A Nonparametric Test of A Storage Theory : Japanese oil Markets

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Abstract : This paper investigates the correlation between the volatility of the price change and the past change of storage volume in the Japanese oil market. In order to investigate this relationship, a nonparametric method is used to estimate the volatility of the oil price and its partial derivative with respect to the past change of the storage. In order to compare with the nonparametric results, the parametric model is also used both to estimate the volatility and to test the relationship.

Two important features are found. First, extra high volatilities are found after the market shocks that lead both to the falls and the rises of the Japanese oil prices. Second, there is a negative relationship between the past level of the oil inventory and the volatility of the spot price change.

1 INTRODUCTION

In Japan, oil is the most important energy source in the 20 th century. The oil crisis in 1973 or in 1978 made the oil prices much volatile and had an enormous influence on the whole productive action, and this caused economical confusion in Japan. In Japan that depends on the import for the oil supply, is it possible to suppress the soaring of the oil price by an outside factor?

There are three types of risks in oil import : a risk with the fluctuation of oil prices, a risk by the expected exchange, and a supply stop risk. The first and second risks are hedged by using oil derivatives such as the futures and the options. However, the third risk occurs mainly with political factors in oil–exporting countries, so it cannot be anticipated and cannot be easily evaded with the derivatives. Indeed, the two oil crises caused by the sudden war in the Middle East various countries increased supply stop risk and caused the quantitative securing of oil traders and the purchase acts of the speculators, which made the oil price volatility increase.

The most basic means of evading the supply stop risk is Storage. Kaldor [1939] introduced a theory of storage originally. This theory shows that processors and consumers of a commodity receive some benefits, called Convenience from holding inventory that includes opportunity to benefit from unexpected supply shocks. The storage theory predicts that marginal convenience value, that is the benefit of holding inventory, is inversely related to the level of the inventory. Also, the theory implies that spot price volatility is greater at a lower level of the inventory (see French [1986]). This means that an increase in volatility of a spot price should lead to an increase in storage activity. Inversely, lower volatility is followed by larger investment in storage capacity. Actually, the past oil shocks gave the recognition that the quantitative stable securing of oil is one of the most important problems for the Japanese government. The securing of the oil quantity, which makes possible the supply of oil stable at urgent times and oil storage is placed as one of the state strategies.

Few papers regarded the storage theory, especially in Japanese commodity markets. In U.S., Susmel and Thompson [1997] analyzed the relationship between price volatility and investment in storage facilities in the natural gas industry. In the Japanese oil market, Fujiwara, Niizeki and Kumagai [1999] presented evidence that the oil spot price was cointegrated with the inventory level. However, these papers estimated spot price volatilities using a switching ARCH (SWARCH) model (see Hamilton and Susmel [1997]) and used simplified models which did not test directly the hypothesis that higher levels of volatilities are associated with increases in storage capacity.

This paper examines the relation between the price volatility and the investment of storage in the Japanese oil market, using a nonparametric method (a normal KERNEL regression model). A nonparametric method has been developed recently to estimate a regression curve without making strong assumptions about the shape of the true regression function (see Silverman [1986]). The nonparametric method is not only employed to estimate the volatility but also used to test the relationship between the volatility and the investment of the storage, which is not used in the earlier work. To prove the storage theory, earlier papers used the ordinary least squares estimation models to which the estimated volatilities were substituted. This article tests the proposed hypothesis using the KERNEL model at the same time of estimating the volatility.

Comparing to the nonparametric model, the parametric SWARCH–L model is also used both to estimate the volatility and to test the relationship predicted by the storage theory.

The analysis in this paper uses monthly data of the Japanese oil market from February 1968 to February 1999, which includes four periods when the oil market was crushed : the first oil shock in 1973, the second oil shock in 1978, the shift to the market price in 1985, and the Persian Gulf War in 1990. During the whole sample period, the negative relationship between the oil price volatility and the investment of the storage is shown, as predicted by the storage theory.

The paper is organized as follows. Section 2 provides details of a storage theory introduced by Kaldor [1939]. Two econometric methods used both to estimate the volatility and to examine the storage theory are shown in section 3. In section 4, a description of the data and details of the empirical results are presented. Finally, section 5 contains a brief conclusion.

2 STORAGE THEORY

It is Kaldor [1939] that first pointed out the relation between investment of a storage capacity and a spot price volatility in a commodity market. Kaldor aimed about the convenience of the storage that plays a role in dealing with the supply or the demand shock and set a name with Convenience Yield. Working [1949] and Brennan [1994] introduced a concept with the convenient yield into a carrying cost and assembled a theory that a basis as an expected profit is equal to the marginal value of a carrying cost. That is,

$$m(S_t)=o(S_t)+r(S_t)-c(S_t), \tag{1}$$

where m is the carrying cost, o is the coast of storage, r is the risk premium, c is the convenience yield, and S_t is the storage level at t. The marginal cost is obtained by differentiating (1) by S_t.

$$\partial m(S_t)/\partial S_t=\partial o(S_t)/\partial S_t+\partial r(S_t)/\partial S_t-\partial c(S_t)/\partial S_t. \tag{2}$$

As the expected return is $E(P_{t+1})-P_t$ is equal to the marginal cost, this equation leads to

Table 1 Japanese oil storage : reservoir type and date

Year	Civillian (Date)	State (Date)	Total Days	Civillian (%)	State (%)	Level (10,000 kl)
1972	0	0	0	0%	0%	0
1973	67	0	67	100%	0%	4250
1974	48	0	48	100%	0%	
1975	71	0	71	100%	0%	4503
1976	85	0	85	100%	0%	5391
1977	90	0	90	100%	0%	5954
1978	81	7	88	92%	8%	6074
1979	88	7	95	93%	7%	6620
1980	90	10	100	90%	10%	7018
1981	101	17	118	86%	14%	7402
1982	93	20	113	82%	18%	6670
1983	94	26	120	78%	22%	6567
1984	97	31	128	76%	24%	7036
1985	92	35	127	72%	28%	7200
1986	94	44	138	68%	32%	7338
1987	92	48	140	66%	34%	7621
1988	94	53	147	64%	36%	8113
1989	89	55	144	62%	38%	8442
1990	88	54	142	62%	38%	8443
1991	80	57	137	58%	42%	8376
1992	77	63	140	55%	45%	8420
1993	76	69	145	52%	48%	8579
1994	81	76	157	52%	48%	9041
1995	74	76	150	49%	51%	9190
1996	79	78	157	50%	50%	9575

Sources : Fujinuma, Uchida and Hasegawa [1986] and SEKIYUKOUDANN [1996].

$$E(P_{t+1})-P_t=\partial o(S_t)/\partial S_t+\partial r(S_t)/\partial S_t-\partial c(S_t)/\partial S_t, \tag{3}$$

where P_t is the spot price and $E(P_{t+1})$ is then expected value of the spot price.

The storage theory predicts that the shape of the convenience yield function is convex. That is, $\partial c(S_t)/\partial S_t>0$ and $\partial^2 c(S_t)/\partial S_t^2<0$. Namely, higher marginal convenience values at lower inventory levels are associated with greater conditional variances of spot price changes. This intuitively means that at the lower level of storage the relative scarceness with the remaining reserve quantity of the commodity is large. In this case, the additional investment of the storage capacity should make the change of the expected oil price less volatile.

This is the reason for extraordinarily high volatility at the first oil shock in 1973. At the time of the first oil shock, the convenience yield and the marginal risk premium by the supply stop risk rose rapidly because there was little oil storage for the urgency. The supply stop risk and the high volatility made increase both the civilian and the state storages (see Table 1). Indeed, at the second oil shock in 1978 the storage level was higher after the additional investment and the volatility was smaller than that of the first oil shock.

This study analyzes the hypothesis that low volatilities are associated with increases in storage capacity in Japanese oil market. The next section shows the two econometric methods both to estimate the oil price volatility and to test the hypothesis predicted by the storage theory.

3 ESTIMATION METHODS

In this section, a new econometric method, a nonparametric estimation method with a KERNEL model, is used to estimate the oil price volatility. In addition, the nonparametric method is used to estimate the partial derivative and employed to test the storage theory. These methods are also compared with a parametric estimation method using a SWARCH–L model.

3. 1 Estimation of the Volatility

The conditional variance of the oil price change, i.e. the volatility, is an unobserved value and must be estimated. A time–series model such as a model from the autoregressive conditional heteroskedasticity (ARCH) class is widely used to estimate commodity price volatilities. Susmel and Thompson [1997] employed the switching ARCH with a leverage effect (SWARCH–L) model to estimate the volatility of the U.S. gas price. A SWARCH–L model is an extended version of a standard ARCH model to take into account structural changes. However, this approach assumes a particular parametric function, which is really just an approximation of the true model. In this paper, a nonparametric regression model (a normal kernel regression (KERNEL) model) is employed to estimate the oil price volatility.

A nonparametric method has been developed recently to estimate a regression curve without making strong assumptions about the shape of the true regression function (see Silverman [1986]). This approach will be useful, especially for estimating volatility if the parametric model such as a SWARCH–L model is mis–specified and does not adequately express a complex nonlinearity in conditional variance. In addition, as the nonparametric method can estimate the volatility depending only on the data series, it is not necessary to consider a leverage effect and the problem of the structure change accounted in the SWARCH–L model.

The storage theory implies that the conditional variance of the oil price change (V^2) depends on both the price change (dP) and the storage change (dS). Then, the oil price volatility at time t can be defined as

$$V_t^2=E[Y_t^2 \mid X_t=x]-(E[Y_t \mid X_t=x])^2, \tag{4}$$

where $Y_t=(dP_t)'$ and $X_t=(dP_{t-1}, dS_{t-1})'$, respectively. Estimates of the conditional means, $E[Y_t^2 \mid X_{t-1}=x]$ and $E[Y_t \mid X_{t-1}=x]$, are obtained from the following two nonparametric regressions,

$$Y_t^2=f_1(X_t)+\nu_{1t},$$

$$Y_t=f_2(X_t)+\nu_{2t},$$

where ν_{1t} and ν_t are disturbances.

The standard nonparametric regression model is

$$Y_t=f(X_t)+\nu_t, \quad t=1, \ldots, T \tag{5}$$

where Y_t is the dependent variable, X_t is a vector of regressors, and ν_t is assumed to be *iid* with mean zero and finite variance.

The aim is to obtain nonparametric estimates of $f(X_t)$ at a point x which implies the estimation of $E[Y_t \mid X_t=x]$. Estimates of $f(X_t)$ are given as

$$\hat{f}(x)=\sum_{t=1}^{T} W_t(x)Y_t, \tag{6}$$

where $W_t(x)$ is a weight function. To estimate the regression function, KERNEL is used, that is, $W_t(x)$ is given by

$$W_t(x)=K(w_t)/\sum_{t=1}^{T} K(w_t), \tag{7}$$

$$w_t=(X_t-x)/h, \tag{8}$$

where $K(w_t)$ and h represent the kernel function and the band–width, respectively.

In this study, the normal kernel function is used for $K(w_t)$ which is given as

$$K(w_t)=\frac{1}{\sqrt{2\pi}}\exp\left(-\frac{w_t^2}{2}\right). \tag{9}$$

Further, the choice of h which minimizes the mean squared error is proportional to $T^{-\frac{1}{4+p}}$ where T denotes the sample size and p is the number of the regressors (see Silverman [1986]). It is important to note that the kernel estimator will be consistent and asymptotically normal. In addition, as can be seen from (6), the regression at each x is a weighted average of linear functions. Hence, an advantage of the nonparametric regression is that the statistical properties of the estimator can be worked out with standard techniques.

Given X_t is assumed to be strictly stationary and strong mixing to obtain the appropriate asymptotic properties, $f_1(X_t)$ and $f_2(X_t)$ can be estimated with the nonparametric estimates given as (6). That is, (4) can be estimated using

$$\hat{V}_t^2 = \frac{\sum_{t=2}^{T}(X_t)^2 K(w_t)}{\sum_{t=2}^{T} K(w_t)} - \left(\frac{\sum_{t=2}^{T} X_t K(w_t)}{\sum_{t=2}^{T} K(w_t)}\right)^2, \tag{10}$$

where $K(w_t)$ is the normal KERNEL function (9).

3. 2 Test of the Storage Theory

As the regression function at each x is easily defined as an expectation and density function involving weighted sums in the KERNEL method, the nonparametric regression formula is available for estimating not only the conditional variance but also the partial derivatives of the regression function with respect to the regressors. In particular, the first order derivative is just similar to estimating the regression coefficient.

In this paper, a nonparametric derivative procedure with the KERNEL model is applied to estimate the first order derivative of V_t^2 with respect to dS_{t-1}, in order to investigate the relation between the conditional variance and the past inventory change, as discussed in the storage theory.

Using the KERNEL model, the first order derivative of V_t^2 with respect to X_t can be estimated. For $\partial V_t^2/\partial X_t$, the estimator $(\hat{\beta}_t)$ is

$$\hat{\beta}_t(x) = \sum_{t=1}^{T}(1-2C)AY_t^2,$$

$$A = \left(\frac{w_t \sum_{t=1}^{T} K(w_t) - \sum_{t=1}^{T} w_t K(w_t)}{h\left(\sum_{t=1}^{T} K(w_t)\right)^2}\right) K(w_t),$$

$$C = \frac{K(w_t)}{\sum_{t=1}^{T} K(w_t)}, \tag{11}$$

where w_t is given by (8).

In addition, the average derivatives can be calculated as

$$\hat{\beta} = \frac{1}{T}\sum_{t=1}^{T} \hat{\beta}_t(x), \tag{12}$$

which is consistent and asymptotically normal, which means that this value can be used in the same way as the estimated coefficient of the parametric regression model (see Rilstone [1991]).

The storage theory predicts that a high volatility is followed by a low level of storage and that the volatility is negatively correlated with the past inventory change. The hypothesis can be formally tested with the hypothesis that $\hat{\beta} < 0$ where $X_t = dS_{t-1}$ and $Y_t = dP_t$.

In this study, the SWARCH-L model developed by Hamilton and Susmel [1994], which takes into account changes in regime and leverage effects is used to estimate the oil price volatility. The discrete-time specification used to estimate the volatility (V_t^2) is the following SWARCH-L(K, q) process :

$$
\begin{aligned}
&Y_t = \alpha + \psi Y_{t-1} + u_t,\\
&u_t = \sqrt{g_{s_t}}\,\tilde{u}_t,\\
&\tilde{u}_t = V_t e_t \quad e_t \sim i.i.d.,\\
&V_t^2 = a_0 + \sum_{i=1}^{q} a_i \tilde{u}_{t-i}^2 + bX_t + \xi d_{t-1}\tilde{u}_{t-1}^2, \qquad (13)\\
&\textit{where} \qquad d_{t-1} = \begin{cases} 1 & \tilde{u}_{t-1} \leq 0 \\ 0 & \tilde{u}_{t-1} > 0. \end{cases}
\end{aligned}
$$

In the above equation, Y_t is the oil price change (dP_t), X_t is the inventory change (dS_{t-1}), V_t^2 is the conditional variance (volatility), $\xi d_{t-1}\tilde{u}_{t-1}^2$ is the leverage effect, and g_{s_t} is the switching parameter. The state of the industry, s_t evolves according to a Markov transition matrix and the possible number of states at t is K (see Fujiwara, Niizeki and Kumagai [1999]).

As the parameter $\hat{\beta}$ in the nonparametric estimation method (12) corresponds to the parameter b in the parametric model (13), the hypothesis that the oil price volatility is negatively related to the storage change can be formally tested $b < 0$. To prove the storage theory, the earlier paper used an ordinary least squares estimation model to which the estimated volatility by the SWARCH-L model was substituted (for example, Susmel and Thompson [1997]). When estimates of volatilities obtained from the SWARCH-L method are used, the estimation procedure suffers from a generated regressor problem (see Pagan [1986]). In this article, however, the proposed hypothesis is investigated using the above two estimation methods at the same time of estimating the volatilities.

4 EMPIRICAL TESTS

In this section, some empirical results are presented. First, the volatilities of price changes are estimated using the two methods in the section 3 and are compared with each other. Next, the relationship between the estimated volatility and the past storage change is examined by the two econometric tests, corresponding to the two estimation methods, respectively.

4. 1 Data

All of the data, the change of the oil import price (dP) and the volume change of the storage (dS), are monthly data series in the Japanese oil market. In this article, the volume of the storage at time t (S_t) is used as a measure of the storage capacity. Avoiding the influence of the change of the exchange rate, the oil import price evaluated in dollars is used for the oil price at time t (P_t). The data series are taken from the *Nikkei NEEDS Data*, SEKIYUKOUDANN [1996], and SEKIYURENNMEI [1999]. The data run from February 1968 to February 1999, and contains 371 data series for dP_t and dS_t. As the period being investigated includes a dramatic decline of the Japanese oil price : the first oil shock on October in 1973, the second oil shock on October in 1978, and the Persian Gulf War on August in 1990, it is appropriate to consider structural change. Figure 1A and Figure 1B show the level of the oil price (P) and the change of the price (dP), respectively. The level of the storage volume (S) and the change of the volume (dS) are plotted in Figure 2A and Figure 2B, respectively. These data series indicate that after the three crushes, both the oil price and the storage volume suddenly increase. On the other hand, rapid falls of the oil prices are shown in 1985 and 1986 when the OPEC formally renounced the official prices and the oil prices shifted to the market prices (see Fujiwara, Niizeki and Kumagai [1999]). After the shift to the market price, the storage volume also increases.

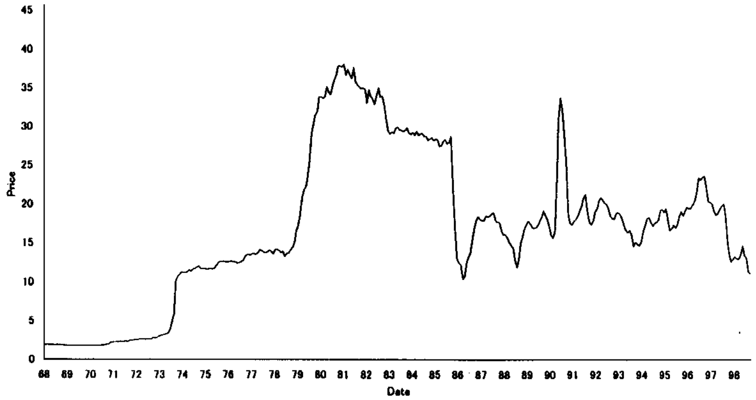

Figure 1A
Level of Japanese Oil Price
(February, 1968–February, 1999)

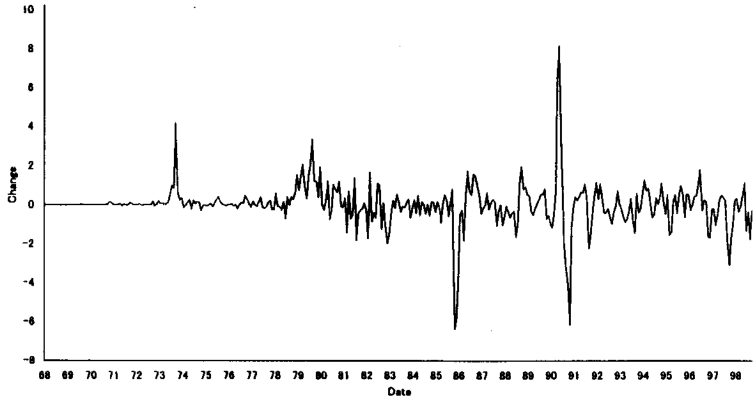

Figure 1B
Change of Japanese Oil Price
(February, 1968–February, 1999)

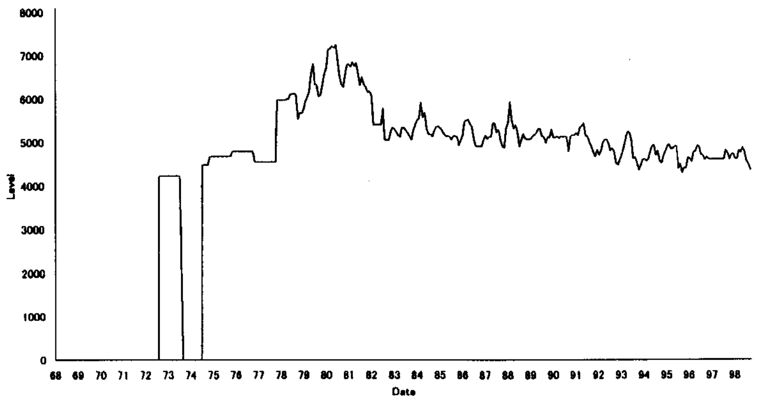

Figure 2A
Level of Japanese Oil Storage
(February, 1968–February, 1999)

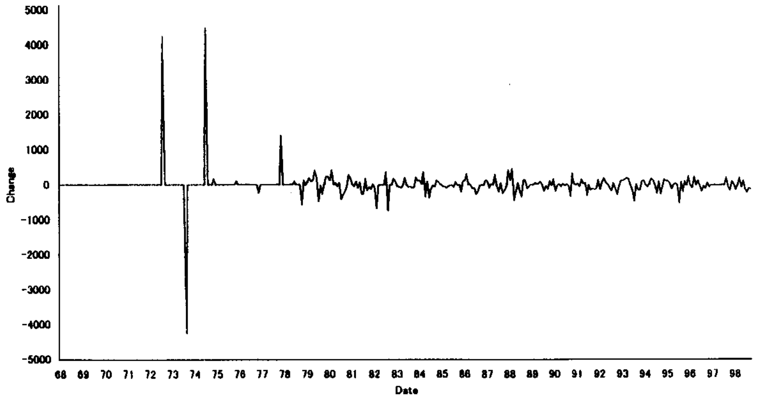

Figure 2B
Change of Japanese Oil Storage
(February, 1968–February, 1999)

The time series properties of the data are explored using tests for a unit–root. A number of statistics have been proposed as tests for the existence of a unit–root (see, for example, Dickey and Fuller [1979], [1981], and Phillips [1987]). In this study, the well–known Dickey–Fuller (*DF*) and Augmented Dickey–Fuller (*ADF*) statistics are used.

An asymptotically valid method of testing for a unit–root in the process generating a variable Y is to employ the *ADF* regression with drift :

$$\Delta Y_t = \alpha_0 + \alpha_1 t + \alpha_2 Y_{t-1} + \sum_{i=1}^{m} \beta_i \Delta Y_{t-i} + \eta_t$$

where the η_t are assumed to be identically and independently distributed random variables. In this experiment, two lags of the differenced variables ($m=2$) are included to account for serial correlation in the error term.[1]

Table 2 reports both Dickey–Fuller and Augmented Dickey–Fuller unit–root tests for levels and their first differences of each variable. The means and standard deviations of the four variables, P,

Table 2 Unit Root Tests

	P	dP	I	dI
MEAN	76.95	1.11	3958.38	29.42
S. D.	12.47	3.72	1942.93	827.68
DF	−1.54	−10.42	−2.46	−19.25
ADF	−1.97	−9.94	−2.47	−13.50

Note : MEAN, and S. D denote the sample mean and the standard deviation of the data, respectively. The 5% critical values for the DF and ADF without trend are 2.87 (source : Dickey and Fuller [1981]).

Table 3 Estimates of Volatilities

	Mean	S. D.	Min	Max
KERNEL	42.12	29.52	0.00467	273.34
SWARCH–L	45.78	110.413	0.0345	1124.90

Note : The volatilities of the price changes are computed using the nonparametric KERNEL model (KERNEL) and the parametric SWARCH–L (4, 1) model (SWARCH–L). Mean is the average, 'S. D.' is the standard deviation, Min is the minimum value, and Max is the maximum value of these estimates, respectively.

dP, S, and *dS*, are also contained in Table 2. All statistics are consistent with the null hypothesis of a unit–root for the levels of all variables at the 5 percent significance level. In contrast, the null hypothesis that there is a unit–root is clearly rejected at the 5 percent significance level for their differences. An appropriate conclusion is that each variable, *P* and *S*, follows an integrated process of order one over the sample periods.[2]

4. 2 Estimate of the Volatility

The standard nonparametric method (KERNEL) in (10) is used to estimate the volatility using the *GAUSS* programming software. In this experiment, the choice of the band–width *h* is determined to be $sT^{-\frac{1}{5}}$ where *s* is the sample standard deviation (see Silverman [1986]).

Table 3 contains the summary statistics for the estimated volatility of the monthly change of the oil price. The volatility measured by the parametric method, the SWARCH–L method in (13) is also presented in the table.[3]

Figure 3 plots the estimated volatilities using the KERNEL model. The maximum value of the estimated volatility is 273.34 on March 1991 after the large decline of the storage investment (−329). The Estimates of the volatility with the SWARCH–L (4, 1) model also plots in Figure 4. These figures show that the volatilities become large four times : after the Persian Gulf War at about 1990, the shift to the market price at about 1986, the first oil shock at about 1973, and the second oil shock at about 1978. The point that it should pay attention to especially is that the volatilities in 1973 is big-

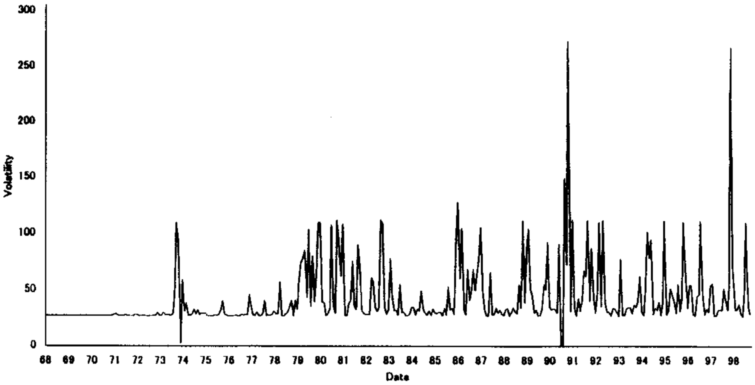

Figure 3
KERNEL Estimate of the Volatility :
Japanese Oil Price Change
(February, 1968–February, 1999)

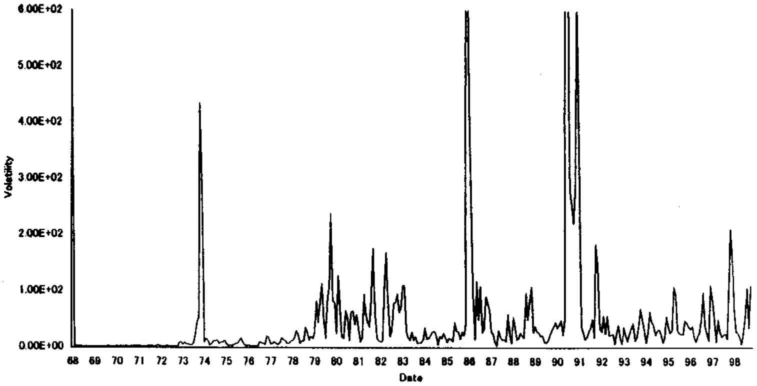

Figure 4
SWARCH–L (4, 1) Estimate of the Volatility :
Japanese Oil Price Change
(February, 1968–February, 1999)

ger than those in 1978 after the additional investment of the storage. This means that there may be the negative relation between the volatility of the price change and the past change of the storage volume.

4. 3 Test of the Relationship between the Volatility and the Storage

In order to investigate the predicted negative correlation, the first order derivative of the conditional variance (V_t) with respect to the past change of the storage volume (dS_{t-1}) can be estimated using (12) for the sample period.

Table 4 includes estimate of the average first order derivative using the KERNEL model. The value of $\partial V_t / \partial dS_{t-1}$ is negative and the hypothesis that $\frac{\partial V_t}{\partial dS_{t-1}} = 0$ cannot be rejected at the 5% level. This result shows that the volatility does not depend negatively on the past change of the storage volume, which does not support the storage theory.

As in previous studies, in order to examine the relationship between the volatility and the change of the storage volume, a maximum likelihood (ML) estimation procedure is used to estimate the parametric model (13) in the SWARCH–L framework, which is simultaneously used to estimate the conditional variance, V_t^2. In particular, the SWARCH–L framework which permits the conditional variance to depend on the past volume change, dS_{t-1}, is useful to investigate the storage theory.

The estimate of b is also shown in Table 4. This result indicates that the hypothesis, b is zero, can be rejected at the 5% significance level. The result of the parametric model supports the negative relationship between the volatility and the change of the storage volume in the Japanese oil market, which is inconsistent with the nonparametric model.

The econometric test, especially the parametric test, supports the hypothesis that after the additional investment of the storage volume, the volatility of the price change decreases in the Japanese oil market. On the other hand, the significant negative correlation between the two variables cannot be found with the nonparametric model. Three problems are thought of the low significant level in the nonparametric model.

First, as the nonparametric method uses the average derivative in (12) to test the hypothesis, the point wise estimates cannot be examined. In the point wise levels, for example, the volatilities in 1973 and 1978, some significant negative sign should be observed.

Second, in order to capture the dynamics of the volatility, the two models : the KERNEL model and the SWARCH–L model that suppose the volatility depend on the past change of the storage level are used. To focus only on the additional investment of the storage volume, the effect of variation in the current level of the storage is not accounted for in the study. However, the data of the storage level is shown to be nonstationary and cannot be used in the nonparametric model as discussed in the previous section.

The third problem should be occured both in the KERNEL model and the SWARCH–L model. Extra high volatilities are observed in the two aspects : the rise of the price and the fall of the price.

Table 4 Relationships between Volatilities and Storage Changes

	Estimate	Statistic
$\partial V_t^2 / \partial dS_{t-1}$	−0.951	0.00459
b	−0.2165	5.743*

Note : For $\partial V_t^2 / \partial dS_{t-1}$ in the nonparametric (KERNEL) model, the test statistic is the χ^2 value which can test the null hypothesis that the partial mean of the derivative (mean derivative) is equal to 0. The 5% critical value for the χ^2 (1) statistics is 3.84. For b in the parametric (SWARCH–L) model, the test statistic is the absolute t value whose 5% critical value is 1.96. The superscript * indicates that the parameter is statistically different from zero at the 5% level.

The latter aspect should be a problem on investigating the hypothesis as predicted in the storage theory. When the oil price falls, there should be excess supply of the oil in the market. Indeed, the oil price refrected the relation between the market demand and the market supply, and fell after the OPEC renounced its sale price in 1985. After the shifts in the market price, there was excess supply and little risk of stopping the supply in the oil market. Under this situation, the marginal benefit of the storage should be small and the storage volume should not effect the volatility of the price change.

5 CONCLUSION

In this paper, the nonparametric regression model is used to estimate the conditional variance of the price change, and its first derivative is also estimated to capture its dynamic in the Japanese oil market. In addition, to compare with the nonparametric model, the parametric model is used to estimate the dynamic of the volatility.

The theory of storage implies that an increase in volatility of the spot price should lead to an increase in inventory levels for convenience assets. An increase level of the storage activity should lead to a low level of the volatility. Therefore, the storage theory implies that the low volatility of the price change should be observed after the investment in the additional storage.

Using the monthly data of the Japanese oil market, two important facts are found for the storage theory. First, the extra high volatilities of the price changes are observed after the big market shock: the first oil shock, the second oil shock, the Persian Gulf War, and the shifts to the market price. The three former shocks are accompanied by the rises of the prices because of the risks of stopping the supplies. In these cases, the hypothesis that the higher the volatility, the lower the inventory level, as predicted in the storage theory should be accepted. However, for the last shock accompanied by the fall of the price, there is little risk of the supply stopping because of the excess supply in the oil market. In this case, the storage theory cannot explain the relationship between the volatility and the storage change.

Second, although a definite relation between the volatility and the storage change cannot be found with the nonparametric (KERNEL) model, a negative signature can be observed using the parametric (SWARCH-L) model. This finding can give an evidence to the storage theory suggesting the negative relationship between the volatility and the past storage change in the Japanese oil market.

In this paper, it is supposed that the volatility of the price change depends on the past change of the storage volume in order to investigate the storage theory. However, it seems to be more desirable that the relationship between the volatility of the price change and the level of the storage volume is tested directly. Because the level of the storage is nonstationary, the relationship cannot be examined with the nonparametric model. A dynamic of the volatility depending on both the level and the change of the storage volume and should be investigated with another econometric model in future applications.

The fluctuations of the oil prices are very important because they have a huge influence on other industrial prices in Japan. Although the oil price has switched to the market price in 1985, an unexpected risk for the oil supply may occur by the trends of the oil exporting countries. Therefore, it is important to study the dynamics of the price change volatility in the Japanese oil market.

Notes

1 The choice of m largely depends on the number of available observations and the serial correlation pattern present in η_t.

2 The hypothesis that the error term in each of their regressions is serially uncorrelated is accepted when tested using the Q statistic due to Box and Pierce [1970]. Using the F test, the hypothesis of being no trend is also accepted.

3 Fujiwara, Niizeki and Kumagai [1999] investigated the Japanese oil market and derived that there were four structural changes in this sample period. Therefore, the SWARCH–L (4, 1) model is used for the parametric model in this paper.

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