

Usefulness of the Forward Curve in Forecasting Oil Prices

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Summary

When people analyse oil prices, the forward curve is often referred to as it reflects the average view among market participants. In this paper, to what extent the forward curve provides useful information in forecasting oil prices was analysed quantitatively.

Although the usefulness of the forward curve is confirmed in forecasting oil prices, the effect in reducing forecast error is small. Additionally, the forward curve is actually useful for one week ahead and for one month ahead in daily and weekly forecasts, respectively. However, the forward curve is scarcely useful in long-term forecast.

1. Trend of crude oil price and its forward curve

Crude oil price¹ exceeded \$70/bbl on 9th June 2009 for the first time in seven months and the price was \$72.68/bbl on 11th June. The high price, which rose by \$14/bbl only in just one month, is one of the concerns for the vulnerable global economy. Oil supply and demand balance was far from tight in general that oil stock in the United States touched the highest level in the last 19 years. However, it is said that the expectation of recovery of the global economy, the side effect by the easy-money policy, etc. lead to this rapid rise of the oil prices.

¹ Light Sweet Crude Oil listed at New York Mercantile Exchange, or NYMEX, front month, so called WTI price. Closing price.

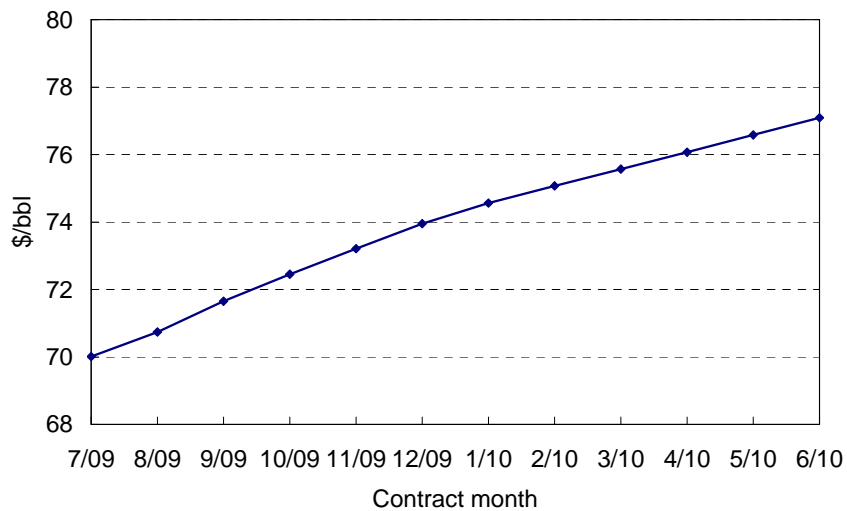
Figure 1: Crude oil price



Source: Department of Energy, United States

The forward curve, a curve of futures price over contract month, is now in contango. It is said that the contango is an indication that the market expects higher prices in the future.

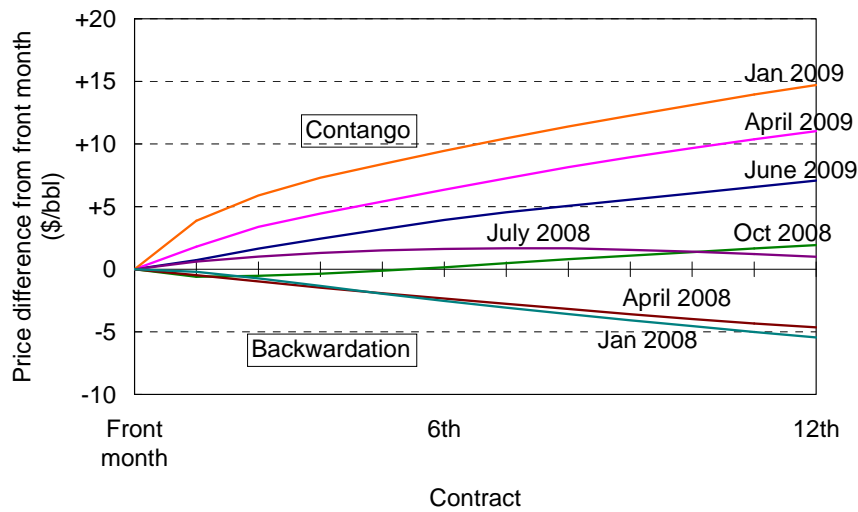
Figure 2: Forward curve (on 9th June 2009)



Source: NYMEX

The forward curves of oil price have so far often in backwardation. The forward curves, however, form different shapes depending on the period. For example, in January 2009, the forward curve was fairly steep and it was said that the forward curve was showing that the oil prices would rise in the future.

Figure 3: Change of forward curves



Source: NYMEX

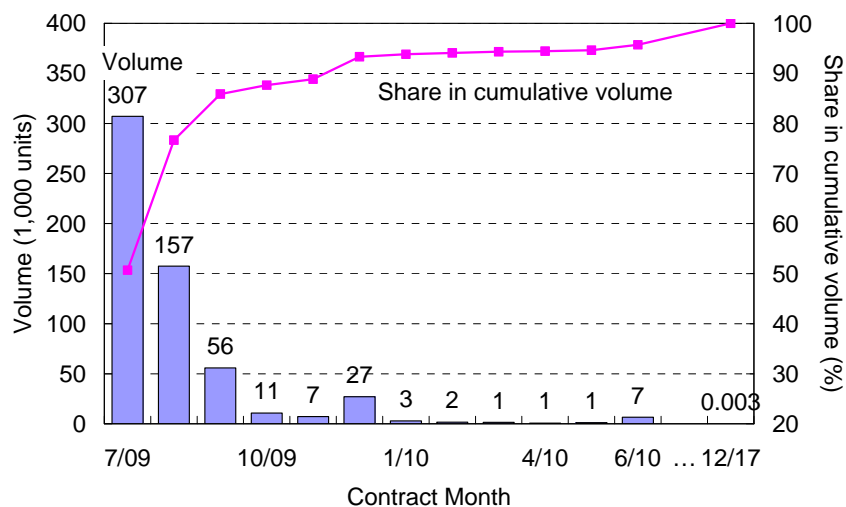
It is widely thought that forward curve reflects the average view of future oil prices among market participants. Additionally, the forward curve provides information on the future in a continuous, immediate and precise manner. Hence, the forward curve is also regarded as one of predictors in forecasting oil prices.

Then to what extent does forward curve provide useful information forecasting oil prices? In this paper, the usefulness of the forward curve is analysed quantitatively using time series models of oil prices.

The contract for December 2017 is the furthest transaction at NYMEX. While about 90% of the transaction volume is concentrated to the nearest few months, the volume of back months is extremely little. For instance, the contract for December 2017 transacted only three units on 19th June 2009 (Figure 4).

The prices of the next three months (second front month to fourth front month) in addition to front month are taken as forward curve in this paper because prices of back months might not be so reliable. This makes long-term forecasts of over a year to be virtually out of focus of the analysis.

Figure 4: Volume by contract month and cumulative share (on 9th June 2009)



Source: NYMEX

2. Inquiry of usefulness of forward curve and Granger causality

2.1 Stationarity of oil prices

For quantitative analysis, the stationarity of oil prices should be considered initially. The biggest problem in non-stationary cases is having a unit root of characteristic equation. AR(1) which has a unit root is called random walk and it is known that its best forecast is the latest value. In other words, if it is assumed that oil price is random walk, immediately we have a conclusion that neither the forward curve nor any information except for the latest value is useful in forecasting its future value.

It is thought that generally, there is some structure behind oil price and many people try to forecast it by investigating the structure. Then it is assumed that oil price is stationary hereafter considering this situation, etc., although it might not be suitable for quantitative analysis².

2.2 Usefulness of forward curve and Granger causality

Hereafter the usefulness of the forward curve in oil price forecast is analysed using Granger causality.

Granger causality is used to determine whether using past information of z_t , or $\{\dots, z_{t-3}, z_{t-2}, z_{t-1}\}$, reduces prediction mean squared error, or PMSE of x_t . In other words, whether z_t is useful to forecast x_t on the average can be determined from Granger causality. Granger causality is quite defined mathematically and that gives people an unnatural impression sometimes comparing it with the general understanding of “causality”. The definition, however,

² Augmented Dickey-Fuller test did not reject null hypothesis that oil price is non-stationary even at 10% level of significance. This result, however, does not mean oil price is judged to be non-stationary.

is very suitable for the inquiry of the usefulness of forward curve in oil price forecast.

In Granger (Granger=Sargent) test, it is tested whether $\sum \hat{v}_t^2$, PMSE of

$$x_t = a_1x_{t-1} + a_2x_{t-2} + \dots + a_px_{t-p} + b_1z_{t-1} + b_2z_{t-2} + \dots + b_pz_{t-p} + v_t$$

is less than $\sum \hat{u}_t^2$, PMSE of

$$x_t = a_1x_{t-1} + a_2x_{t-2} + \dots + a_px_{t-p} + u_t$$

or not. If $\sum \hat{v}_t^2$ is less than $\sum \hat{u}_t^2$ significantly, z_t is said to Granger-cause x_t .

3. An empirical analysis

3.1 Usefulness of the forward curve in oil price forecast

Here, whether prices of the second, third and fourth front month (hereafter F2, F3, F4 respectively) are useful in oil price forecast or not is analysed. Then F2, F3 and F4 are tested whether they Granger-cause the price of front month or not.

Analysis was done for daily, weekly and monthly data and vector autoregressive (VAR) models were built for each. Regression period is shown in Table 1.

Table 1: Regression period

	Start of period	End of period	Number of samples
Daily	4 January 2004	2 June 2009	1,357
Weekly	The first week in January 2004	The fifth week in May 2009	283
Monthly	January 2004	May 2009	65

The lag length of each model was chosen referring to the Akaike information criterion, or AIC; 5-lags for daily, 4-lags for weekly and 3-lags for monthly models. The summary of the models is shown in “5. Appendix: Summary of the models”. Most of monthly models are considered not reasonable judging by the sign of their coefficients, etc. Also weekly models with both F2 and F3 and with all of F2, F3 and F4 are considered not reasonable³.

Afterwards, the Granger test was done using the models. The null hypothesis is that price(s) of back month(s) do not Granger-cause the price of front month. If this null hypothesis is rejected, the price(s) of back month(s) do Granger-cause oil prices and the usefulness of forward curve in oil price forecast is proven statistically. Results of the test are shown in Table 2.

³ Hereafter, their results are shown but out of consideration.

Table 2: Results of Granger test (P value)

Null Hypothesis	F2 does not Granger-cause oil price.	F3 does not ...	F4 does not ...	F2 and F3 do not ...	F3 and F4 do not ...	F2, F3 and F4 do not ...
Daily	0.003 **	0.133	0.376	0.000 **	0.009 **	0.000 **
Weekly	0.005 **	0.009 **	0.009 **	0.001 **	0.006 **	0.005 **
Monthly	0.191	0.282	0.325	0.036 *	0.217	0.120

Note (1): **: Significant at 1% level, *: significant at 5% level.

Note (2): Strike-through shows the models are considered not reasonable.

In eight models, four daily models and four weekly models, the null hypotheses were rejected. Therefore, it was shown that the forward curve is useful in forecasting the daily and weekly oil prices in some cases.

On the other hand, as there were scarcely available reasonable models for the monthly basis, the usefulness of the forward curve in oil price forecast could not be determined.

3.2 Effect of using the forward curve in the forecast

Then to what extent is the forward curve useful in forecast? Standard errors, which show the accuracy of the forecasts, are shown in Table 3.

Table 3: Standard errors

	Reference	With F2	With F3	With F4	With F2 and F3	With F3 and F4	With F2, F3 and F4
Daily	1.818	1.809	1.816	1.818	1.782	1.809	1.785
Weekly	2.955	2.897	2.904	2.905	2.858	2.884	2.867
Monthly	5.642	5.557	5.601	5.618	5.282	5.526	5.389

Note: Strike-through shows the models are considered not reasonable.

To get the intuitive image, forecast errors for one period ahead at the beginning of each month are shown as samples in Figure 5 and Figure 6.

Figure 5: Errors in forecast for one period ahead, daily, with F2, F3 and F4

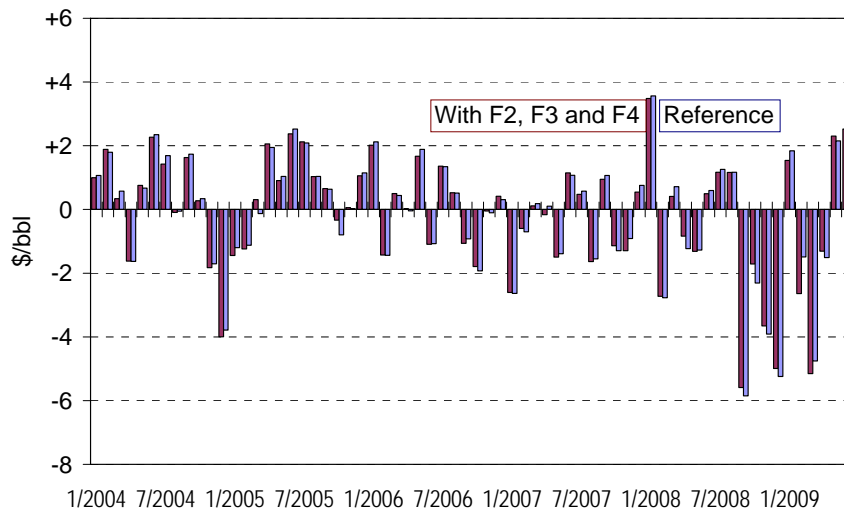
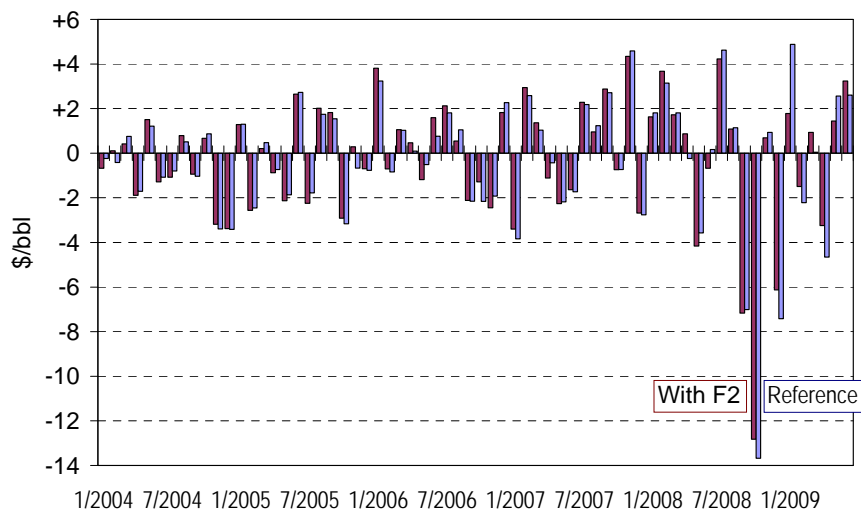


Figure 6: Errors in forecast for one period ahead, weekly, with F2



Like in the beginning of 2009 in weekly forecast with F2, we can see some cases in which forecast errors are fairly reduced. As a collective impression, however, reduction of errors is limited compared with the degree of forecast errors.

Considering the result in the previous section, we have to say that although the forward curve is statistically useful in forecasting oil price forecast, the effect in reducing forecast error is small.

3.3 Usefulness of the forward curve in forecast for further period ahead

So far, the usefulness of the forward curve in forecast for one period ahead is discussed. Then how further is forward curve useful? Results of Granger tests are shown in Table 4 and Table 5.

Table 4: Results of Granger test (P value), daily

Null hypothesis	F2 does not Granger cause oil price.	F3 does not ...	F4 does not ...	F2 and F3 do not ...	F3 and F4 do not ...	F2, F3 and F4 do not ...
Forecast for 1 period ahead	0.003 **	0.133	0.376	0.000 **	0.009 **	0.000 **
2 periods	0.012 *	0.224	0.473	0.000 **	0.003 **	0.000 **
3 periods	0.029 *	0.196	0.306	0.000 **	0.000 **	0.000 **
4 periods	0.018 *	0.096	0.161	0.000 **	0.000 **	0.000 **
5 periods	0.026 *	0.127	0.193	0.000 **	0.000 **	0.000 **
6 periods	0.017 *	0.095	0.158	0.000 **	0.000 **	0.000 **
7 periods	0.102	0.324	0.405	0.000 **	0.000 **	0.000 **
8 periods	0.374	0.789	0.768	0.000 **	0.000 **	0.000 **

Table 5: Results of Granger test (P value), weekly

Null hypothesis	F2 does not Granger cause oil price.	F3 does not ...	F4 does not ...	F2 and F3 do not ...	F3 and F4 do not ...	F2, F3 and F4 do not ...
Forecast for 1 period ahead	0.005 **	0.009 **	0.009 **	0.001 **	0.006 **	0.005 **
2 periods	0.005 **	0.016 *	0.016 *	0.000 **	0.001 **	0.000 **
3 periods	0.013 *	0.052	0.052	0.000 **	0.000 **	0.000 **
4 periods	0.006 **	0.017 *	0.016 *	0.000 **	0.000 **	0.000 **
5 periods	0.004 **	0.006 **	0.005 **	0.000 **	0.000 **	0.000 **
6 periods	0.006 **	0.006 **	0.005 **	0.000 **	0.000 **	0.000 **
7 periods	0.065	0.058	0.047 *	0.000 **	0.000 **	0.000 **
8 periods	0.083	0.091	0.080	0.000 **	0.000 **	0.000 **

Note (1): **: Significant at 1% level, *: significant at 5% level.

Note (2): Strike-through shows the models are considered not reasonable.

The null hypotheses “price(s) of back month(s) do not Granger-cause oil price” in forecast for 6 periods ahead in daily and 7 periods ahead in weekly prices were rejected. However, if we see the forecast accuracy of the result of the weekly models, the coefficient of determination, or R^2 , exceeds about 0.9 by four period ahead. Considering comprehensively, it should be said that the forward curve is useful for one week ahead and for one month ahead in daily forecast and weekly forecast, respectively.

To see the effect by using the forward curve in oil price forecast, forecast errors at the beginning of each month are shown in Figure 7 and Figure 8.

Figure 7: Errors in forecast for five periods ahead, daily, with F2

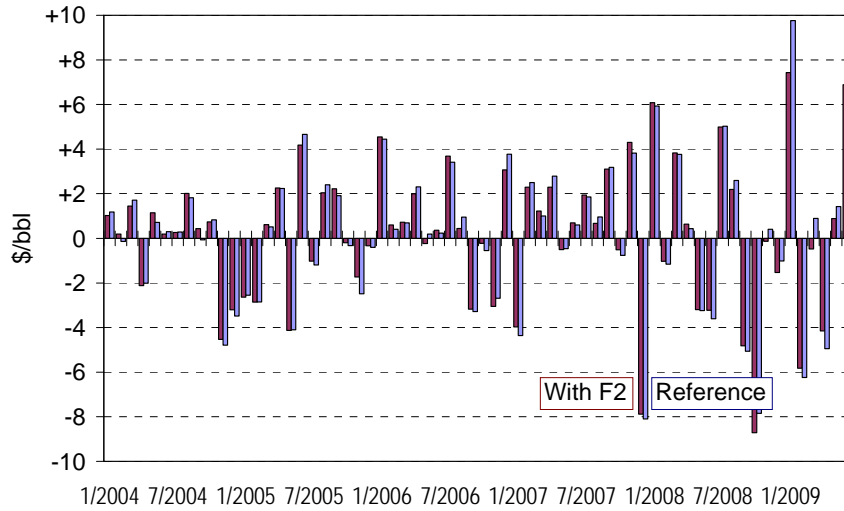
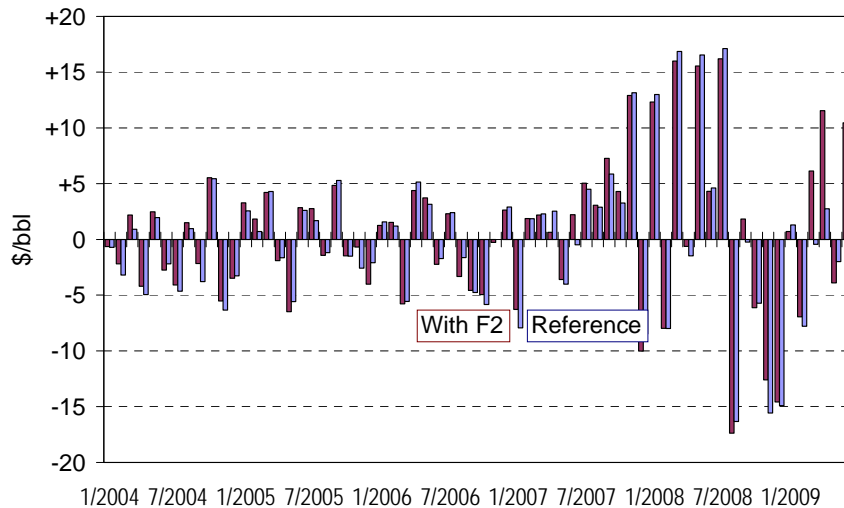


Figure 8: Errors in forecast for four periods ahead, weekly, with F2



In both results, the collective tendency is not so much different from forecast for one period ahead. The effect of using the forward curve is limited compared with the degree of forecast errors.

4. In closing

When people analyse oil prices, the forward curve is often referred to as it reflects average view of the future prices among market participants. Although the usefulness of the forward curve in forecasting oil prices is confirmed in daily and weekly bases, the effect in reducing forecast error is small. Additionally, the forward curve is actually useful for one week ahead and for one month ahead in daily forecast and weekly forecast, respectively. However, the forward

curve is scarcely useful in long-term forecasts.

The reasons why the forward curve is useful only in short-term forecast and its effect is limited are the following:

- No information on unexpected events in the future is considered,
- The forecast of prices tends to be inaccurate because the equilibrium price is a cross of two uncertainty, namely supply and demand, and
- The price inelastic supply and demand curve of oil leads to huge fluctuation of prices even with slight changes in supply and/or demand.

Additionally as the nature of the forecast itself, the following things could be listed.

- In forecasts, people tend to stick to past trends and past forecasts,
- In forecasts, there is Keynesian beauty contest effect, and
- Correction of forecasts is generally done slowly.

This time, the prices of back months were included in the models directly. However, this leads to risks of multi-correlation if we think about the nature of data. To capture information provided by the forward curve better, the application of principal component analysis before building VAR models should be considered.

5. Appendix: Summary of the models

Table 6: Summary of the daily models (Equations of price of front month)

		Equations (Endogenous variables)						
		F1	F1, F2	F1, F3	F1, F4	F1, F2, F3	F1, F3, F4	F1, F2, F3, F4
Exogenous variables	F1(-1)	0.918 (33.802)	0.719 (7.083)	0.842 (9.585)	0.880 (11.145)	0.390 (3.346)	0.752 (7.990)	0.376 (3.200)
	F1(-2)	0.030 (0.805)	0.113 (0.928)	0.054 (0.480)	0.039 (0.377)	0.097 (0.755)	0.035 (0.303)	0.087 (0.676)
	F1(-3)	0.068 (1.842)	0.312 (2.550)	0.205 (1.817)	0.156 (1.513)	0.410 (3.195)	0.218 (1.900)	0.401 (3.093)
	F1(-4)	0.041 (1.101)	0.204 (1.673)	0.157 (1.389)	0.134 (1.293)	0.231 (1.803)	0.148 (1.287)	0.217 (1.676)
	F1(-5)	-0.060 (-2.195)	-0.379 (-3.753)	-0.263 (-3.009)	-0.208 (-2.641)	-0.609 (-5.247)	-0.373 (-3.918)	-0.634 (-5.270)
	F2(-1)		0.222 (2.021)			2.604 (5.207)		2.822 (5.015)
	F2(-2)		-0.089 (-0.669)			-1.372 (-1.969)		-1.417 (-1.913)
	F2(-3)		-0.281 (-2.098)			-1.206 (-1.706)		-1.135 (-1.505)
	F2(-4)		-0.182 (-1.366)			-0.448 (-0.645)		-0.380 (-0.513)
	F2(-5)		0.359 (3.304)			1.597 (3.410)		1.764 (3.188)
	F3(-1)			0.088 (0.899)		-2.105 (-4.708)	0.810 (2.095)	-2.562 (-3.283)
	F3(-2)			-0.026 (-0.206)		1.356 (2.036)	-0.120 (-0.289)	1.532 (1.651)
	F3(-3)			-0.165 (-1.293)		0.841 (1.240)	-0.625 (-1.498)	0.699 (0.738)
	F3(-4)			-0.136 (-1.067)		0.244 (0.368)	-0.092 (-0.223)	0.115 (0.124)
	F3(-5)			0.240 (2.474)		-1.032 (-2.424)	0.939 (2.460)	-1.290 (-1.651)
	F4(-1)				0.045 (0.499)		-0.643 (-1.836)	0.254 (0.628)
	F4(-2)				-0.010 (-0.081)		0.119 (0.311)	-0.122 (-0.295)
	F4(-3)				-0.109 (-0.921)		0.455 (1.177)	0.080 (0.193)
	F4(-4)				-0.112 (-0.950)		-0.034 (-0.088)	0.076 (0.185)
	F4(-5)				0.181 (2.039)		-0.590 (-1.720)	0.114 (0.289)
Constant	0.257 (1.779)	0.213 (1.351)	0.253 (1.610)	0.270 (1.743)	0.160 (1.027)	0.092 (0.561)	0.213 (1.269)	
R^2	0.994	0.994	0.994	0.994	0.995	0.994	0.995	

Note (1): F1, F2, F3 and F4 refer price of front month, the second front month, the third front month and the fourth front month respectively.

Note (2): F1(-1) refers price of F1 in the previous term.

Note (3): Number in parentheses refers t value.

Table 7: Summary of the weekly models (Equations of price of front month)

		Equations (Endogenous variables)						
		F1	F1, F2	F1, F3	F1, F4	F1, F2, F3	F1, F3, F4	F1, F2, F3, F4
Exogenous variables	F1(-1)	1.167 (19.519)	1.597 (4.989)	1.492 (6.610)	1.441 (7.390)	0.854 (1.646)	1.227 (3.454)	0.757 (1.393)
	F1(-2)	-0.090 (-0.979)	-1.060 (-2.782)	-0.703 (-2.491)	-0.580 (-2.320)	-1.708 (-3.057)	-1.066 (-2.722)	-1.733 (-2.997)
	F1(-3)	-0.004 (-0.048)	-0.510 (-1.335)	-0.384 (-1.356)	-0.352 (-1.406)	-0.524 (-0.947)	-0.259 (-0.654)	-0.657 (-1.155)
	F1(-4)	-0.087 (-1.453)	0.910 (2.842)	0.589 (2.593)	0.497 (2.535)	0.460 (0.901)	0.258 (0.730)	0.471 (0.867)
	F2(-1)		-0.473 (-1.382)			1.579 (1.039)		2.519 (1.118)
	F2(-2)		1.107 (2.715)			2.997 (1.696)		3.452 (1.431)
	F2(-3)		0.438 (1.090)			-0.163 (-0.094)		1.465 (0.604)
	F2(-4)		-1.023 (-3.114)			0.128 (0.090)		-1.341 (-0.610)
	F3(-1)			-0.374 (-1.514)		-1.352 (-1.242)	0.474 (0.224)	-3.412 (-0.798)
	F3(-2)			0.748 (2.431)		-1.254 (-0.940)	3.515 (1.367)	-2.185 (-0.455)
	F3(-3)			0.330 (1.082)		0.649 (0.491)	-1.695 (-0.665)	-3.517 (-0.729)
	F3(-4)			-0.712 (-3.007)		-0.676 (-0.670)	1.114 (0.560)	3.901 (0.952)
	F4(-1)				-0.327 (-1.510)		-0.603 (-0.325)	1.222 (0.462)
	F4(-2)				0.628 (2.261)		-2.441 (-1.052)	0.498 (0.159)
	F4(-3)				0.308 (1.123)		1.950 (0.848)	2.702 (0.870)
	F4(-4)				-0.629 (-3.030)		-1.484 (-0.853)	-3.151 (-1.259)
	Constant	0.989 (1.931)	0.900 (1.635)	0.999 (1.833)	1.043 (1.938)	0.469 (0.838)	0.388 (0.653)	0.630 (1.045)
	R^2	0.985	0.986	0.986	0.986	0.986	0.986	0.987

Note (1): F1, F2, F3 and F4 refer price of front month, the second front month, the third front month and the fourth front month respectively.

Note (2): F1(-1) refers price of F1 in the previous term.

Note (3): Number in parentheses refers t value.

Table 8: Summary of the monthly models (Equations of price of front month)

		Equations (Endogenous variables)						
		F1	F1, F2	F1, F3	F1, F4	F1, F2, F3	F1, F3, F4	F1, F2, F3, F4
Exogenous variables	F1(-1)	1.364 (10.870)	-1.233 (-1.015)	-0.127 (-0.159)	0.207 (0.315)	-9.201 (-2.974)	-3.540 (-1.895)	-10.491 (-2.917)
	F1(-2)	-0.211 (-0.982)	2.991 (1.705)	1.783 (1.506)	1.416 (1.417)	-0.222 (-0.077)	1.548 (0.871)	-1.476 (-0.411)
	F1(-3)	-0.243 (-1.962)	-1.604 (-1.308)	-1.096 (-1.360)	-0.951 (-1.426)	-3.911 (-1.355)	-2.365 (-1.402)	-4.326 (-1.178)
	F2(-1)		2.710 (2.159)			21.830 (2.854)		31.574 (2.301)
	F2(-2)		-3.354 (-1.825)			8.015 (0.984)		11.822 (0.831)
	F2(-3)		1.410 (1.111)			2.390 (0.340)		4.480 (0.324)
	F3(-1)			1.602 (1.913)		-11.282 (-2.355)	16.124 (1.948)	-29.572 (-1.400)
	F3(-2)			-2.153 (-1.700)		-8.176 (-1.444)	1.683 (0.176)	-10.616 (-0.474)
	F3(-3)			0.909 (1.072)		1.530 (0.346)	2.185 (0.297)	-1.715 (-0.086)
	F4(-1)				1.271 (1.809)		-11.179 (-1.680)	9.840 (0.893)
	F4(-2)				-1.796 (-1.656)		-3.660 (-0.444)	-0.102 (-0.008)
	F4(-3)				0.770 (1.086)		0.171 (0.029)	1.544 (0.154)
	Constant	6.091 (2.917)	4.872 (2.171)	5.158 (2.321)	5.301 (2.411)	0.038 (0.014)	0.468 (0.146)	1.163 (0.362)
	R ²	0.947	0.951	0.950	0.950	0.958	0.954	0.959

Note (1): F1, F2, F3 and F4 refer price of front month, the second front month, the third front month and the fourth front month respectively.

Note (2): F1(-1) refers price of F1 in the previous term.

Note (3): Number in parentheses refers t value.

References

Taku Yamamoto (1988), 'Time-series Analysis of Economy', Sobunsha Publishing.

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