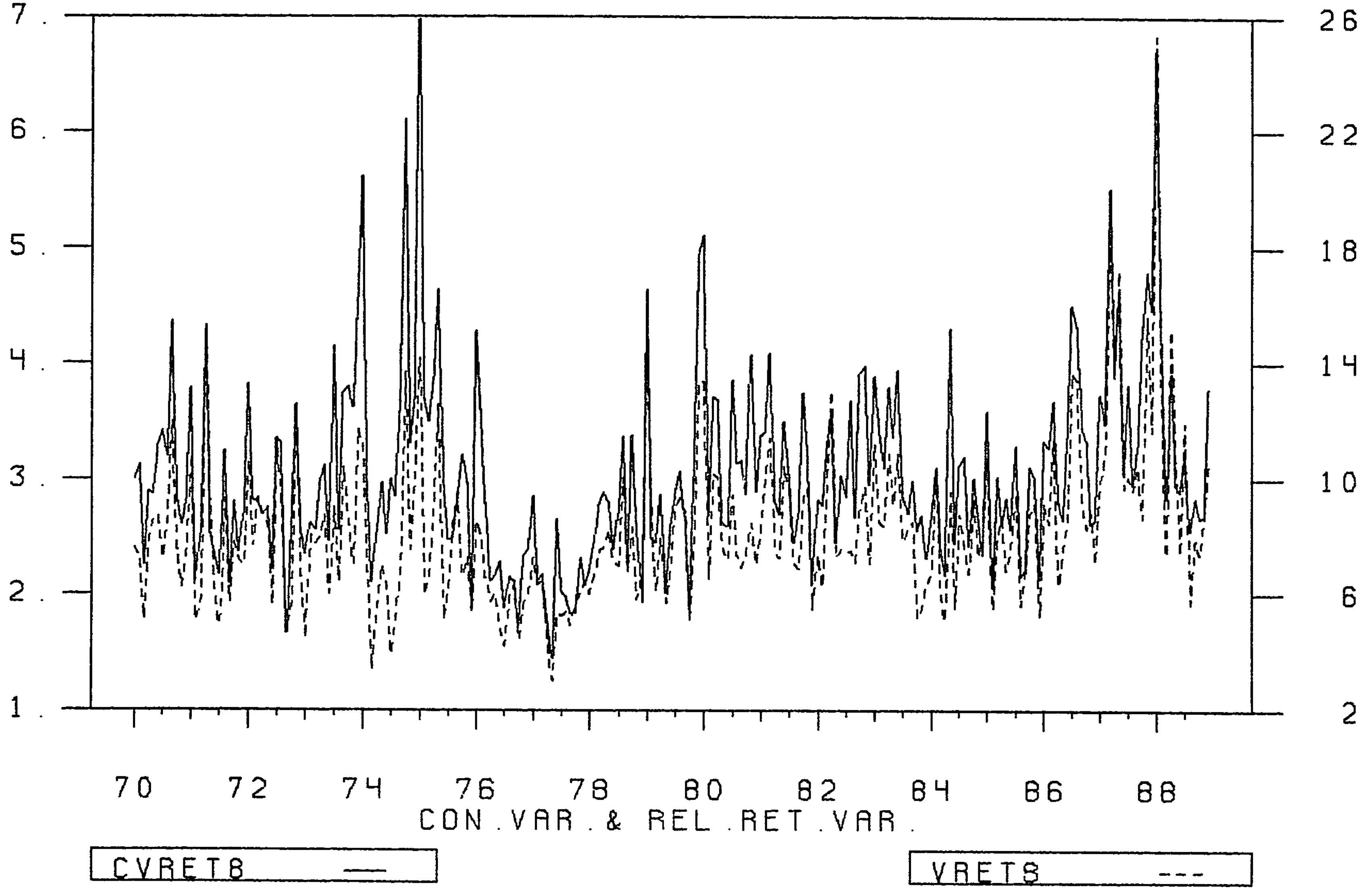


FIGURE II.9 : FABRICATED METAL

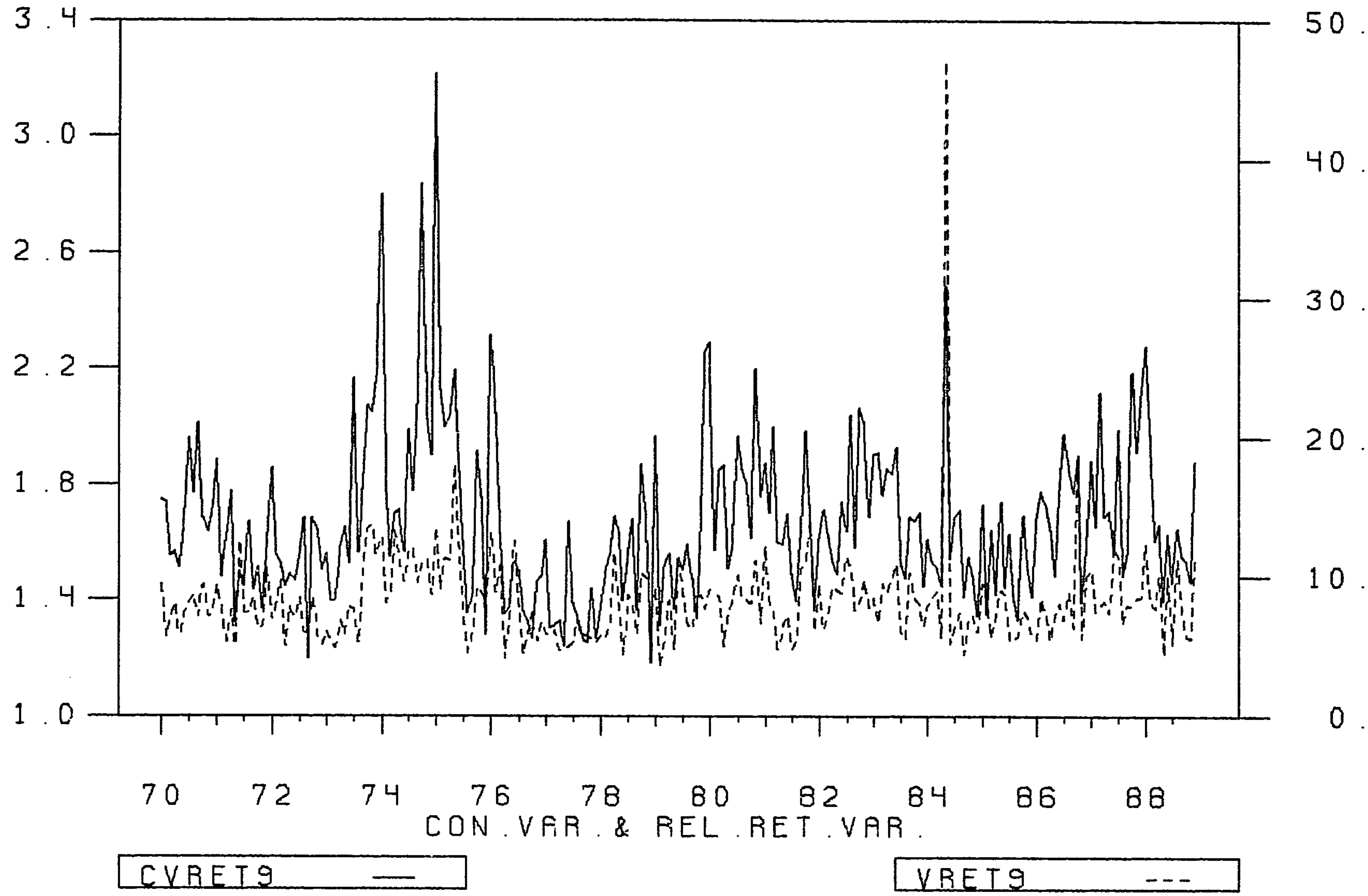


FIGURE II.10 : MACHINERY

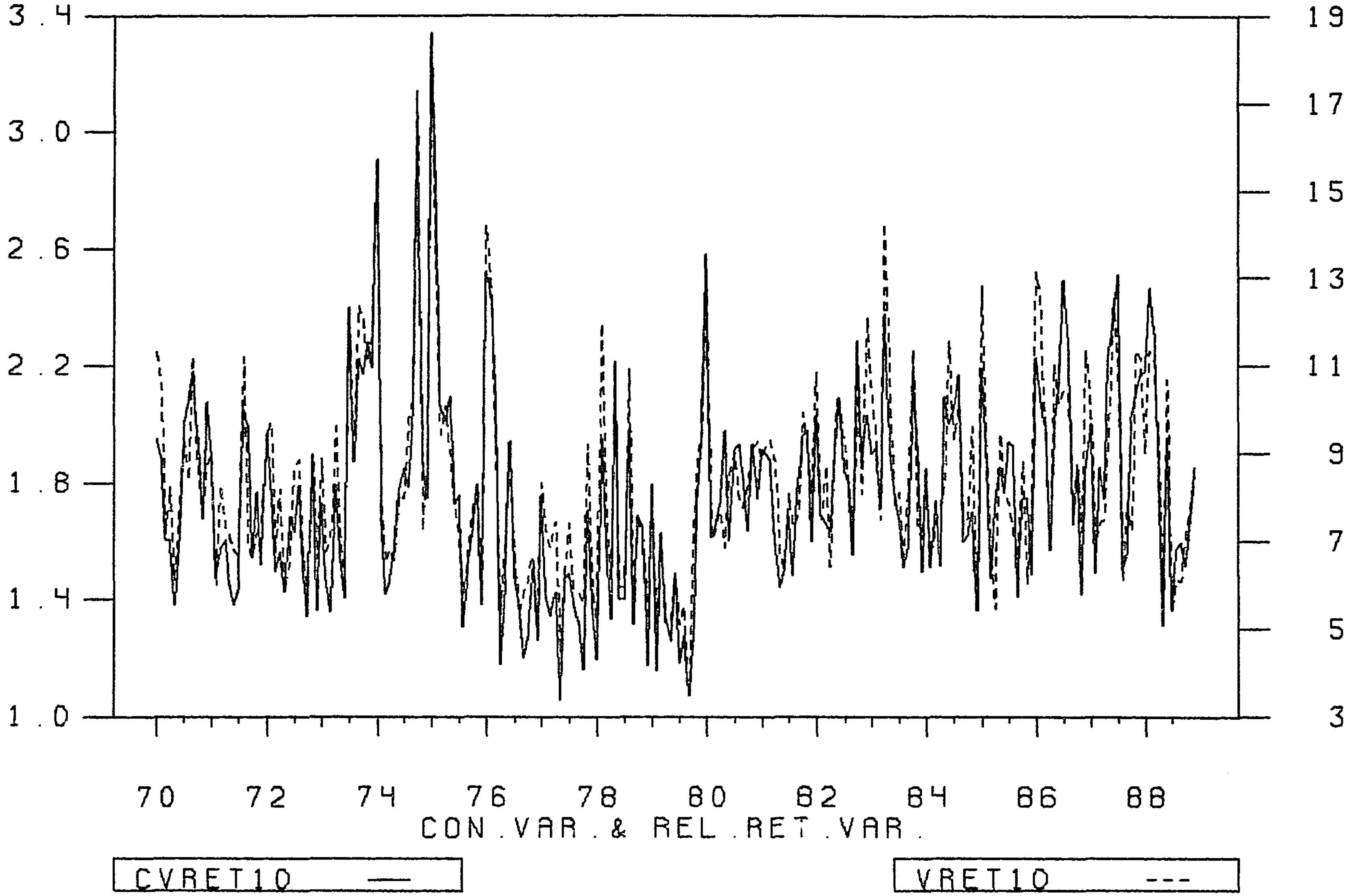


FIGURE II.11 : ELECTRONIC

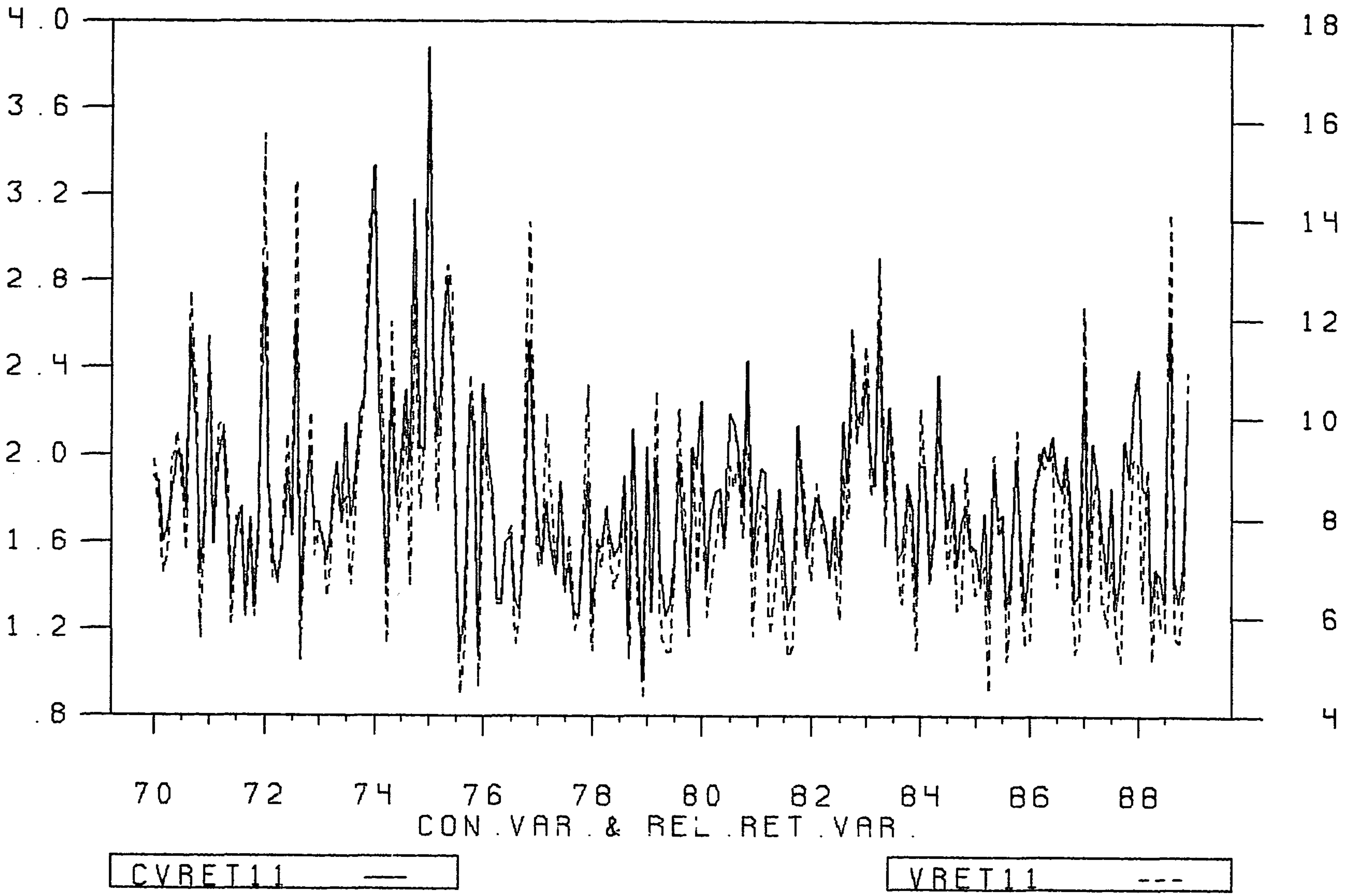


FIGURE II.12 : OTHERS IN MFG.

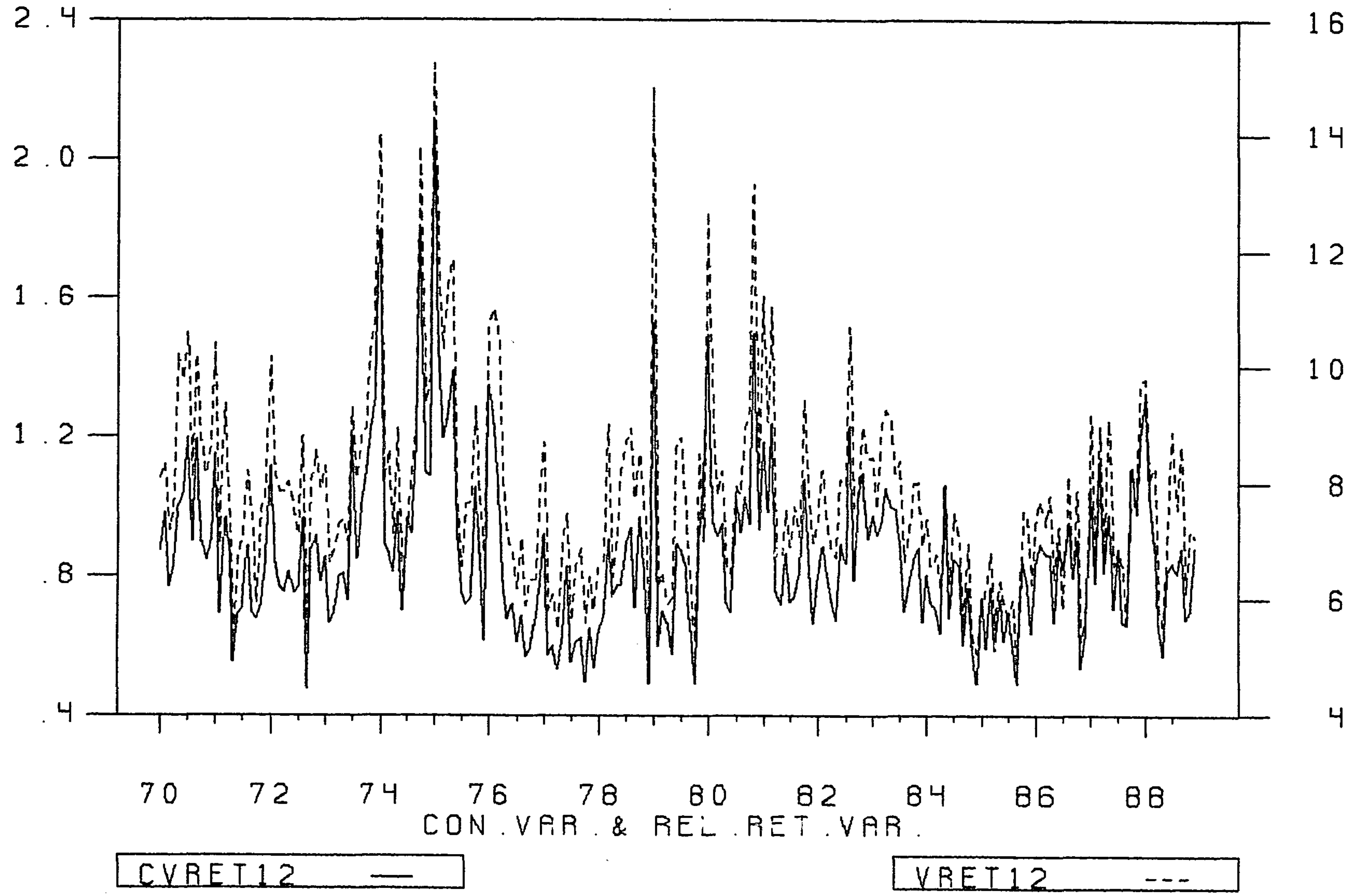


FIGURE II.13 : CONSTRUCTION

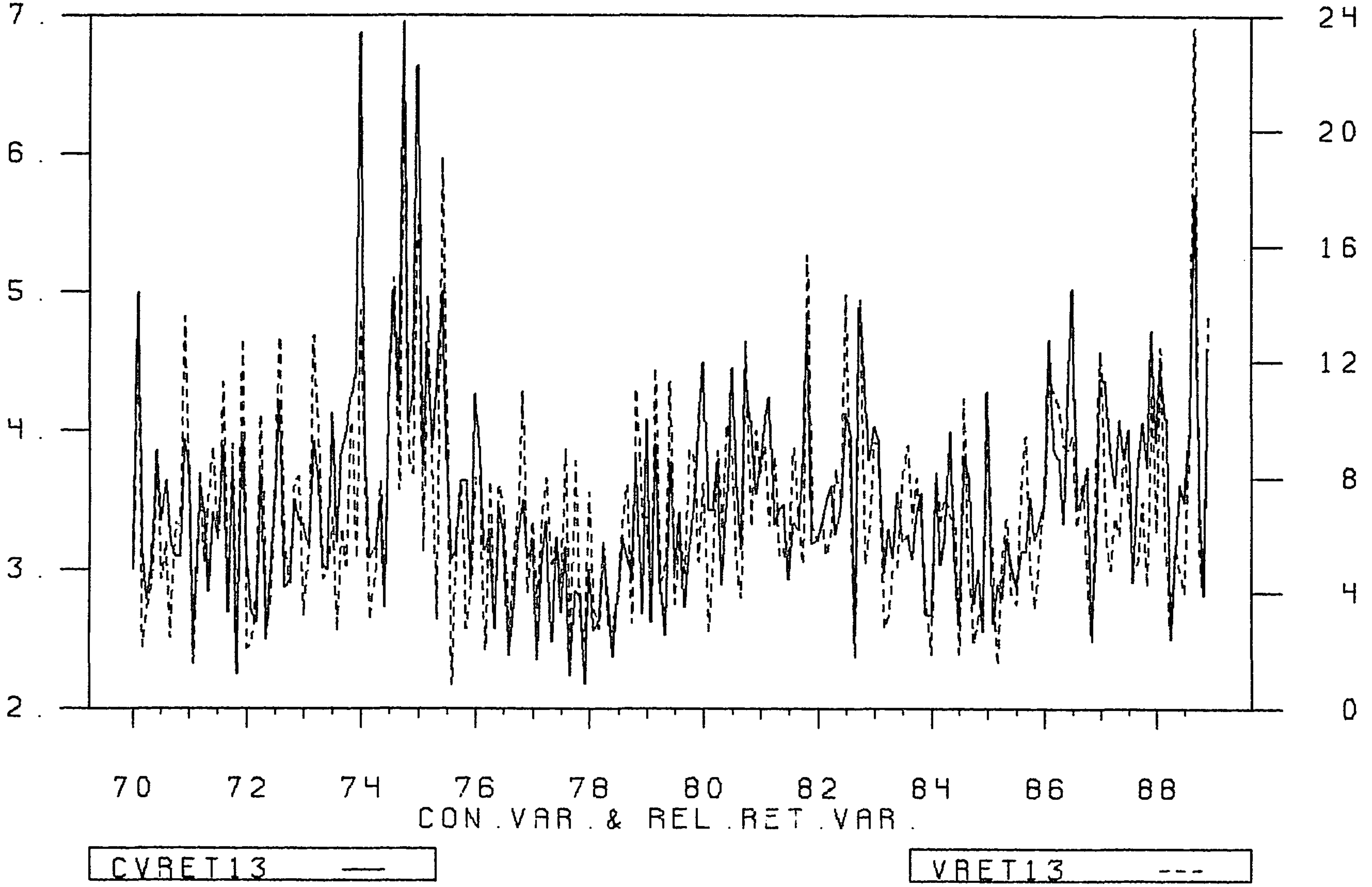


FIGURE II.14 : TRANSPORTATION

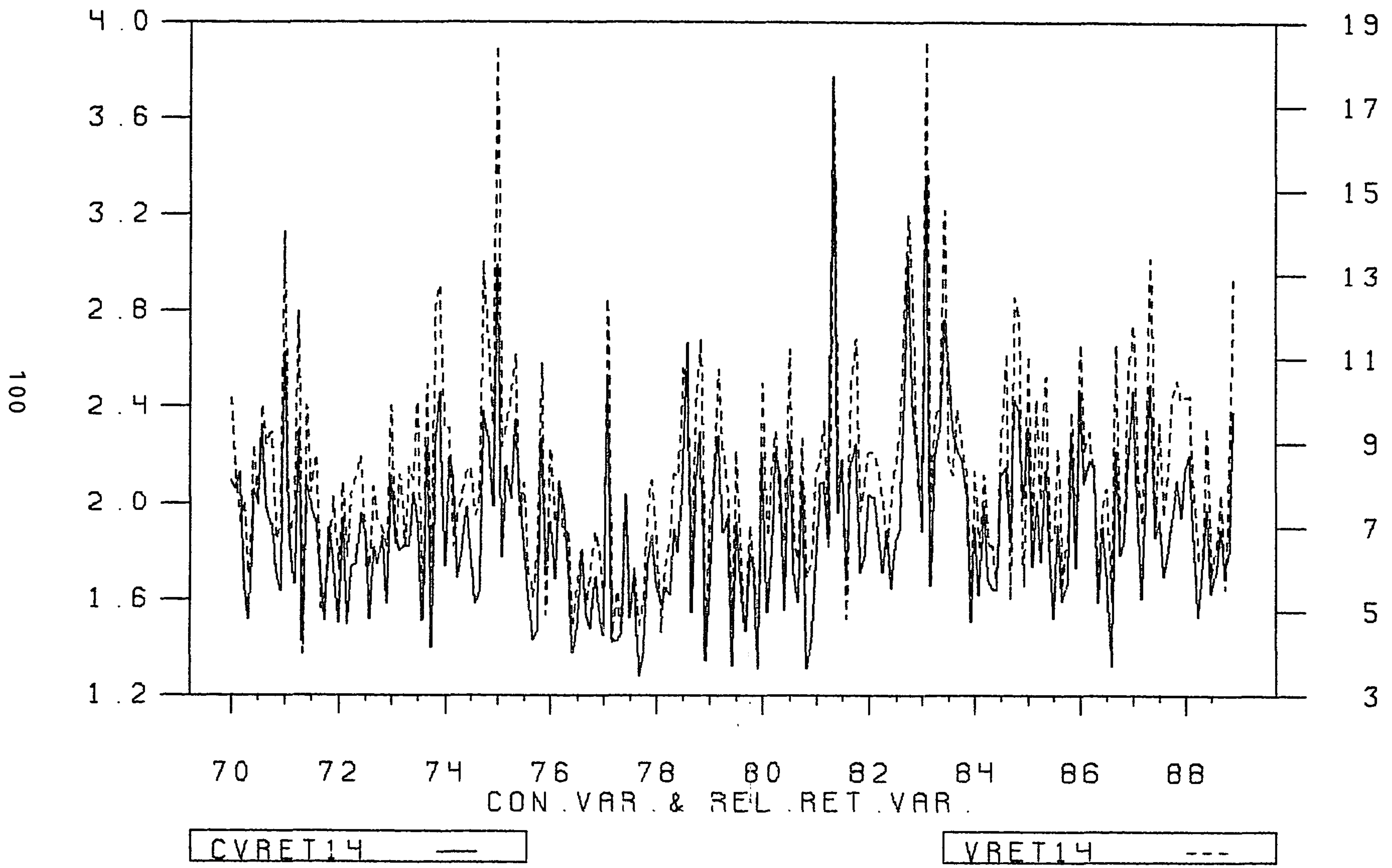


FIGURE II.15 : ELECTRIC & GAS

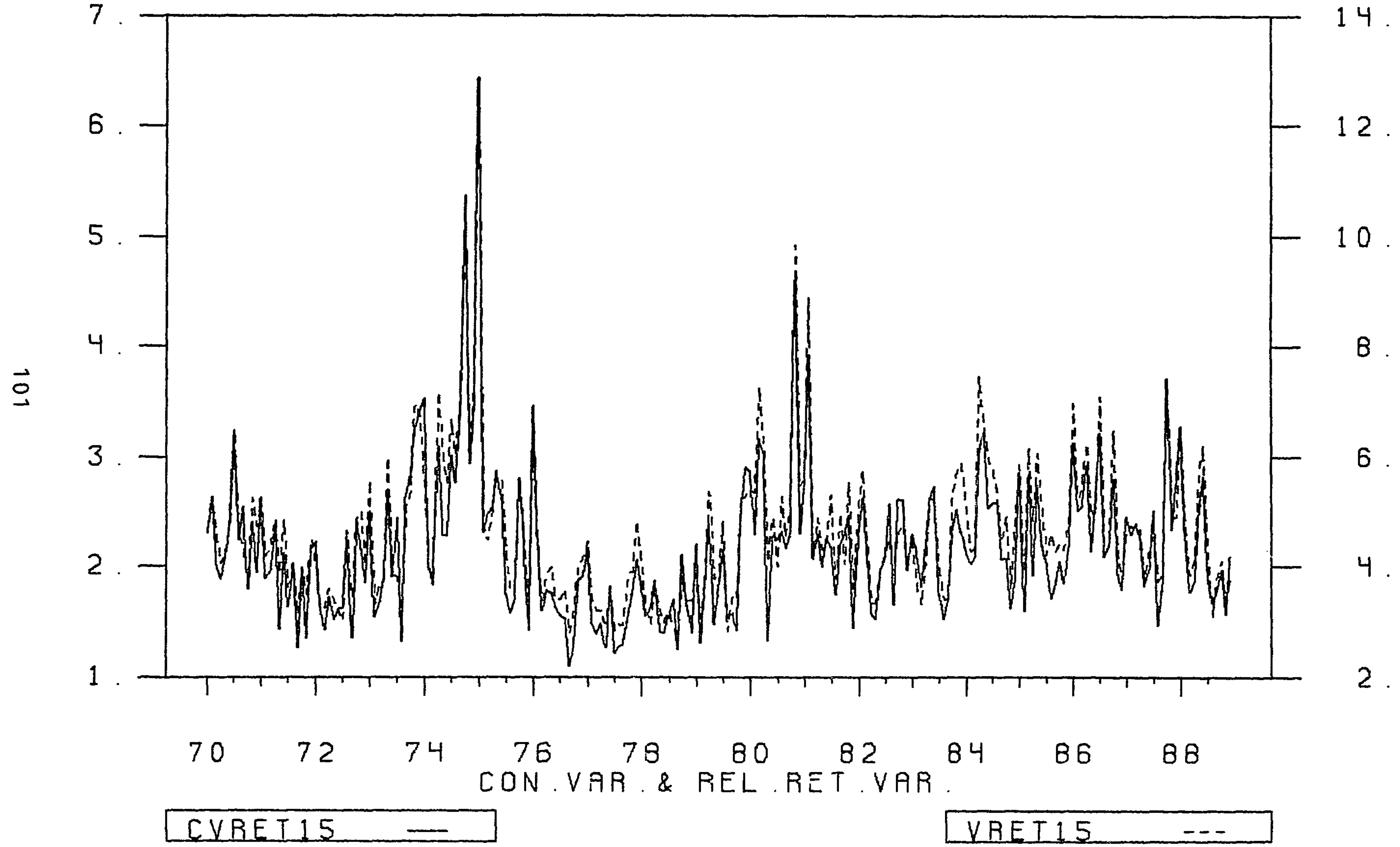


FIGURE II.16 : WHOLESALE

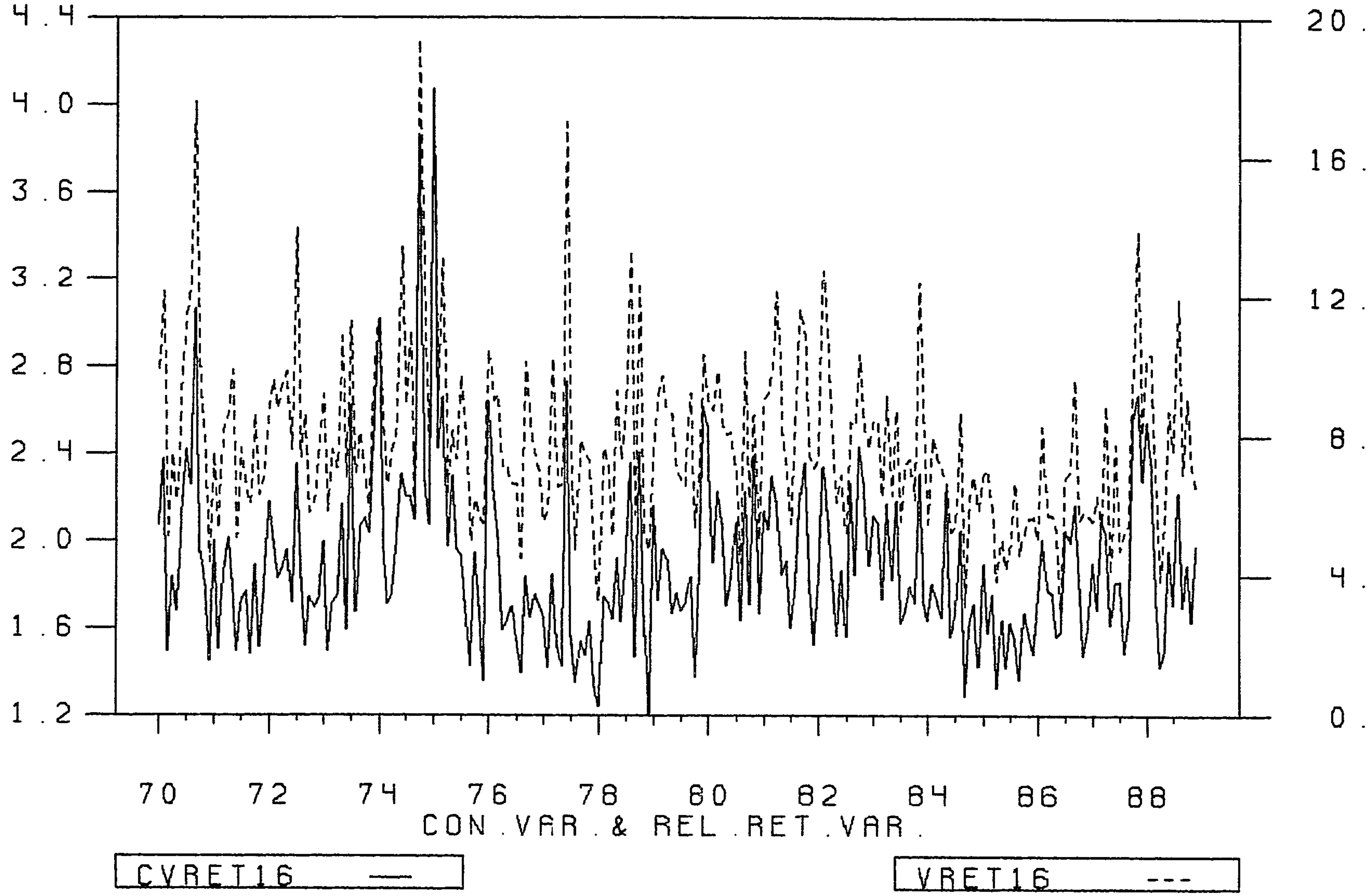


FIGURE II.17 : RETAIL

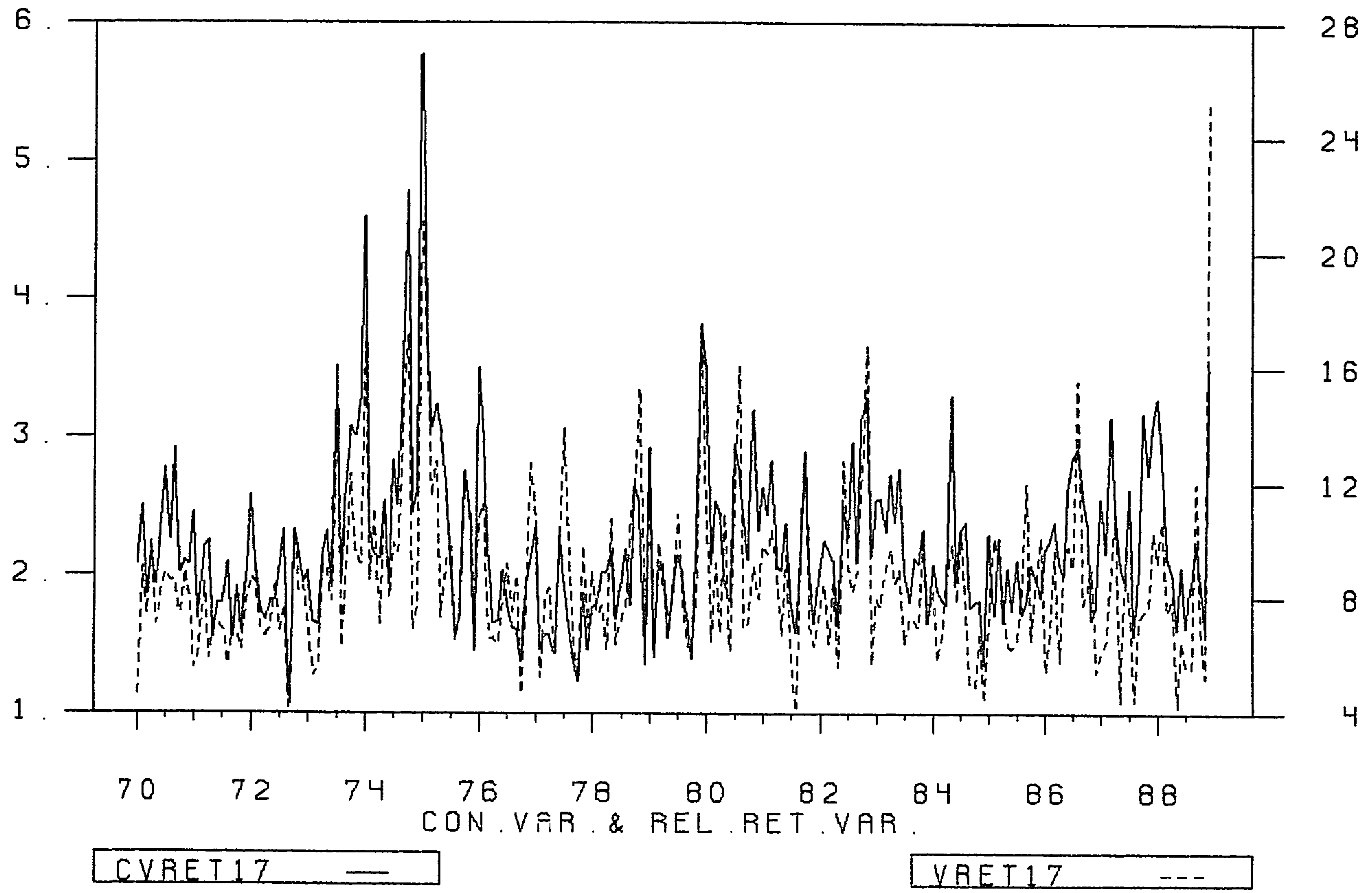


FIGURE II.18 : FINANCE

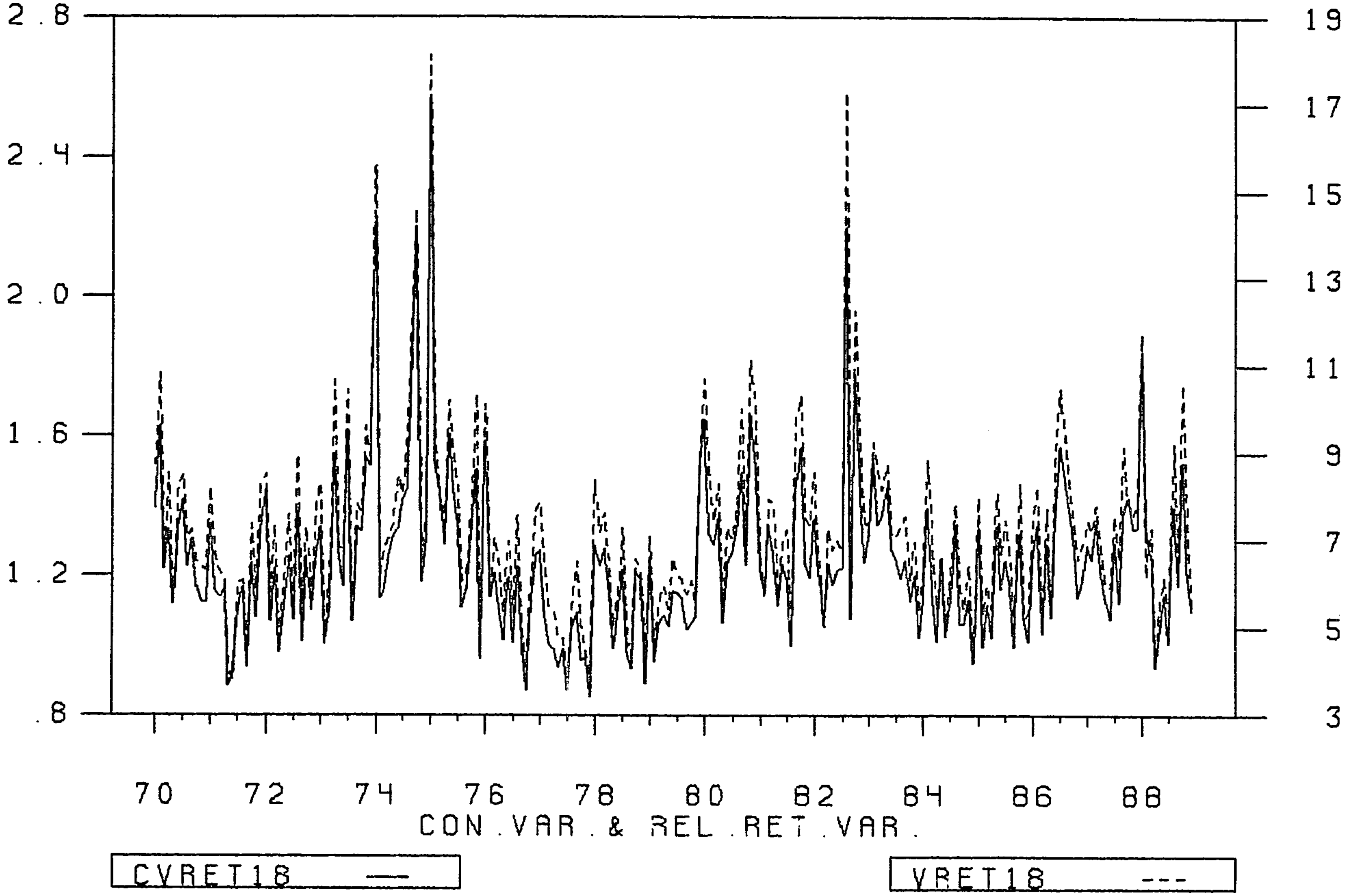


FIGURE II.19 : SERVICES

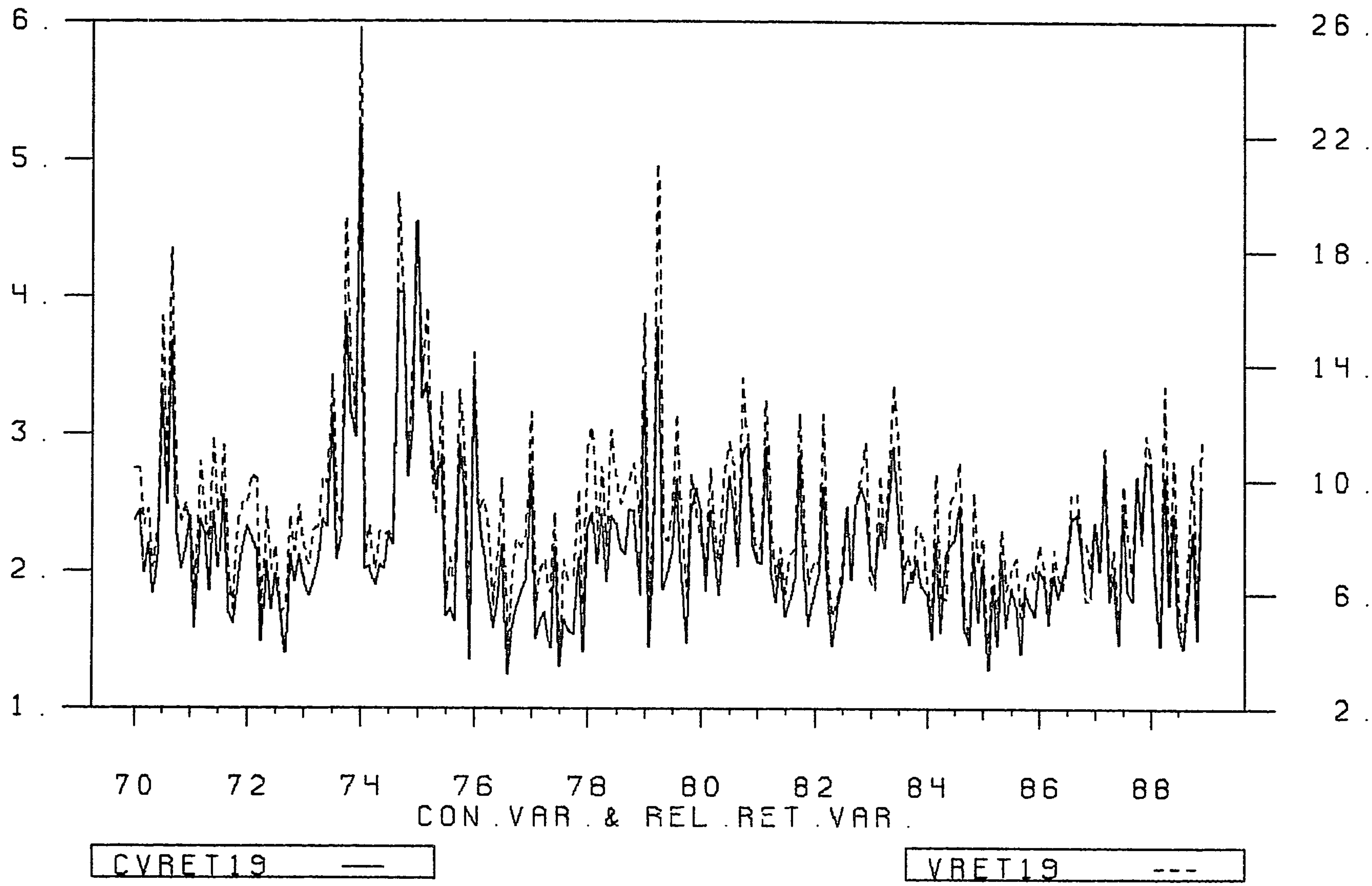


FIGURE III.1 : MINING

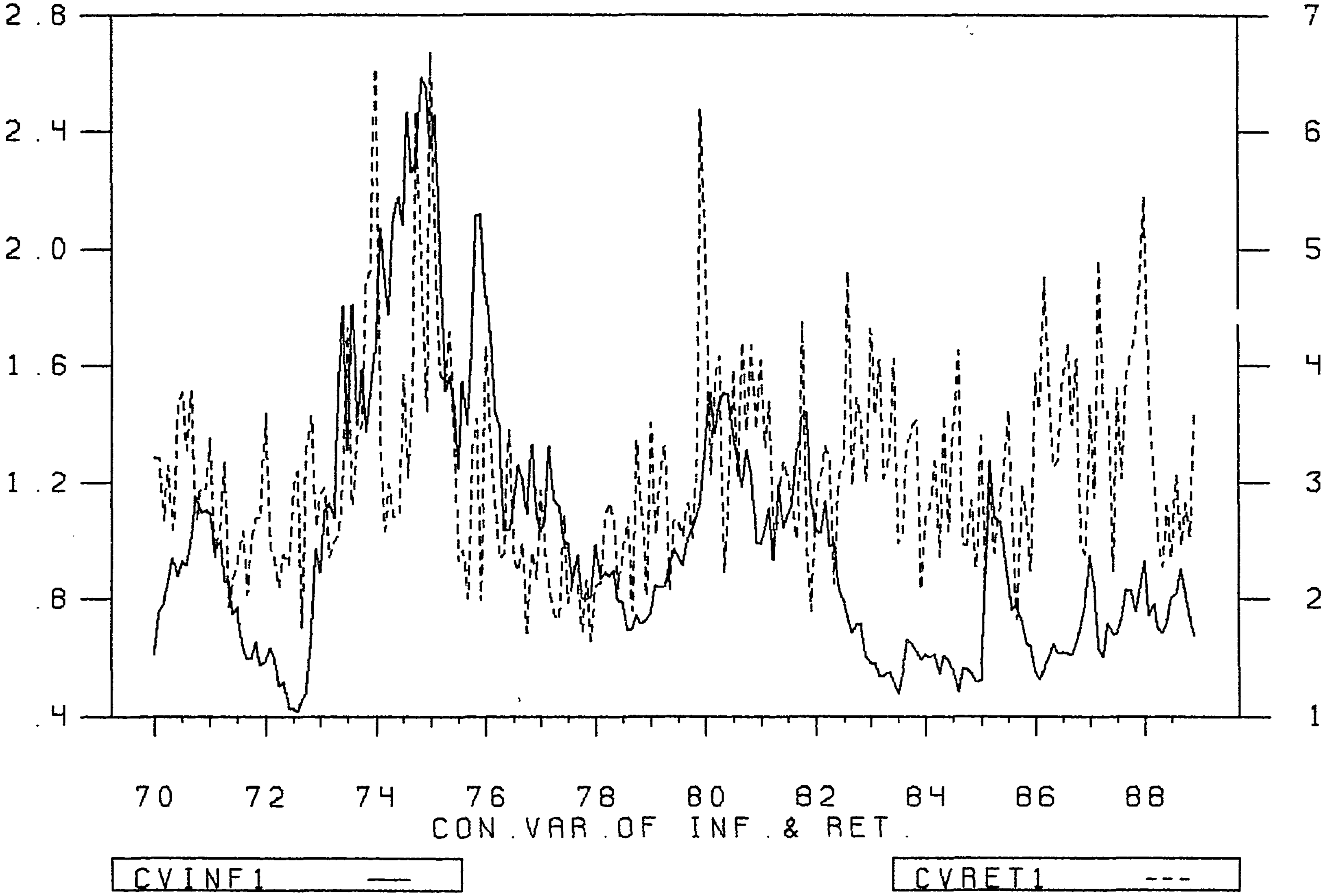


FIGURE III.2 : FOOD

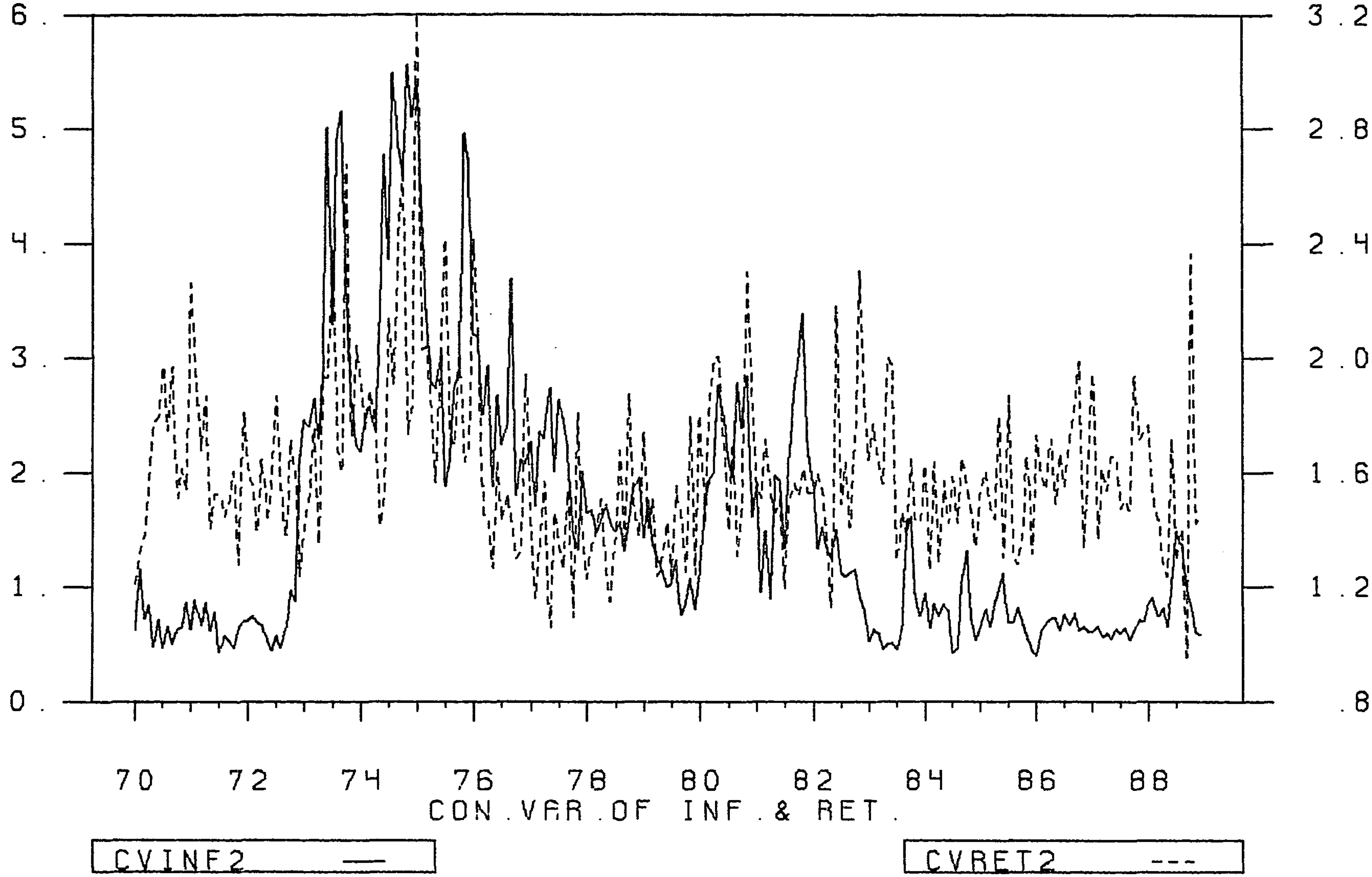


FIGURE III.3 : TEXTILE

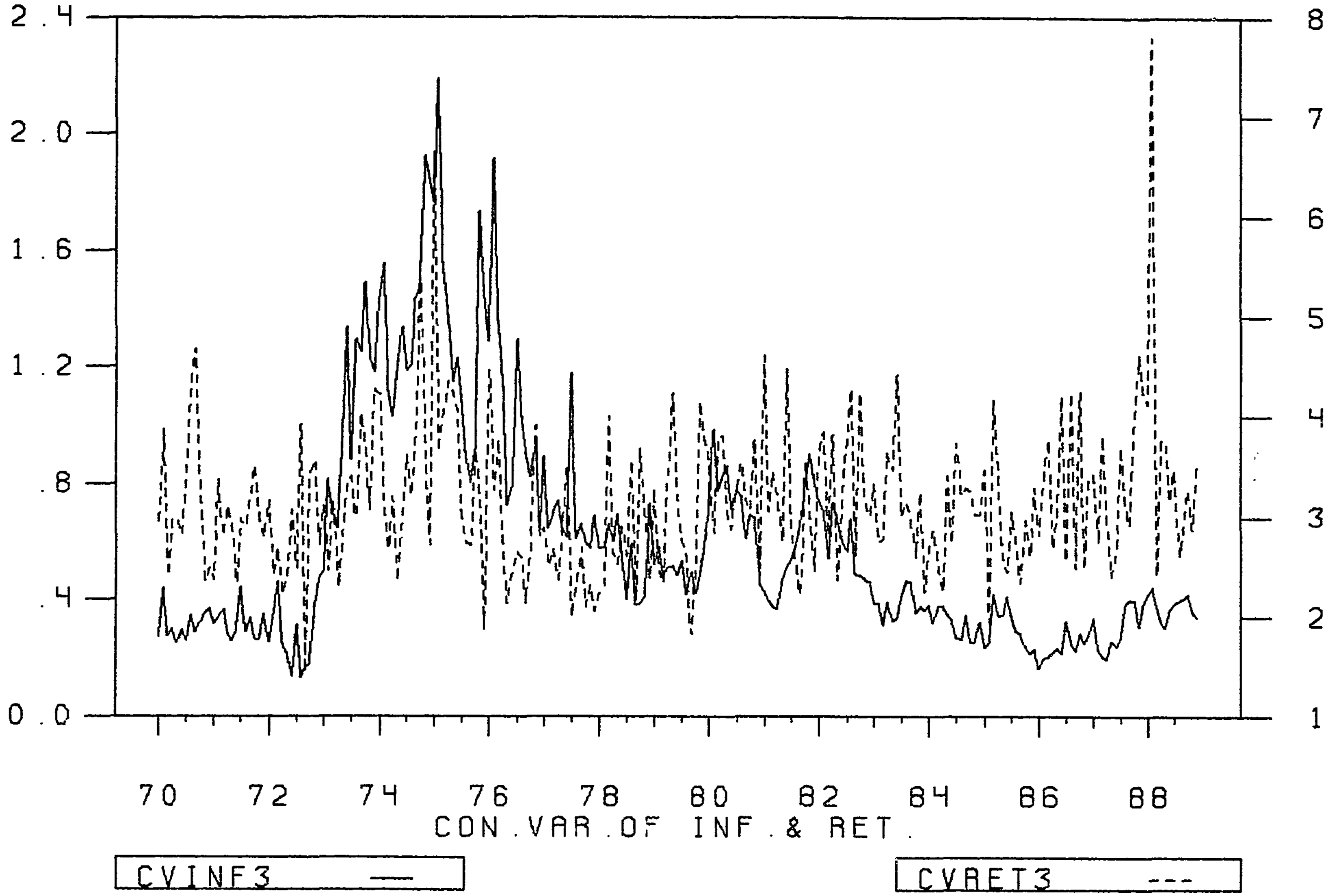


FIGURE III.4 : APPAREL

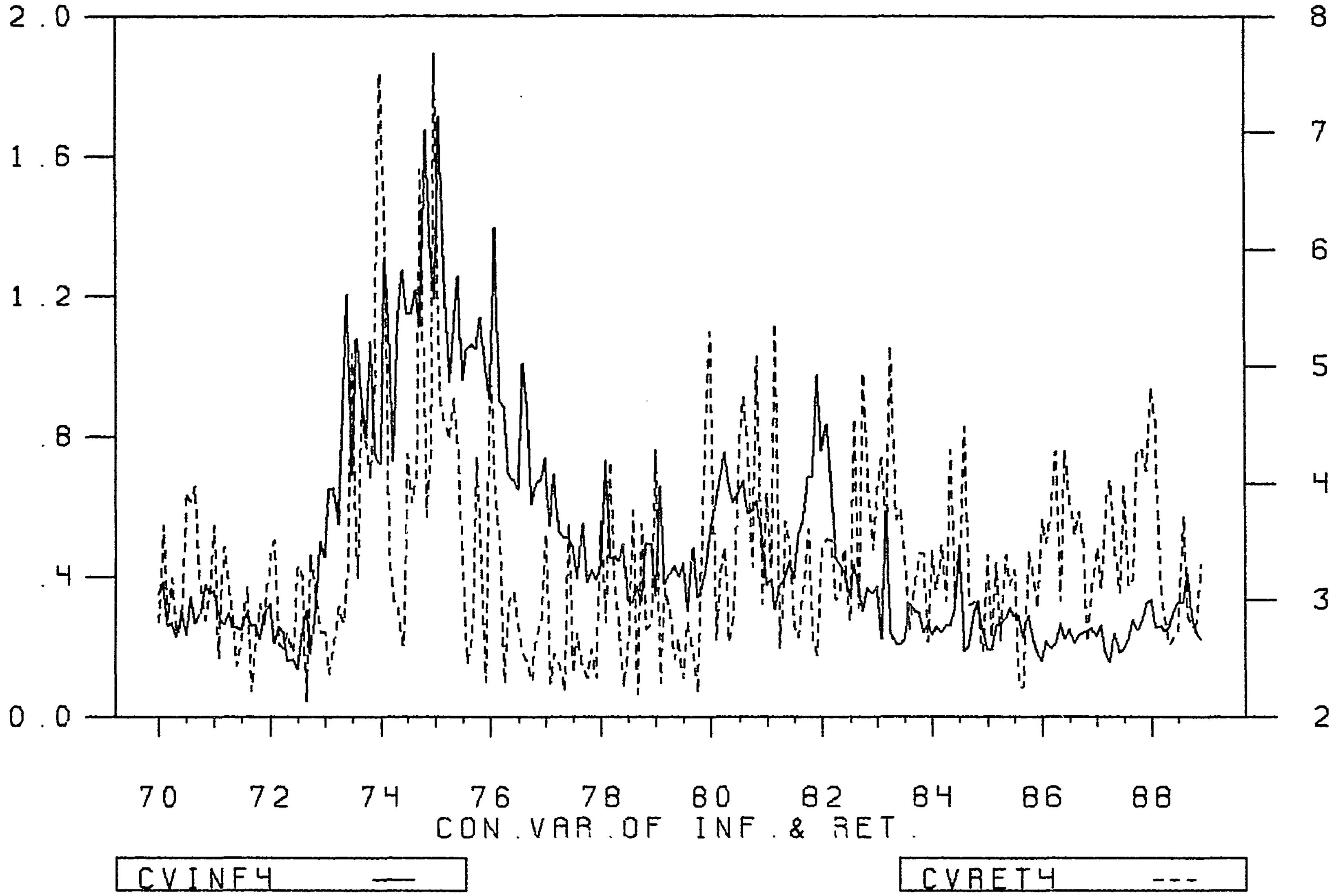


FIGURE III.5 : LUMBER

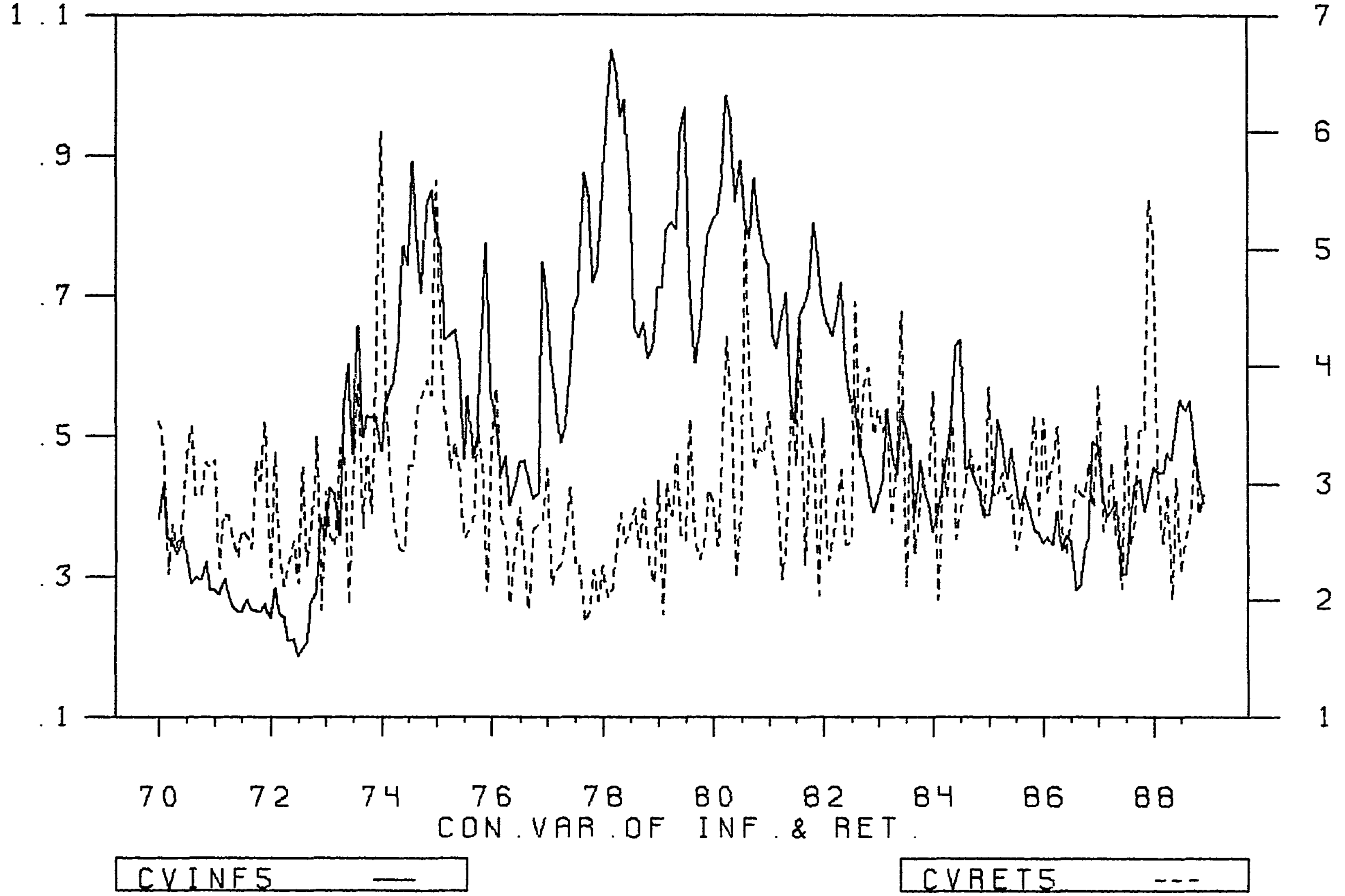


FIGURE III.6 : CHEMICALS

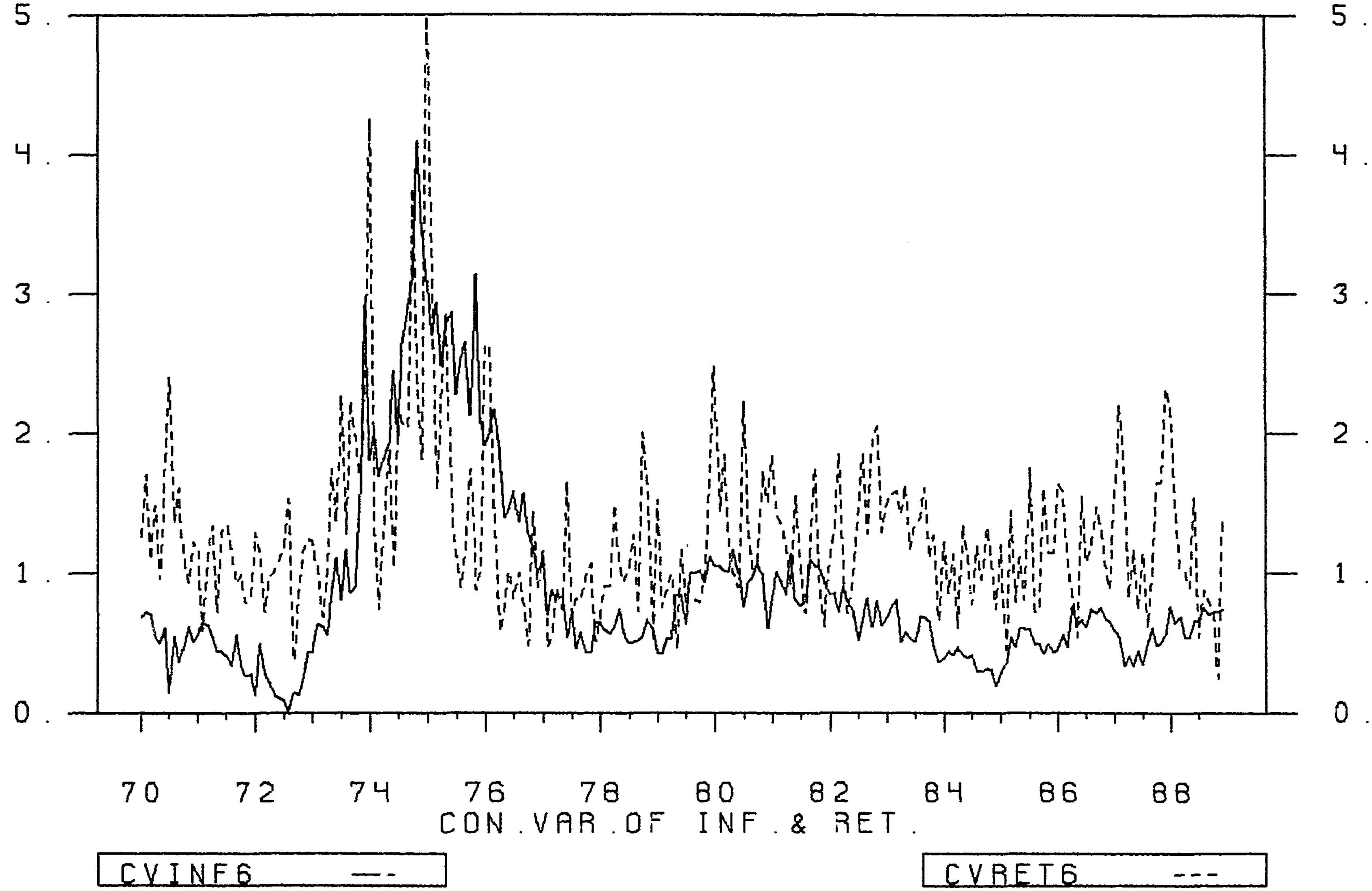


FIGURE III.7 : STONE

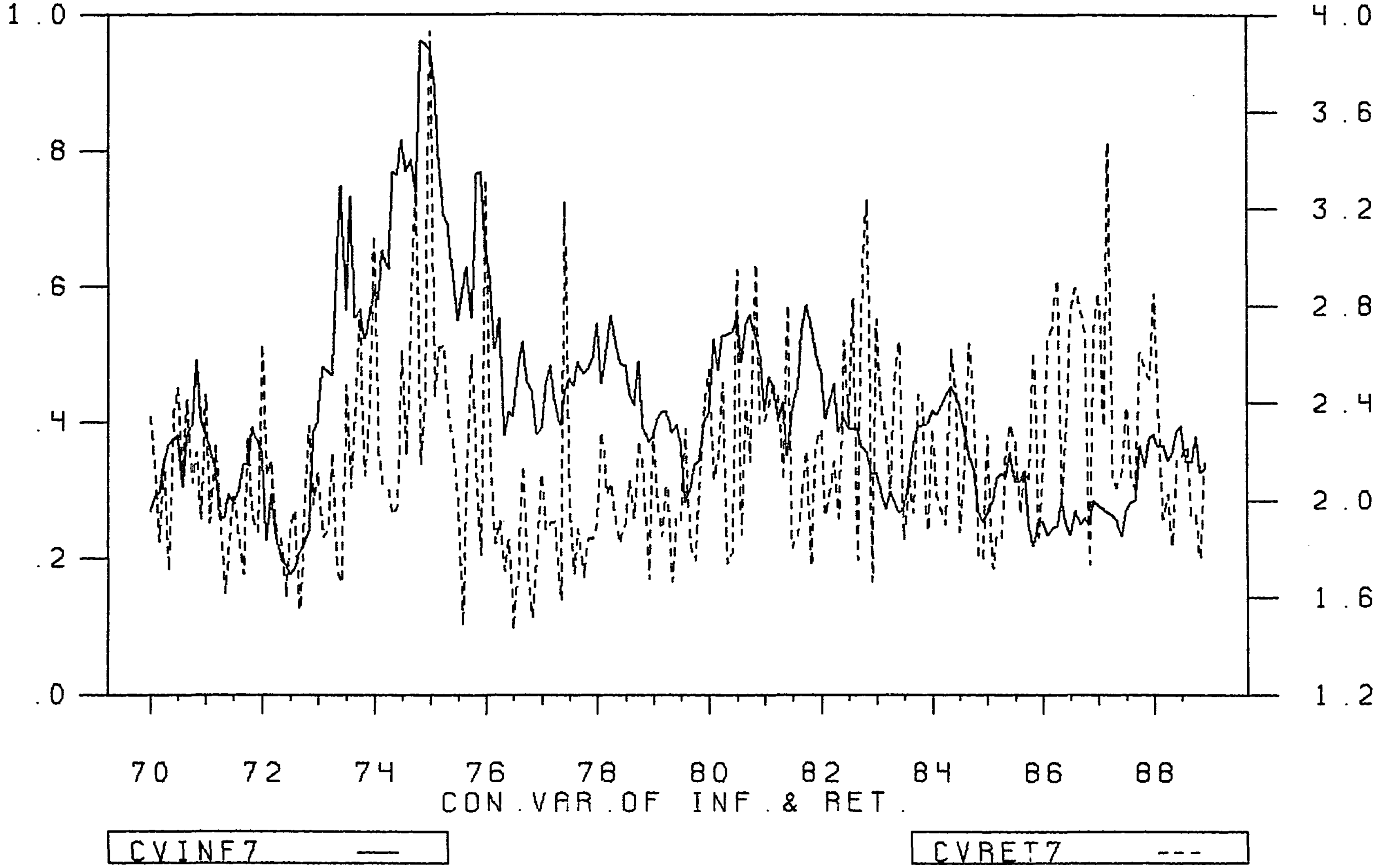


FIGURE III.8 : PRIMARY METAL

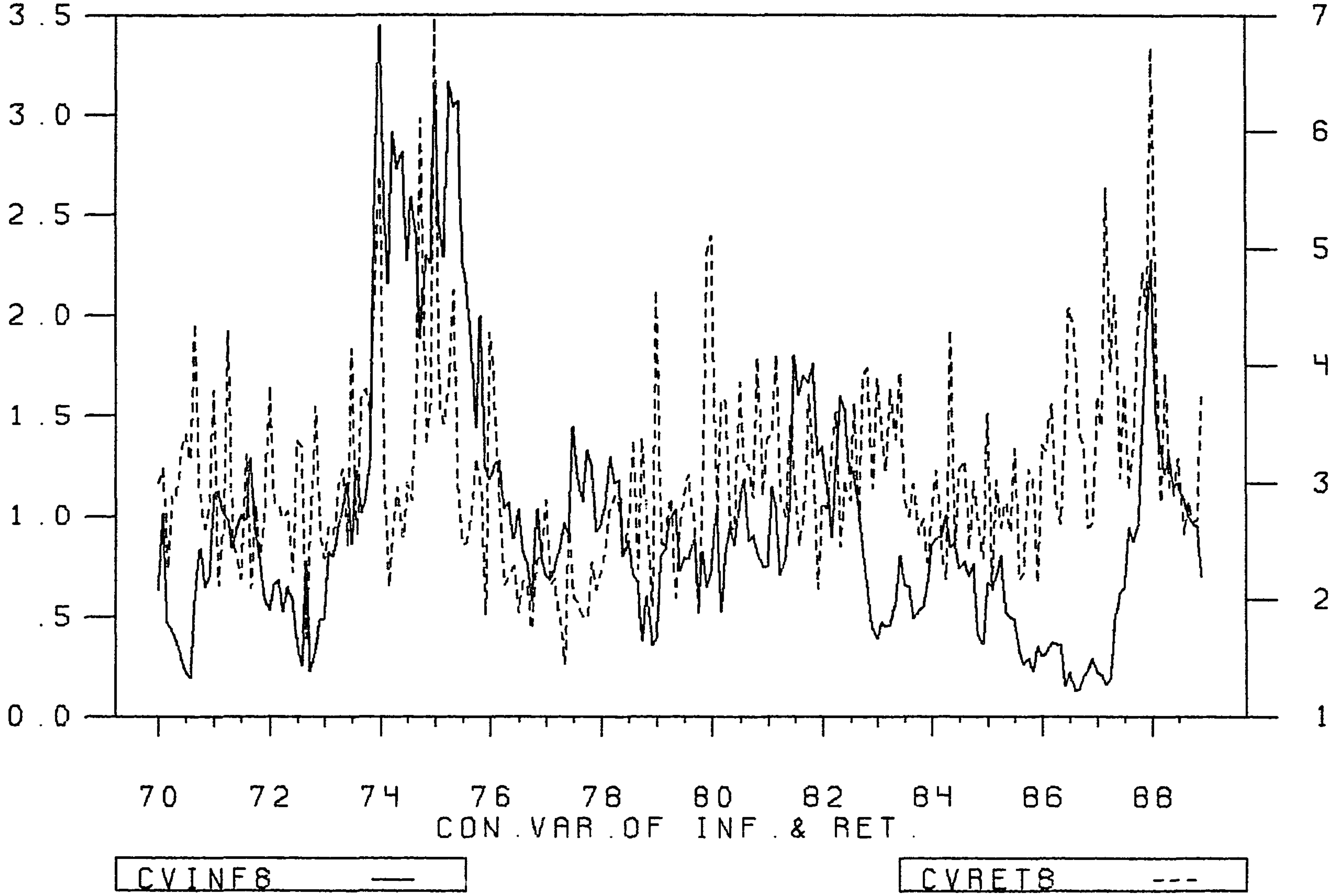


FIGURE III.9 : FABRICATED METAL

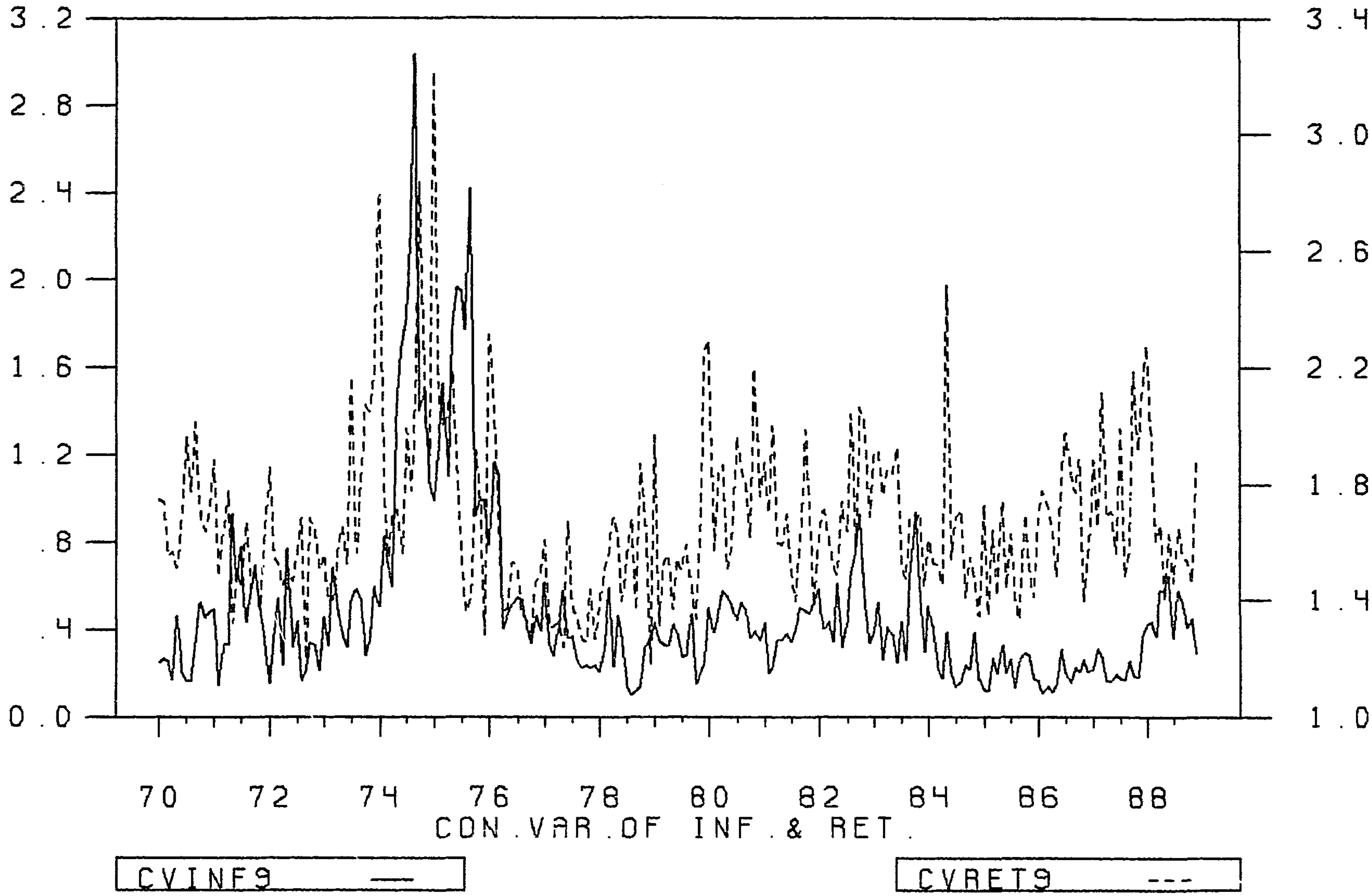


FIGURE III.10 : MACHINERY

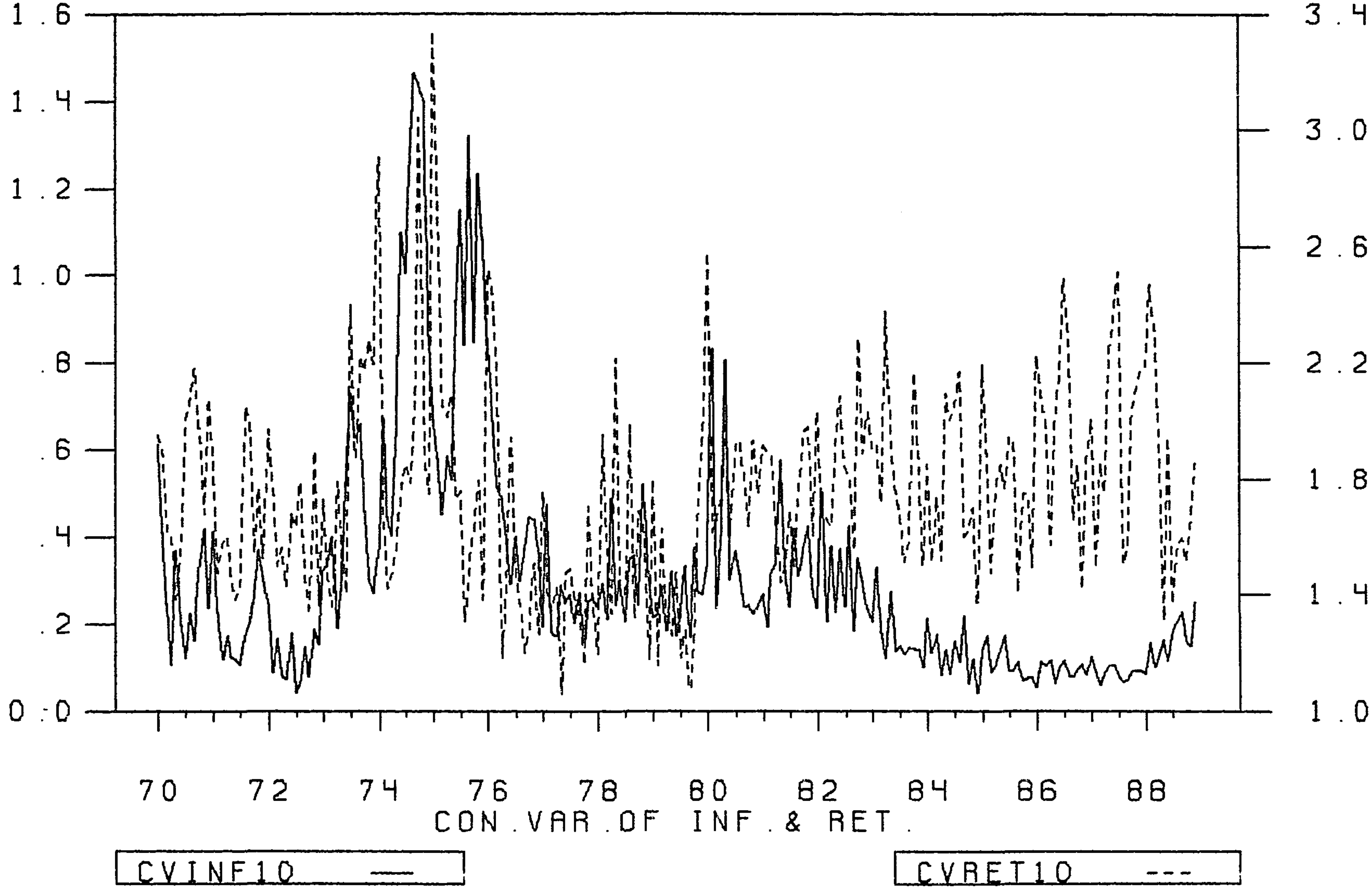


FIGURE III.11 : ELECTRONIC

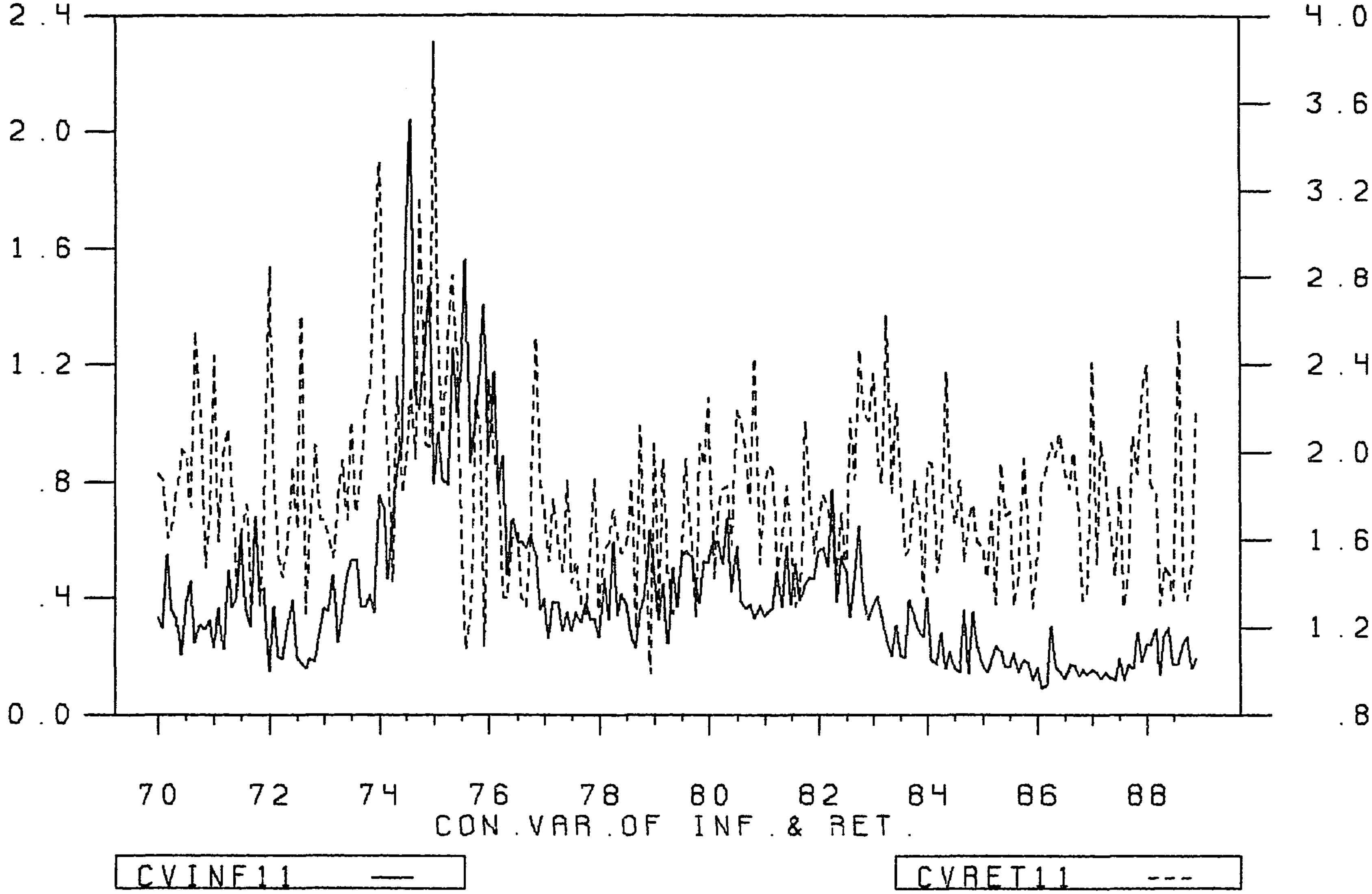
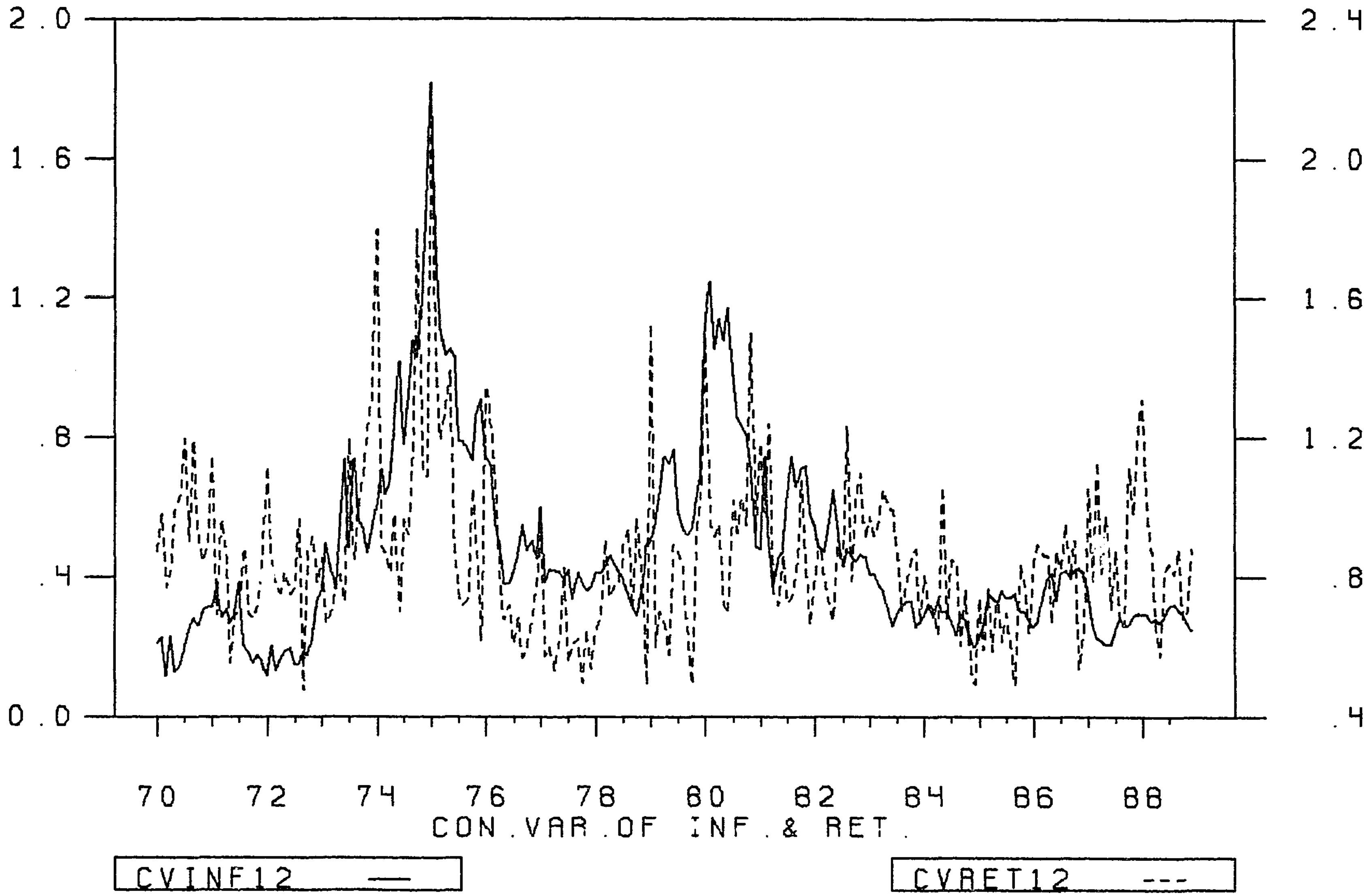


FIGURE III.12 : OTHERS IN MFG.



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